2023

Semrock® Optical Filters Catalog

Visit www.idex-hs.com/semrock
for Online Custom-sizing,
Quoting, & Ordering Options

All Filters are Guaranteed for Ten Years

IDEX HEALTH & SCIENCE | Semrock

Intelligent Solutions for Life™
Fluidics | Optics | Consumables | Assemblies

Welcome to the 2023 Master Catalog

A lot has changed at IDEX Health & Science since our last Semrock catalog in 2019. We've settled into our new location in Rochester, NY, added more coating equipment, and welcomed great new people to our talented team. What has not changed is our commitment to provide world-class optical filters to support our customers' instrument and experimental needs.

Our commitment to our customers has driven new technology investments and new products that we're proud to share. Our award-winning KolaDeep™ Spectral Measurement System provides an unparalleled tool to measure the deepest and steepest spectral features of our Semrock filters. Further ongoing investments in our coating technology have enabled us to develop two new product families to support more demanding Raman and fluorescence-based applications.

The Verona™ family, named for the tallest known cliff in the solar system on the moon, Miranda, provides the steepest cut-on edge available as well as significantly improved transmission band ripple. This enables researchers to examine ever more subtle signals in their Raman data. Our innovative Avant™ filter set family combines two strengths

of Semrock filters: steep edges and precise spectral edge placement. When combined, these filter sets allow instruments to capture more precious light from popular fluorophores with short Stokes Shifts such as Cy3, Cy5.5, and Cy7. As a result, researchers are able to detect signals more quickly and accelerate the pace of discovery.

Behind every Semrock filter is a great team dedicated to the mission of IDEX Health & Science: developing intelligent solutions for life. We're eager to help you find the right filter, choosing from among our large collection of catalog filters, or working with you to develop a custom filter specifically and thoughtfully designed for your application and budget.

Thank you for your business.
— The Semrock Optical Filters Team of IDEX Health & Science

We're here to help

www.idex-hs.com/semrock

Applications & Parts:
Semrock@idexcorp.com

Orders:
IHSOpticsOrders@idexcorp.com

OEM Customers:
IHSOpticsOrders@idexcorp.com

North American Government, University, and National Labratory customers:
SemrockSales@avr-optics.com

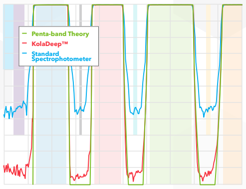
Please see inside back cover for a full list of our distributing partners.

Visit www.idex-hs.com/semrock to Order

Semrock

All Semrock Optical Filters are proudly manufactured by IDEX Health & Science in Rochester, New York, USA

What's New in 2023

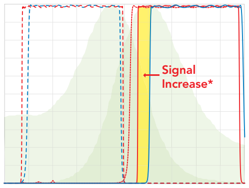


KolaDeep™ Spectral Measurement System

- **Learn more: p 8**
- Proven Measurement of Steepest and Deepest Spectral Features
- Ensures Instrument's Delivery of Best-in-class Sensitivity

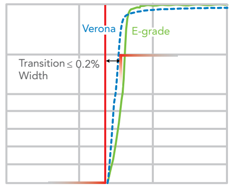
New Website

- **Learn more: p 9**
- Enhanced Product and Resource Pages
- Improved Search Functionality
- Enhanced Mobile User Experience



Avant™ Optical Filter Set Family

- **Learn more: p 17**
- 10% ~ 40% Signal Increase
- Designed for Specific Popular Short Stokes Shift Fluorophores
- Steep Spectral Edges and High OD Blocking



Verona™ Optical Filters

- **Learn more: p 90**
- Designed to Increase Raman System Performance
- 532 & 785 nm Available
- Low Ripple and Best Signal-to-noise Ratio

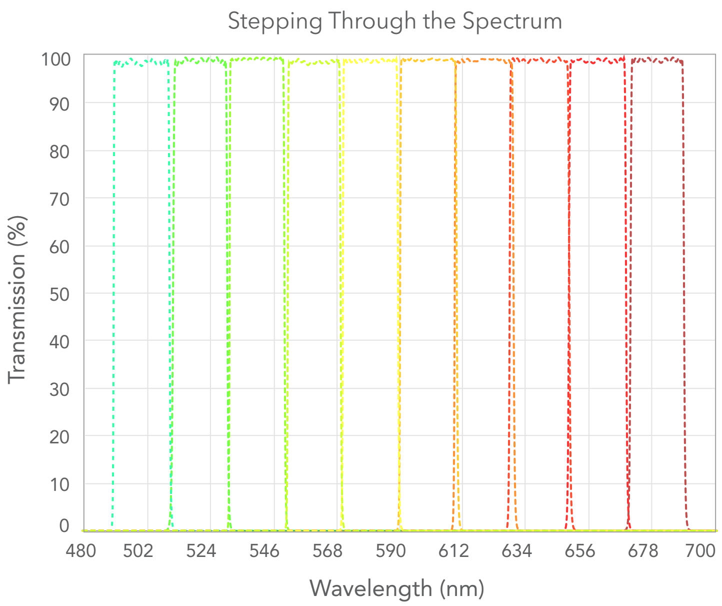
Coming Soon

Nanopede™

In flow cytometry, back-to-back (spectrally adjacent) filters ensure capture of precious photons while more easily distinguishing between different fluorophores. The first ten Nanopede™ filters have center wavelengths from 500 to 680 nm in full-width half-max (FWHM) steps of 20 nm. With high transmission and OD5 blocking across the spectrum, confidence in your flow cytometry filter selection has never been easier.

- The right specifications
- The right price
- **Coming Spring 2023**

Industry-leading performance at an attractive price point with Semrock brand quality.



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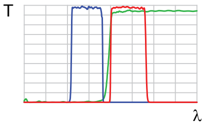

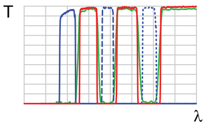

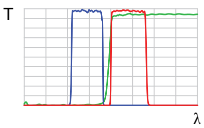

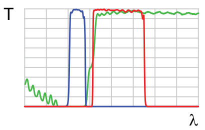

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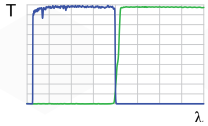
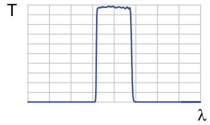
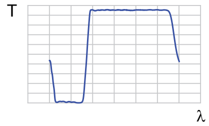
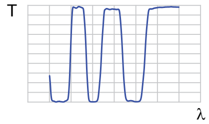
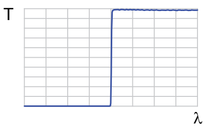


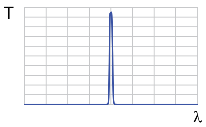


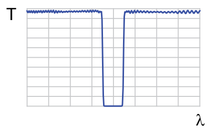


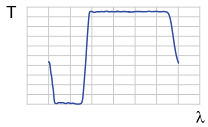


Raman Spectroscopy Filters



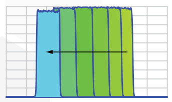


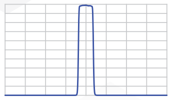


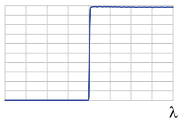


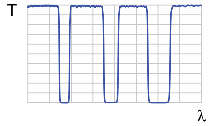
Click the tabs to easily navigate to different sections of the catalog

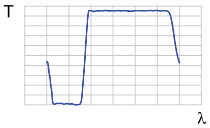
Laser & Optical System Filters

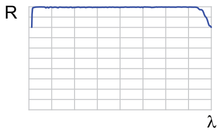












Reference, Technical and Product Notes

The LightSuite™ Online Toolbox

Semrock LightSuite

Semrock has developed a full complement of online tools designed to assist you in evaluating optical filters in terms of their use, design and overall optical system performance. The LightSuite toolbox was created to easily put the power of Semrock a mouse click away…anytime of the day or night. With the LightSuite toolbox (SearchLight™ and MyLight™), we want to make your optical filter performance, compatibility and design questions easier and more efficient to answer.

SearchLight™

SearchLight is a dedicated website that allows fluorescence microscope users and optical instrument designers to evaluate the optimal spectral performance of fluorophores, filter sets, light sources, and detectors as components of an overall system. Will your existing filter set work with a new fluorophore or light source? What if a new exciter was installed or you changed cameras? With this tool, you can compare optical signal and signal-to-background ratio (contrast) to noise while changing any and all components of your system. SearchLight allows you to upload your own spectra for any component and also save and share results securely. SearchLight can be found at: http://searchlight.idex-hs.com. Use SearchLight now to save time later.

Intelligent User Experience

SearchLight uses sophisticated algorithms to provide an enhanced user experience. For example, you can find compatible products for a selected fluorophore to narrow a list of potentially compatible exciters, emitters, dichroics or filter sets. Current algorithms are optimized for broadband light sources; user judgement is required to optimize the filter selection. We continue to make improvements for other illumination sources such as LED based light engines and lasers.

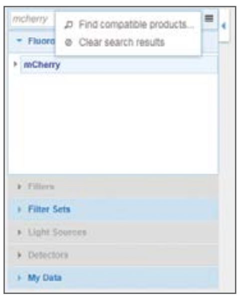
Finding compatible products

There are two ways to activate the [Find compatible products...] feature.

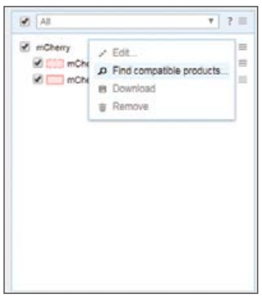
1. Add a fluorophore of interest to the plot / legend.

2. Select [Find compatible products...] from the product selection menu:

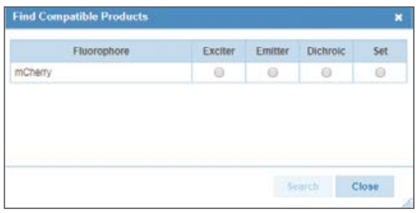
3. Select [Find compatible products...] from a fluorophore in the legend:



4. Once activated, select the type of product to search for (Exciter, Emitter, Dichroic, or Filter Set).

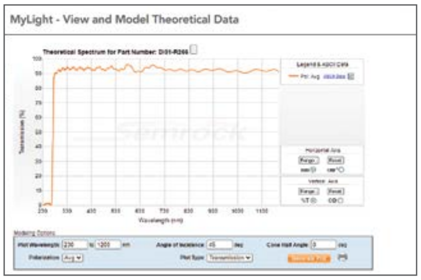


5. A list of compatible products will appear in the appropriate product selection panel.



MyLight™

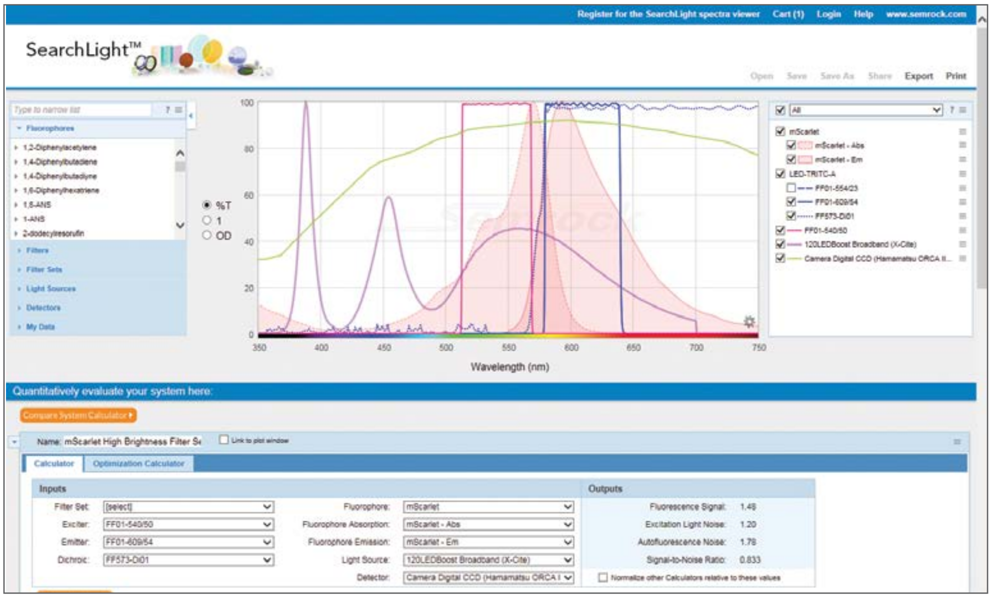
Interested in seeing how a Semrock catalog filter behaves at a particular angle of incidence, polarization state or Cone Half Angle of illumination?



MyLight theoretical spectral modeling is enabled within SearchLight [Model this filter...] for all Semrock filters or on individual filter product pages by clicking [Click for MyLight Tool] button. The MyLight modeling window will access our theoretical design data and allow you to see spectral shifts in filter performance under varying illumination conditions. MyLight data can be downloaded as numeric data (ASCII link), saved to MyData or shared with colleagues who also use Searchlight. Assess filter performance in real time to iterate towards an answer.

SearchLight Optimization Calculator

SearchLight's optimization calculator allows optical instrument designers to quickly determine the impact of filter spectral edge wavelengths on optical system performance. The SearchLight optimization calculator allows users to simulate the impact on fluorescence signal, noise, and signal-to-noise ratio as a function of the filter spectral edge locations. Any combination of exciter, emitter and dichroic spectra can be simultaneously selected for such simulations. Eliminate trial-and-error headaches and work more efficiently with SearchLight's optimization calculator.



Visit www.idex-hs.com/semrock

Get the Right Solution, Right Now

With proven results, we give you access to high-level engineering know-how that will help make every photon count in your system. As the pioneering experts in optical filters for life science, analytical instrumentation, and medical diagnostics applications, we have continually set the standards for advanced performance and reliability. Our unwavering commitment to quality and customer service allows us to consistently deliver much more than just filters.

When you are developing optical instrumentation you continually face new challenges: new customer requirements and product expectations, evolving technologies, changing markets, and the need for a rapid and decisive response. To help you conquer those challenges, we provide superior products and expert, personalized support.

Overall, Semrock filters are brighter, more durable, and spectrally more sophisticated than those made by other coating technologies, driving significant improvements for our customers and their applications: faster measurement times, reduced downtime, repeatable manufacturing, and lower optical component count.

We make our unique products with lot-to-lot consistency in high volumes, providing our OEM customers with a dependable supply. We find solutions "within the box" of our standard catalog, and "out of the box" with the help of our expert design staff, and we apply each strategy in the right proportion.

Filter and Optical System Design Capabilities

Versatility — Our design engineers are experts in optical science, physics, electrical & mechanical engineering, and biology, all are experienced problem-solvers.

Industry's fastest design turnaround — We've implemented proprietary thin film design software to complete spectrally complex tasks in minutes. Now we can typically design and quote a prototype within a week, where previously it could take two to four weeks.

Modeling toolbox — We use our own state-of-the-art software to simulate complex coating runs before they reach manufacturing, to ensure high confidence in the engineering design.

Custom evaluation — By evaluating the entire optical system we can design and optimize the right filters the first time. This inclusive approach minimizes system redesigns which add cost and delay to your project development.

Volume Manufacturing

Dedicated high-volume coating facility — We support the needs of our OEM customers by producing tens of thousands of spectrally complex, sputtered optical filters per month. Building on our renowned filter manufacturing capability, we can now match the volume demands of customers in the life science, analytical instrumentation, and medical point of care markets.

Rapid prototyping high-mix facility — Ideal for developing custom coatings, products, and sizes using flexible work cells. This enables rapid iteration with aggressive lead times at an economical price for small to moderate volume levels.

Scalability — We can quickly design and develop a prototype filter and then produce it repeatably in high volume. Manage demand with a personalized kanban system and pull inventory when you need it.

Product Capabilities

Types of Filters We Produce

Fluorescence filters; Raman spectroscopy filters; tunable filters; deep notch and laser-line filters; laser diode clean-up filters; filters to combine or separate laser beams; polarization filters; dispersion controlled coating designs, and laser mirrors.

Custom Solutions

Wavelength functionality to specification, 230 nm – 2000 nm

Ability to produce tens of thousands of parts per month

Filter sizes down to 2x2 mm and as large as 200 mm

Glass substrate thickness range from 0.5 mm to 6.0 mm

Spectrally complex custom designs for customers (e.g. laser diode optimized filter designs)

Custom sizing – Round, square, or rectangular, from several mm to a few inches

Product labeling – On-filter laser engraving for easy identification and storage

The Semrock Advantage

Proven Reliability

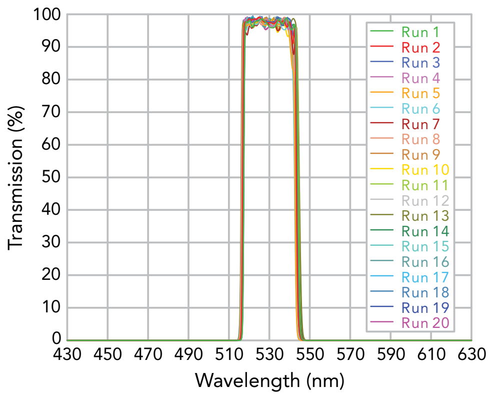
All Semrock filters demonstrate exceptional reliability. The simple all-glass structure combined with ion-beam-sputtered hard coatings are virtually impervious to humidity and temperature induced degradation. Plus, Semrock filters don't "burn out" and they can be readily cleaned and handled.

Semrock confidently backs our filters with a comprehensive ten-year warranty. Built to preserve their high level of performance in test after test, year after year, our filters reduce your cost of ownership by eliminating the expense and uncertainty of replacement costs.

Repeatable Results

Batch-to-batch reproducibility. Whether you are using a filter manufactured last year or last week, the results will always be the same. Our highly automated volume manufacturing systems closely monitor every step of our processes to ensure quality and performance of each and every filter. End users never need to worry whether results will vary when setting up a new system, and OEM manufacturers can rely on a secure supply line.

20 different batches; reproducible results!



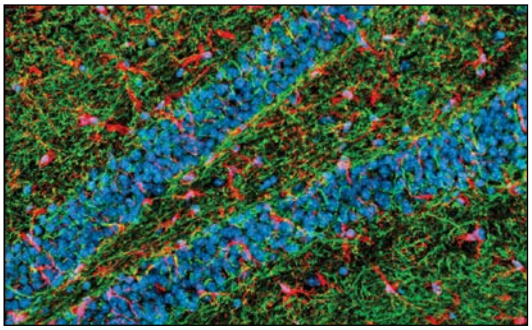
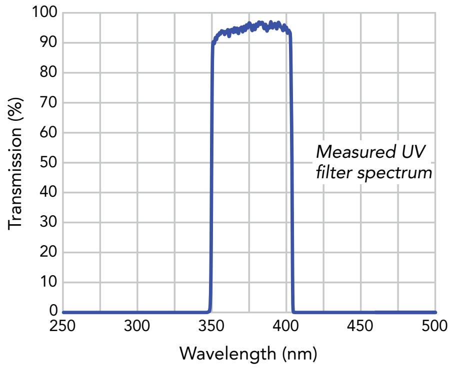


Image courtesy of Mike Davidson at Molecular Expressions™ using BrightLine fluorescence filter sets.

Superior Performance

Semrock successfully combines the most sophisticated and modern ion-beam-sputtering deposition systems, renowned for their stability, with our own proprietary deposition control technology, unique predictive algorithms, process improvements, and volume manufacturing capability. The result is optical filters of unsurpassed performance that set the standard for the Biotech and Analytical Instrumentation industries. These filters are so exceptional that they are patented and award-winning. We never stop innovating.

Semrock's no burn-out optical filters are all made with ion-beam sputtering and our exclusively single-substrate construction for the highest transmission on the market. Steeper edges, precise wavelength accuracy, and carefully optimized blocking mean better contrast and faster measurements – even at UV wavelengths.



Environmental Durability Testing	Mil Spec Standard / Procedure
Humidity	MIL-STD-810F (507.4)
High Temperature	MIL-STD-810F (501.4)
Low Temperature	MIL-STD-810F (502.4)

Physical Durability Testing	Mil Spec Standard / Procedure
Adhesion	MIL-C-48497A (4.5.3.1)
Humidity	MIL-C-48497A (4.5.3.2)
Moderate Abrasion	MIL-C-48497A (4.5.3.3)
Solubility/Cleanability	MIL-C-48497A (4.5.4.2)
Water Solubility	MIL-C-48497A (4.5.5.3)

Semrock filters have been tested to meet or exceed the requirements for environmental and physical durability set forth in the demanding U.S. Military specifications MIL-STD-810F, MIL-C-48497A, MIL-C-675C, as well as the international standard ISO 9022-2.

What's New in 2023

MEASURE DEEPER BLOCKING

KolaDeep™ Spectral Measurement System

New fluorescence-based life science and biomedical instrumentation increasingly requires high-performance optical filters with very high blocking (OD) and steep spectral edges that transition between high transmission and high OD. Our IDEX Health & Science Semrock engineers therefore developed the KolaDeep Spectral Measurement System (SMS), a proprietary award-winning platform for proven measurements of the steepest and deepest spectral features of our optical filters. This system is used in routine production to ensure that instruments made from these filters will deliver their intended performance.

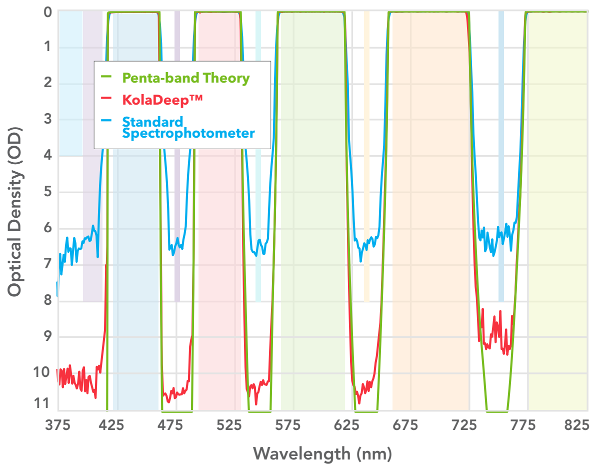
The platform's capabilities include:

- KolaDeep measures blocking to OD 8-9 across wavelength spans in the UV, visible and NIR ranges, and spectral features to OD 11
- KolaDeep resolves edges steeper than 0.2% relative to the edge wavelength from 90% transmission to OD > 7.

Our engineering team performed extensive qualification testing on KolaDeep to characterize and confirm the wavelength and photometric accuracy of the system.

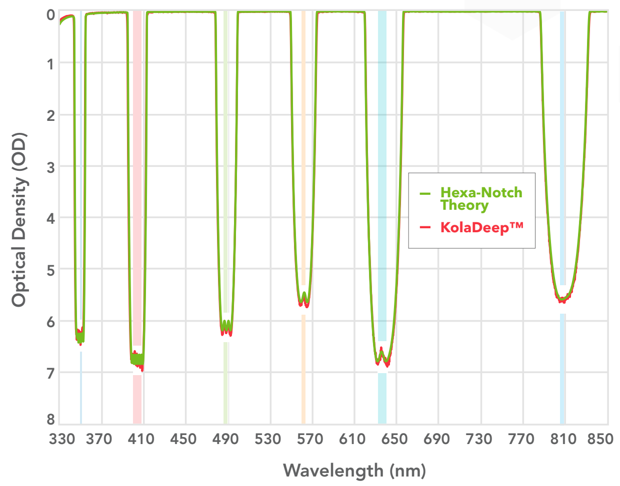
The recent white paper "Advanced Spectral Measurement Systems at IDEX Health & Science Semrock" presents examples and analyses of Semrock filters based on measurements by the KolaDeep SMS; a few are shown here.

The graph below shows OD measured on a custom penta-band filter. The blocking between passbands is specified to exceed OD 8 to prevent excitation light leakage. Theory and measurement agree to OD > 8, with some blocking reaching from OD > 9 to the noise floor.

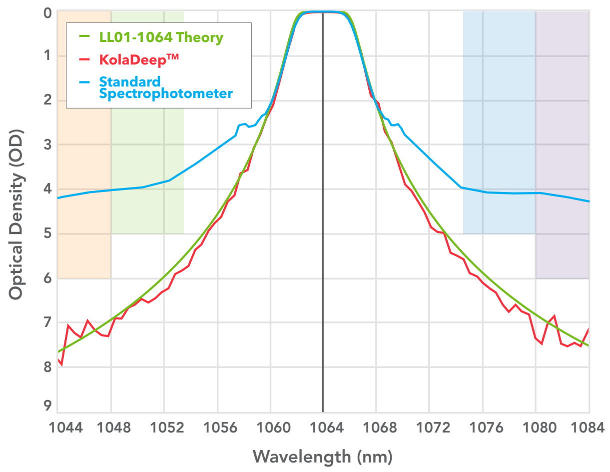


Read the full white paper at www.idex-hs.com/white-papers

The graph below shows spectral performance for a custom hexa-notch filter designed to ensure precise blocking of six laser lines. This customer required assurance that each laser line is repeatably blocked at a specific level. The spectra measured with our KolaDeep SMS show precise matches to the specifications, even in the UV region. The measured blocking (red) matches theory (green).



The KolaDeep SMS performs well over the UV and NIR spectral range. An example is shown below for the 1064 nm Semrock MaxLine® laser-line cleanup filter. Measurements (red) confirm the required blocking and agree with the theoretical design (green) to OD > 7. Data (blue) from a superior commercially available system are not accurate beyond OD 3.



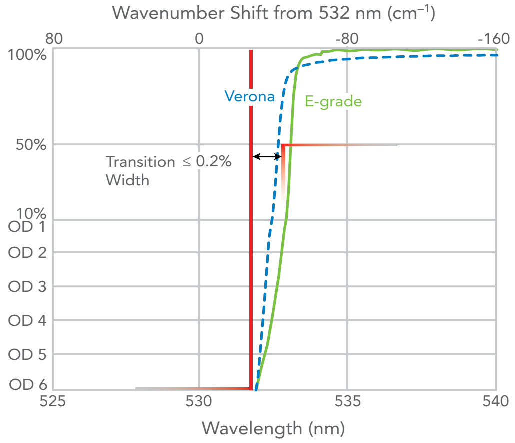
INCREASE RAMAN SYSTEM PERFORMANCE

Optimize Your Raman System and Maximize Signal Contrast with Verona™

Semrock long-pass Verona optical filters were designed from the ground up specifically for Raman instruments with your needs in mind.

- Transition width (cut-off) ≤ 0.2%
- Steepness improved from our RazorEdge series
- Low ripple to provide the best signal-to-noise ratio
- New wavelengths available at 532 nm and 785 nm
- Backed by the KolaDeep Spectral Measurement System

Learn more on page 90



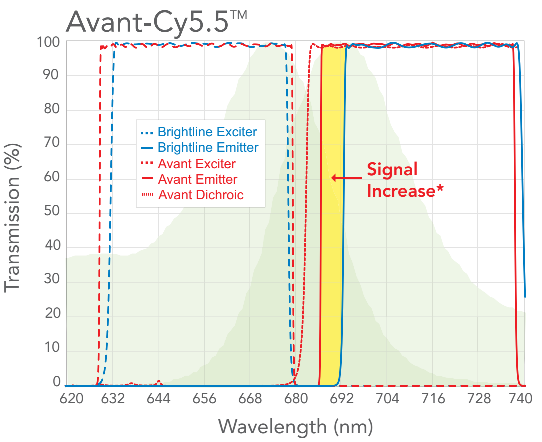
Verona's reduced transition width enables you to collect more Raman signal closer to the laser line for higher resolution images and spectra.

MAXIMIZE YOUR SIGNAL

The Avant™ Filter Set Family Maximizes Signals for Gathering More Accurate Data, and Creating Superior Images

- Fluorophores Available Now: Cy3, Cy5.5, Cy7, Alexa Fluor 555, Alexa Fluor 680, Alexa Fluor 750, YFP, Venus
- More signal by capturing more light near the peak emission
- Precise Edge Placement allows closer spectral edges
- OD10 complementary blocking (design specification) to reduce bleedthrough

Learn more on page 17



*Avant-Cy5.5 set: 10% ~ 40% more signal than the Brightline® set

STREAMLINE YOUR VIEWING EXPERIENCE

The new IDEX Health & Science Website is Live! Aside from a New Look and Feel, Our Website Has Some New and Exciting Features.

- Enhanced Product and Resource Pages
- Improved Search Functionality
- Enhanced Mobile User Experience
- Faster Load Times
- New Customer Account Features

Visit www.idex-hs.com

BrightLine® Fluorescence Filters

Hard-coated Durability – The No Burn-out Promise

- Can be cleaned and handled, even with acetone
- Impervious to humidity, insensitive to temperature
- No soft coatings – no exceptions

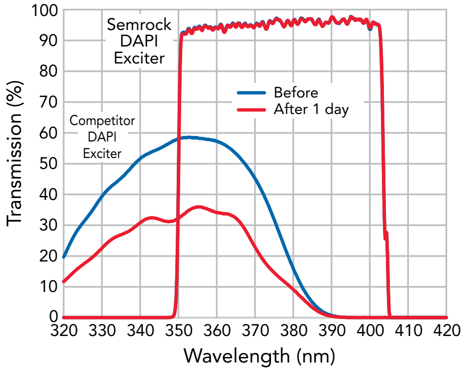
No Burn-out, No Periodic Replacement Needed

- Stands up to intense xenon, mercury, metal halide, LED, and halogen light sources
  No adhesives in the optical path to darken, degrade, or autofluoresce
- Made with the same refractory materials as our high "laser damage threshold" laser optics
- Extremely dense, sputtered coatings do not absorb moisture and are insensitive to temperature

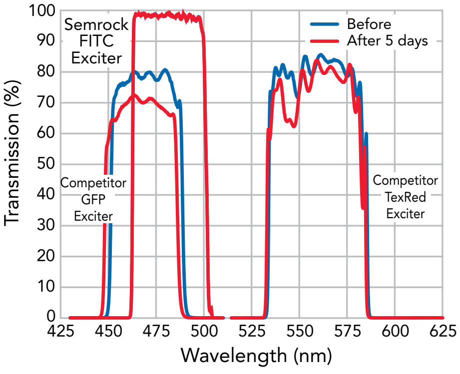
Tests were performed to illustrate the resistance to optical damage of Semrock's hard-coated filters as compared to that of a leading competitor's soft-coated and absorbing glass filters. Continous irradiation from a conventional xenon arc lamp was used for the testing.

The graph on the bottom left shows how a leading competitor's DAPI exciter filter can become severely burned out even after only one day of exposure to 8 W/cm² of total intensity – here the transmission has dropped by 42%. By contrast, the Semrock DAPI exciter is unchanged. Exposure of these two filters was continued with 1 W/cm² of total intensity (closely simulating the intensity seen by an exciter near the arc lamp source in a typical fluorescence microscope). The photographs above show that the competitor's DAPI exciter failed catastrophically after 300 hours – both the large crack and burn-out degradation go all the way through the filter. The Semrock filter is again unchanged even after more than 1000 hours of exposure.

The graph at bottom right shows that a leading competitor's soft-coated filters for visible wavelengths also show significant degradation after optical exposure, even at the intensity levels typical of most fluorescence microscopes. The transmission of these filters drops, and the spectra shift in wavelength. As always, the Semrock hard-coated filter shows no change.



Transmission spectra of DAPI exciters before (blue) and after (red) exposure to 8 W/cm² (over 15 mm diameter) for 1 day.



Transmission spectra of soft-coated exciters (for GFP and Texas Red) compared to a Semrock hard-coated exciter (for FITC) before (blue) and after (red) exposure to 1 W/cm² (over 25 mm diameter) for 5 days.

BrightLine® Single-band Sets

When You Want the Best

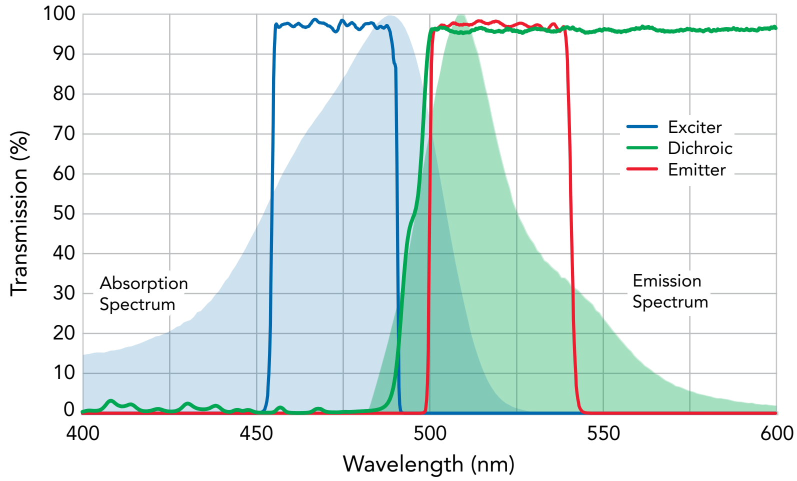
We stock a wide selection of filter sets optimized for the most popular fluorophores and fluorescence microscopes and imaging systems.

High transmission, steeper edges, precise wavelength accuracy and carefully optimized blocking mean better contrast and faster measurements.

We also stock a wide selection of individual bandpass filters and beamsplitters which may be combined for non-standard applications.

World-class manufacturing and advanced metrology ensure consistent, batch-to-batch performance that always meets specifications.

Spectacular Spectra



Typical measured GFP-3035D Filter Set for Green Fluorescent Protein. Hard-coating technology combined with single-substrate filter construction results in the highest transmission and steepest edges available.

At Semrock, our engineering team is well known for designing interference filters with exceptional edge steepness, exact blocking and transmission bands. Our manufacturing team brings the most complex designs to reality each and every time. We make spectrally complex optical filters a reality, everyday.

The result:

- The world's first 5-color full multiband, pentaband fluorescence filter sets.
- 24 patents issued with additional patents pending.
- Laser and Raman specific filters with world-class edge steepness specifications.

Need a Different Size?

Our manufacturing process allows us to offer custom sizing for most standard filters. Semrock now provides the ability for customers to custom size and order filters right on our website for OEM customers. See page 112 for more information. Need a size outside the online sizing limits for a given filter? Contact us at Semrock@idexcorp.com.

Pricing & Availability

All prices are domestic USD and subject to change without notice. For current pricing and availability please check our website.

Not Sure a Filter or Filter Set Will Meet Your Needs?

You may request any standard filter or set for a 30-day test drive. If you are not satisfied, just return it in like new condition and in original packaging. We have shipped over six million sputtered filters to many happy customers, but if you are not fully satisfied with your purchase simply request an RMA number within 30 days from the date of shipment. Our 30-day return policy does not apply to custom-sized parts. Full details and our RMA request form may be found online: www.idex-hs.com/return

BrightLine® Single-band Sets for Popular Fluorophores

Primary Fluorophores	Peak EX	Peak EM	Recommended BrightLine Sets	Page
5-FAM (5-carboxyfluorescein)	492	518	FITC-3540C LED-FITC-A	19 30
5-ROX (carboxy-X-rhodamine)	578	604	TXRED-4040C TXRED-A-Basic	18 27
5-TAMRA (5-carboxytetramethyl-rhodamine, high pH > 8)	542	568	TRITC-B	18
Alexa Fluor® 350	343	441	DAPI-1160B DAPI-5060C BFP-A-Basic	18 18 27
Alexa Fluor® 405	402	422	DAPI-1160B DAPI-5060C LED-DAPI-B	18 18 30
Alexa Fluor® 488	499	520	FITC-3540C FITC-A-Basic	19 27
Alexa Fluor® 532	534	553	TRITC-B	18
Alexa Fluor® 546	556	572	TRITC-B TRITC-A-Basic	18 27
Alexa Fluor® 555	553	565	Cy3-4040C	18
Alexa Fluor® 568	579	603	TXRED-4040C TXRED-A-Basic	18 27
Alexa Fluor® 594	590	618	TXRED-4040C TXRED-A-Basic	18 27
Alexa Fluor® 647	653	668	Cy5-4040C Cy5-A-Basic	18 27
Alexa Fluor® 660	663	691	Cy5-4040C Cy5-A-Basic	18 27
Alexa Fluor® 680	679	702	Cy5.5-C	18
Alexa Fluor® 750	751	776	Cy7-B LED-Cy7-A	18 30
AMCA / AMCA-X	350	448	DAPI-1160B DAPI-5060C BFP-A-Basic	18 18 27
AmCyan	458	489	CFP-2432C	19
BFP (EBFP)	380	440	DAPI-1160B DAPI-5060C BFP-A-Basic LED-DAPI-B LF405-C	18 18 27 30 40
BODIPY	505	512	FITC-3540C FITC-A-Basic	19 27
BD Horizon Brilliant™ Ultraviolet 395	348	395	BUV395-3018A	18
BD Horizon Brilliant™ Violet 421	407	421	BV421-3824A	18
BD Horizon Brilliant™ Violet 480	440	479	BV480-2432A	18
Calcofluor White	349	439	DAPI-1160B DAPI-5060C CFW-LP01 CFW-BP01	18 18 27 27
Cascade Blue™	401	419	DAPI-1160B DAPI-5060C	18 18
CFP (cyan GFP)	433	475	CFP-2432C CFP-A-Basic LED-CFP-A	19 27 30

Primary Fluorophores	Peak EX	Peak EM	Recommended BrightLine Sets	Page
Cerulean	434	473	CFP-2432C CFP-A-Basic LED-CFP-A LF442-C	19 27 30 40
CoralHue Kusabira Orange (mKO)	549	559	Cy3-4040C	18
Cy2™	492	507	GFP-3035D GFP-A-Basic LED-FITC-A LF488-D	19 27 30 40
Cy3™	554	566	Cy3-4040C LF561-B	18 40
Cy3.5™	578	591	Cy3.5-A-Basic TXRED-4040C	27 18
Cy5™	649	666	Cy5-4040C Cy5-A-Basic LED-Cy5-A LF635-C	18 27 30 40
Cy5.5™	672	690	Cy5.5-C	18
Cy7™	753	775	Cy7-B LED-Cy7-A	18 30
DAPI	359	461	DAPI-1160B DAPI-5060C BFP-A-Basic LED-DAPI-B LF405-C	18 18 27 30 40
DsRed Monomer	559	583	Cy3-4040C LF561-C	18 40
DsRed2	563	582	Cy3-4040C LF561-C	18 40
DsRed-Express	556	584	Cy3-4040C LF561-C	18 40
dTomato	556	582	TRITC-B Cy3-4040C TRITC-A-Basic LED-TRITC-A LF561-C	18 18 27 30 40
DyLight 800	777	794	IRDYE800-33LP-A	18
Emerald	491	511	FITC-3540C GFP-3035D	19 19
FITC (Fluorescein)	495	519	FITC-3540C FITC-A-Basic LED-FITC-A LF488-C	19 27 30 40
Fluo-3	506	527	YFP-2427B YFP-A-Basic LF514-C	18 27 40
Fura-2	393, 338	512, 505	FURA2-C	19
Fura Red™ (high pH)	572	657	TXRED-4040C	18
GFP (EGFP)	489	511	GFP-3035D GFP-A-Basic LED-FITC-A LF488-D	19 27 30 40
HcRed	588	618	TXRED-4040C	18
Hoechst 33258 Hoechst 33342 Hoechst 34580	352 350 392	455 462 440	DAPI-1160B DAPI-5060C BFP-A-Basic	18 18 27
ICG	768	807	ICG-B	18

BrightLine® Single-band Sets for Popular Fluorophores

Primary Fluorophores	Peak EX	Peak EM	Recommended BrightLine Sets	Page
IRDye800 CW	775	792	IRDYE800-33LP-A	18
LysoTracker Green	501	509	FITC-3540C	19
LysoTracker Red	573	592	Cy3-4040C	18
mApple	566	594	TXRED-A-Basic LED-TRITC-A LF561-C LF561/LP-C	27 30 40 40
mCherry (mRFP)	587	610	mCherry-C TXRED-A-Basic LED-mCherry-A LF561-C or LF594-D	18 27 30 40 40
mHoneydew	478	562	FITC-3540C YFP-2427B	19 18
mKate2	588	633	mCherry-C TXRED-4040C TXRed-A-Basic LED-mCherry-A LF594-D	18 18 27 30 40
mOrange	546	562	TRITC-B Cy3-4040C	18 18
mPlum	589	649	TXRED-4040C LF594-D	18 40
mStrawberry	574	596	TRITC-B Cy3-4040C Cy3.5-A-Basic LF561-C	18 18 27 40
mTangerine	568	585	TRITC-B Cy3-4040C LED-TRITC-A LF561-C	18 18 30 40
mTFP1 (Teal)	462	492	LED-mTFP-A	30
MitoTracker™ Green	490	512	FITC-3540C LED-FITC-A	19 30
MitoTracker™ Orange	551	575	Cy3-4040C	18
MitoTracker™ Red	578	598	TXRED-4040C	18
Nicotine	270	390	TRP-A	18
Nile Red (Phospholipid)	553	637	TRITC-B TXRED-4040C	18 18
Oregon Green™	503	522	FITC-3540C	19
Oregon Green™ 488	498	526	FITC-3540C	19
Oregon Green™ 500	497	517	FITC-3540C	19
Oregon Green™ 516	513	532	FITC-3540C	19
Phycoerythrin (PE)	567	576	Cy3-4040C	18
Qdot® 525 Nanocrystals	UV-Blue	525	QD525-C QDLP-C	23 23
Qdot® 605 Nanocrystals	UV-Blue	605	QD605-C QDLP-C	23 23
Qdot® 625 Nanocrystals	UV-Blue	625	QD625-C QDLP-C	23 23
Qdot® 655 Nanocrystals	UV-Blue	655	QD655-C QDLP-C	23 23
Rhodamine (Phalloidin)	558	575	TRITC-B TRITC-A-Basic	18 27
Rhodamine Green	497	523	YFP-2427B	18
SNARF (carboxy) 488 Excitation pH6	548	586	Cy3-4040C	18
SNARF (carboxy) 514 Excitation pH6	549	587	Cy3-4040C	18
SNARF (carboxy) Excitation pH9	576	638	TXRED-4040C	18
Sodium Green	507	532	FITC-3540C	18
SpectrumAqua™	434	481	SpAqua-C	23
SpectrumFRed™ (Far Red)	650	673	Cy5-4040C	18
SpectrumGold™	530	556	SpGold-B	23
SpectrumGreen™	497	538	SpGr-B	23
SpectrumOrange™	554	587	SpOr-B LED-TRITC-A	23 30
SpectrumRed™	587	615	SpRed-B	23
Texas Red®	592	614	TXRED-4040C TXRED-A-Basic LF561-C or LF594-D	18 27 40 40
TRITC (Tetramethylrhodamine)	552	578	TRITC-B LED-TRITC-A	18 30
TRITC (Tetramethylrhodamine) - "reddish" appearance	545	623	TRITC-A-Basic	27
Tryptophan	295	340	TRP-A	18
Venus	516	528	YFP-2427B LED-Venus-A LED-YFP-A	18 30 30
wtGFP	474	509	WGFP-A-Basic LED-FITC-A LF488-D	27 30 40
YFP (yellow GFP) EYFP	513	530	YFP-2427-B YFP-A-Basic LED-YFP-A LF514-C	18 27 30 40
Zs Yellow1	539	549	YFP-2427B YFP-A-Basic LED-YFP-A	18 27 30

For a complete list, visit www.idex-hs.com/optical-filter-sets and select your desired Fluorophore in the left side menu

BrightLine® Multiband Sets for Popular Fluorophores

Broadband Sets

Multiband Filter Set	Page	Set Type	Blue	Cyan	Green	Yellow	Orange	Red	Far Red
			BFP, DAPI, Hoechst, Alexa Fluor 350	CFP, AmCyan, BOBO-1, BO-PRO1	FITC, GFP, Bodipy, Alexa Fluor 488	Cy3, DsRed, Alexa Fluor 555	TRITC, DsRed, Cy3, Alexa Fluor 555, YFP	Texas Red, mCherry, Alexa Fluor 568 & 594,Cy5	Cy7
DA/FI-A	33	Full Multi	●		●				
GFP/DsRed-A	33	Full Multi			●			●	
FITC/TxRed-A	33	Full Multi			●			●	
Cy3/Cy5-A	33	Full Multi				●		●	
DA/FI/TR-A	33	Full Multi	●		●		●		
DA/FI/TX-B	33	Full Multi	●		●			●	
DA/FI/TR/Cy5-A	33	Full Multi	●		●		●	●	
DA/FI-2X-B	34	Pinkel	●		●				
CFP/YFP-2X-A	34	Pinkel		●		●			
GFP/DsRed-2X-A	34	Pinkel			●			●	
FITC/TxRed-2X-B	34	Pinkel			●			●	
Cy3/Cy5-2X-B	34	Pinkel				●		●	
CFP/YFP/HcRed-3X-B	34	Pinkel		●		●		●	
DA/FI/TR-3X-A	34	Pinkel	●		●		●		
DA/FI/TX-3X-C	34	Pinkel	●		●			●	
DA/FI/TR/Cy5-4X-B	34	Pinkel	●		●		●	●	
DA/FI/TR/Cy5/Cy7-5X-A	34	Pinkel	●		●		●	●	●
DA/FI-2X2M-B	35	Sedat	●		●				
CFP/YFP-2X2M-B	35	Sedat		●		●			
GFP/DsRed-2X2M-C	35	Sedat			●			●	
FITC/TXRed-2X2M-B	35	Sedat			●			●	
Cy3/Cy5-2X2M-B	35	Sedat				●		●	
DA/FI/TR-3X3M-C	35	Sedat	●		●		●		
DA/FI/TX-3X3M-C	35	Sedat	●		●			●	
DA/FI/TR/Cy5-4X4M-C	35	Sedat	●		●		●	●	
DA/FI/TR/Cy5/Cy7-5X5M-B	35	Sedat	●		●		●	●	●

For a complete list, visit www.idex-hs.com/optical-filter-sets
and select your desired Fluorophore in the left side menu

BrightLine® Multiband Sets for Popular Fluorophores

LED Light Engine Sets

Multiband Filter Set	Page	Set Type	Blue BFP, DAPI, Hoechst, Alexa Fluor 350	Cyan CFP, AmCyan, BOBO-1, BO-PRO1	Green FITC, GFP, Bodipy, Alexa Fluor 488	Yellow YFP, Alexa Fluor 514, 532	Orange TRITC, DsRed, Cy3, Alexa Fluor 555	Red Texas Red, mCherry, Alexa Fluor 568 & 594,Cy5	Far Red Cy7
LED-DA/FI/TX-A	30	Full Multi	●		●			●	
LED-CFP/YFP/mCherry-A	30	Full Multi		●		●		●	
LED-DA/FI/TR/Cy5-B	30	Full Multi	●		●		●	●	
LED-DA/FI/TR/Cy5/Cy7-A	30	Full Multi	●		●		●	●	●
LED-DA/FI/TX-3X-B	31	Pinkel	●		●			●	
LED-CFP/YFP/mCherry-3X-A	31	Pinkel		●		●		●	
LED-mTFP/Venus/mCherry-3X-A	31	Pinkel		●		●		●	
LED-DA/FI/TR/Cy5-4X-B	31	Pinkel	●		●		●	●	
LED-DA/FI/TR/Cy5/Cy7-5X-A	31	Pinkel	●		●		●	●	●
LED-DA/FI/TX-3X3M-B	31	Sedat	●		●			●	
LED-CFP/YFP/mcherry-3X3M-A	31	Sedat		●		●		●	
LED-DA/FI/TR/Cy5-4X4M-B	31	Sedat	●		●		●	●	
LED-DA/FI/TR/Cy5/Cy7-5X5M-A	31	Sedat	●		●		●	●	●

For a complete list, visit www.idex-hs.com/optical-filter-sets and select your desired Fluorophore in the left side menu

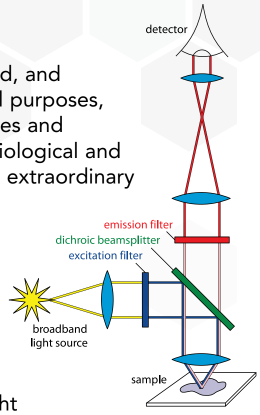
Laser Sets

Multiband Filter Set	Page	Set Type	Blue BFP, DAPI, Hoechst, Alexa Fluor 350	Cyan CFP, AmCyan, BOBO-1, BO-PRO1	Green FITC, GFP, Bodipy, Alexa Fluor 488	Yellow YFP, Alexa Fluor 514, 532	Orange TRITC, DsRed, Cy3, Alexa Fluor 555	Red Texas Red, mCherry, Alexa Fluor 568 & 594,Cy5	Far Red Cy7
LF488/561-B	41	Full Multi			●			●	
LF405/488/594-A	41	Full Multi	●		●			●	
LF405/488/532/635-B	41	Full Multi	●		●	●		●	
LF405/488/561/635-B	41	Full Multi	●		●		●	●	
LF488/561-2X-C	42	Pinkel			●			●	
LF405/488/594-3X-B	42	Pinkel	●		●			●	
LF405/488/532/635-4X-B	42	Pinkel	●		●	●		●	
LF405/488/561/635-4X-B	42	Pinkel	●		●		●	●	
LF488/561-2X2M-C	42	Sedat			●		●		
LF405/488/594-3X3M-B	42	Sedat	●		●			●	
LF405/488/561/635-4X4M-B	42	Sedat	●		●		●	●	

For a complete list, visit www.idex-hs.com/optical-filter-sets and select your desired Fluorophore in the left side menu

TECHNICAL NOTE

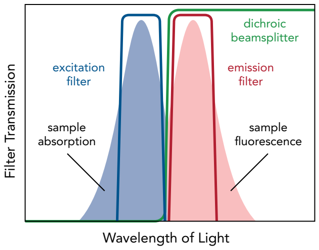
Introduction to Fluorescence Filters



Optical fluorescence occurs when a molecule absorbs light at wavelengths within its absorption band, and then nearly instantaneously emits light at longer wavelengths within its emission band. For analytical purposes, strongly fluorescing molecules known as fluorophores are specifically attached to biological molecules and other targets of interest to enable identification, quantification, and even real-time observation of biological and chemical activity. Fluorescence is widely used in biotechnology and analytical applications due to its extraordinary sensitivity, high specificity, and simplicity.

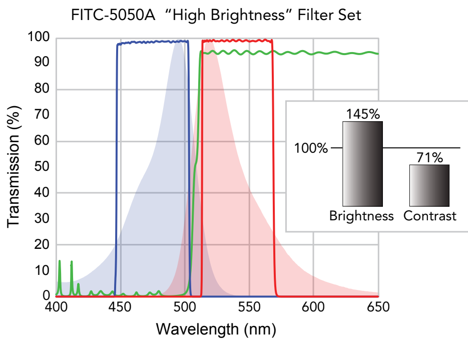
Most fluorescence instruments, including fluorescence microscopes, are based on optical filters.

A typical system has three basic filters: an excitation filter (or exciter), a dichroic beamsplitter (or dichromatic mirror), and an emission filter (or barrier filter). The exciter is typically a bandpass filter that passes only the wavelengths absorbed by the fluorophore, thus minimizing excitation of other sources of fluorescence and blocking excitation light in the fluorescence emission band. The dichroic is an edge filter used at an oblique angle of incidence (typically 45°) to efficiently reflect light in the excitation band and to transmit light in the emission band. The emitter is typically a bandpass filter that passes only the wavelengths emitted by the fluorophore and blocks all undesired light outside this band – especially the excitation light. By blocking unwanted excitation energy (including UV and IR) or sample and system autofluorescence, optical filters ensure the darkest background.

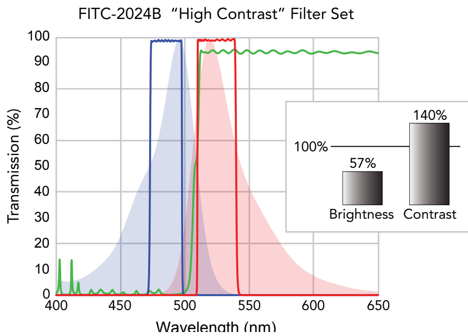


An appropriate combination of optical filters, making up a filter set, enables the visualization of a given fluorophore. See pages 12-15 for a listing of popular fluorophores and corresponding filter sets that can be used to image these fluorophores. A filter set needs to be optimized not only for imaging of distinct fluorophores but also designed to image a given fluorophore under different experimental conditions.

Most of Semrock filter sets are a balance between high-brightness and high-contrast. These filter sets are the best choice of filters under standard imaging conditions. However, when the signal level from a sample is low, sets with wider passbands of the excitation and emission filters enable maximum signal collection efficiency. Studies such as imaging of single molecules typically utilize a filter set with a wide passband or a long pass emission filter. In studies utilizing such filter sets, it is required to maintain very low background autofluorescence signal by means of appropriate sample preparation protocols. However, since the wide passbands of such filter sets occupy a large spectral bandwidth, such filters are not preferred in multiplexing assays when imaging of several fluorophores is required.



Filter sets with narrower passbands are preferred options when imaging a sample labeled with multiple fluorophores. Such filter sets reduce cross-talk between multiple fluorophores. Narrower passbands allow only the strongest portion of the fluorophore emission spectrum to be transmitted, reduce autofluorescence noise and thus improve the signal-to-noise ratio in high background autofluorescence samples. Such filter sets are ideal for samples with ample fluorescent signal level.



In most fluorescence instruments, the best performance is obtained with thin-film interference filters, which are comprised of multiple alternating thin layers of transparent materials with different indices of refraction on a glass substrate. The complex layer structure determines the spectrum of light transmission by a filter. Thin-film filters are simple to use, inexpensive, and provide excellent optical performance: high transmission over an arbitrarily determined bandwidth, steep edges, and high blocking of undesired light over the widest possible wavelength range.

Advances in thin-film filter technology pioneered by Semrock, and embodied in all BrightLine filters, permit even higher performance while resolving the longevity and handling issues that can plague filters made with older soft-coating technology. This advanced technology is so flexible that users have a choice between the highest-performance BrightLine filter sets and the best-value BrightLine Basic™ filter sets.

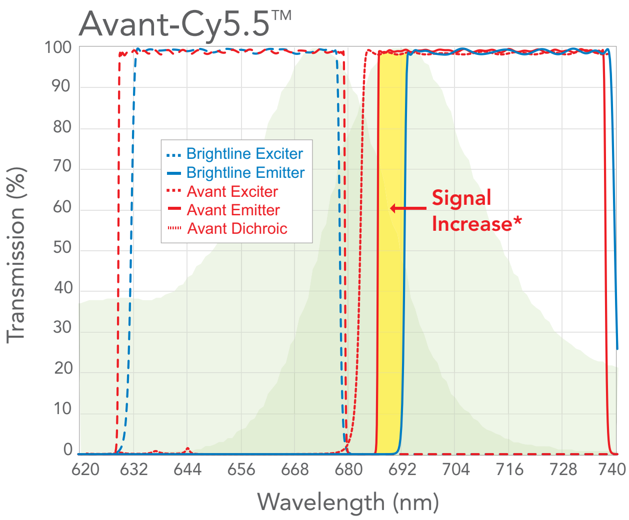
Avant™ Filter Set Family

Maximize Fluorescence Performance

While every fluorescent filter set has a Gap separating excitation and emission passbands, many sets for short Stokes Shift probes have large Gaps that result in the emission filter shifting to longer wavelengths and missing the peak of the emission output. The emission filter captures less fluorescence and the filter set performance is therefore reduced.

Until now, limitations in the coating process and excessive bleedthrough into the emission channel have resulted in lower-performing filter sets that that hinder many fluorescence systems today.

The new Semrock Avant technology from IDEX Health & Science narrows this Gap, provides steeper edges, and brings the emission and excitation passbands closer together. The Avant filter set family thereby delivers significant increases in fluorescence signal. The secret? Precisely controlled steep spectral edges and very deep OD in the excitation and emission filter blocking bands. The spectral features are confirmed by Semrock's high-resolution KolaDeep™ Spectral Measurement System, and the new Precise Edge Placement capability assures that every filter set delivers consistent performance. **Learn more at www.idex-hs.com/improve-your-signal**



*Avant-Cy5.5™ Set Compared to Brightline™ Set as modeled in Searchlight. Visit searchlight.idex-hs.com/avant

Avant Filter Family Sets

Filter Set / Primary Fluorophores	Excitation (CWL/BW)	Emission (CWL/BW)	Dichroic (Laser)	Filter Set Part Numbers	Base Price
Avant-Cy5.5 Cy5.5 and Alexa Fluor 680 and other deep-red and near-infrared fluorophores	653/47	712/48	683 nm	**Avant-Cy5.5-000**	**$1105**
Avant-YFP Yellow Fluorescent Protein (YFP) and Venus	504/24	539/27	521 nm	**Avant-YFP-000**	**$1105**
Avant-Cy3 Cy3 and Alexa Fluor 555 and with other orange fluorophores	535/40	584/40	560 nm	**Avant-Cy3-000**	**$1105**
Avant-Cy7 Cy7 and Alexa Fluor 750 and with other near-infrared fluorophores	720/75	811/81	764 nm	**Avant-Cy7-000**	**$1105**

Avant Single-band Bandpass

Center Wavelength	Avg. Transmission and Bandwidth[1]	Housed Size (Diameter x Thickness)	Glass Thickness	Filter Part Number	Price
653 nm	Tavg > 93% over 47 nm	25 mm x 5.0 mm	2.0 mm	AF01-653/47-25	$395
712 nm	Tavg > 93% over 48 nm	25 mm x 3.5 mm	2.0 mm	AF01-712/48-25	$395
504 nm	Tavg > 93% over 24 nm	25 mm x 5.0 mm	2.0 mm	AF01-504/24-25	$395
539 nm	Tavg > 93% over 27 nm	25 mm x 3.5 mm	2.0 mm	AF01-539/27-25	$395
535 nm	Tavg > 93% over 40 nm	25 mm x 5.0 mm	2.0 mm	AF01-535/40-25	$395
584 nm	Tavg > 93% over 40 nm	25 mm x 3.5 mm	2.0 mm	AF01-584/40-25	$395
720 nm	Tavg > 93% over 75 nm	25 mm x 5.0 mm	2.0 mm	AF01-720/75-25	$395
811 nm	Tavg > 93% over 81 nm	25 mm x 3.5 mm	2.0 mm	AF01-811/81-25	$395

Avant Single-edge Dichroic Beamsplitters

Nominal Laser Wavelength	Avg. Reflection Wavelength	Avg. Transmission Band	Size (mm) (L x W)	Glass Thickness	Filter Part Number	Price
683 nm	Ravg > 98% 600 – 677 nm	Tavg > 93% 688 – 770 nm	25.2 x 35.6	1.05 mm	AF683-Di01-25x36	$315
521 nm	Ravg > 98% 470 – 516.5 nm	Tavg > 93% 525.5 – 580 nm	25.2 x 35.6	1.05 mm	AF521-Di01-25x36	$315
560 nm	Ravg > 93% 490 – 555 nm	Tavg > 93% 564 – 640 nm	25.2 x 35.6	1.05 mm	AF560-Di01-25x36	$315
764 nm	Ravg > 98% 650 – 758 nm	Tavg > 93% 770.5 – 890 nm	25.2 x 35.6	1.05 mm	AF764-Di01-25x36	$315

BrightLine® Single-band Sets

Filter Set / Primary Fluorophores	Excitation (CWL/BW)	Emission (CWL/BW)	Dichroic (Edge)	Filter Set Part Numbers / –ZERO Set Part Numbers	Base Price / –ZERO Price
TRP-A **Tryptophan** *Designed for UV fluorescence* *Use with UV LED or filtered Xe arc lamps, or detectors not sensitive to near-IR light.*	280/20	357/44	310 nm	**TRP-A-000**	**$1465**
DAPI-11LP-A *(Longpass)* **DAPI**, Hoechst, AMCA, BFP, Alexa Fluor® 350	387/11	409/LP	409 nm	**DAPI-11LP-A-000** DAPI-11LP-A-000-ZERO	**$1055** $1164
DAPI-50LP-A *(Longpass)* **DAPI**, Hoechst, AMCA, BFP, Alexa Fluor® 350	377/50	409/LP	409 nm	**DAPI-50LP-A-000** DAPI-50LP-A-000-ZERO	**$1055** $1164
BV421-3824A **BD Horizon Brilliant™ Violet 421,** DAPI, Alexa Fluor® 405, DyLight405	389/38	433/24	414 nm	**BV421-3824A-000** BV421-3824A-000-ZERO	**$1125** $1234
DAPI-1160B *(Highest Contrast)* **DAPI**, Hoechst, AMCA, BFP, Alexa Fluor® 350	387/11	447/60	409 nm	**DAPI-1160B-000** DAPI-1160B-000-ZERO	**$1055** $1164
DAPI-5060C *(Highest Brightness)* **DAPI**, Hoechst, AMCA, BFP, Alexa Fluor® 350	377/50	447/60	409 nm	**DAPI-5060C-000** DAPI-5060C-000-ZERO	**$1055** $1164
BV480-2432A **BD Horizon Brilliant™ Violet 480,** CFP, Cerulean, SpectrumAqua	438/24	483/32	458 nm	**BV480-2432A-000** BV480-2432A-000-ZERO	**$1055** $1164
CFP-2432C **CFP**, AmCyan, SYTOX Blue, BOBO-1, Cerulean	438/24	483/32	458 nm	**CFP-2432C-000** CFP-2432C-000-ZERO	**$1055** $1164
FURA2-C *(Four Filter Set)* **Fura-2 Ca^{2+} indicator**, LysoSensor Yellow/Blue	Ex1: 340/26 Ex2: 387/11	510/84	409 nm	**FURA2-C-000** FURA2-C-000-ZERO	**$1455** $1564
GFP-1828A *(Highest Contrast)* **GFP**, (EGFP), DiO, Cy2™, YOYO-1, YO-PRO-1	482/18	520/28	495 nm	**GFP-1828A-000** GFP-1828A-000-ZERO	**$1085** $1194
GFP-3035D *(All Purpose)* **GFP**, (EGFP), DiO, Cy2™, YOYO-1, YO-PRO-1	472/30	520/35	495 nm	**GFP-3035D-000** GFP-3035D-000-ZERO	**$1055** $1164
GFP-30LP-B *(Longpass)* **GFP**, (EGFP), DiO, Cy2™, YOYO-1, YO-PRO-1	472/30	496/LP	495 nm	**GFP-30LP-B-000** GFP-30LP-B-000-ZERO	**$1055** $1164
GFP-4050B *(Highest Brightness)* **GFP**, (EGFP), DiO, Cy2™, YOYO-1, YO-PRO-1	466/40	525/50	495 nm	**GFP-4050B-000** GFP-4050B-000-ZERO	**$1055** $1164
FITC-2024B *(Highest Contrast)* **FITC**, rsGFP, Bodipy, 5-FAM, Fluo-4, Alexa Fluor® 488	485/20	524/24	506 nm	**FITC-2024B-000** FITC-2024B-000-ZERO	**$1085** $1194
FITC-3540C *(All Purpose)* **FITC**, rsGFP, Bodipy, 5-FAM, Fluo-4, Alexa Fluor® 488	482/35	536/40	506 nm	**FITC-3540C-000** FITC-3540C-000-ZERO	**$1055** $1164
FITC-5050A *(Highest Brightness)* **FITC**, rsGFP, Bodipy, 5-FAM, Fluo-4, Alexa Fluor® 488	475/50	540/50	506 nm	**FITC-5050A-000** FITC-5050A-000-ZERO	**$1055** $1164
YFP-2427B **YFP**, Calcium Green-1, Eosin, Fluo-3, Rhodamine 123	500/24	542/27	520 nm	**YFP-2427B-000** YFP-2427B-000-ZERO	**$1080** $1189
TRITC-B **TRITC**, Rhodamine, DiI, 5-TAMRA, Alexa Fluor® 532 & 546	543/22	593/40	562 nm	**TRITC-B-000** TRITC-B-000-ZERO	**$1055** $1164
Cy3-4040C **Cy3™**, DsRed, PE, 5-TAMRA, Calcium Orange, Alexa Fluor® 555	531/40	593/40	562 nm	**Cy3-4040C-000** Cy3-4040C-000-ZERO	**$1055** $1164
TXRED-4040C **Texas Red®**, Cy3.5™, 5-ROX, Mitotracker Red, Alexa Fluor® 568 & 594	562/40	624/40	593 nm	**TXRED-4040C-000** TXRED-4040C-000-ZERO	**$1055** $1164
mCherry-40LP-A *(Longpass)* **mCherry,** mRFP1	562/40	593/LP	593 nm	**mCherry-40LP-A-000** mCherry-40LP-000-ZERO	**$1055** $1164

BrightLine® Single-band Sets

Filter Set / Primary Fluorophores	Excitation (CWL/BW)	Emission (CWL/BW)	Dichroic (Edge)	Filter Set Part Numbers / –ZERO Set Part Numbers	Base Price / –ZERO Price
mCherry-C **mCherry**, mRFP	562/40	641/75	593 nm	**mCherry-C-000** mCherry-C-000-ZERO	**$1055** $1164
Cy5-4040C **Cy5™**, APC, DiD, Alexa Fluor® 647 & 660	628/40	692/40	660 nm	**Cy5-4040-C-000** Cy5-4040-C-000-ZERO	**$1055** $1164
Cy5.5-C **Cy5.5™**, Alexa Fluor® 680 & 700	655/40	716/40	685 nm	**Cy5.5-C-000** Cy5.5-C-000-ZERO	**$1055** $1164
Cy7-B **Cy7™**, Alexa Fluor® 750	708/75	809/81	757 nm	**Cy7-B-000** Cy7-B-000-ZERO	**$1055** $1164
IRDYE800-33LP-A *(Longpass)* **IRDye800 CW**, DyLight 800	747/33	776/LP	776 nm	**IRDYE800-33LP-A-000** IRDYE800-33LP-A-000-ZERO	**$1130** $1239
ICG-B **Indocyanine Green**	769/41	832/37	801 nm	**ICG-B-000** ICG-B-000-ZERO	**$1160** $1269
DyLight405-C	379/34	440/40	562 nm	**DyLight405-C-000**	**$1055**
LuciferYellow-C	438/24	538/40	482 nm	**LuciferYellow-C-000**	**$1035**
SYBRGold-A	497/16	542/27	516nm	**SYBRGold-A-000**	**$975**
YFP-2427B	497/16	542/27	516 nm	**YFP-2427B-000**	**$1080**

CUBES PAGE 37

(continued)

Filter Specifications on page 36

"–ZERO" denotes zero pixel shift performance (see page 38)

TECHNICAL NOTE

Fluorescence Imaging with Quantum Dot Nanocrystals

Quantum dot nanocrystals are fluorophores that absorb photons and then re-emit longer-wavelength photons nearly instantaneously. However, there are some important differences between quantum dots (e.g., Qdot® nanocrystals made by Thermo Fisher Scientific) and traditional fluorophores including organic dyes and naturally fluorescing proteins. Quantum dots are nanometer-scale clusters of semiconductor atoms, typically coated with an additional semiconductor shell and then a polymer coating to enable coupling to proteins, oligonucleotides, small molecules, etc., which are then used for direct binding of the quantum dots to targets of interest.

Nanocrystals are extremely bright and highly photostable, making them ideal for applications that require high sensitivity with minimal label interference, as well as long-term photostability, such as live-cell imaging and dynamic studies. Their excellent photostability also means they are fixable and archivable for permanent sample storage in pathology applications. Because there is a direct relationship between the size of a nanocrystal and the wavelength of the emitted fluorescence, a full range of nanocrystals can be made – each with a narrow, distinct emission spectrum and all excited by a single blue or ultraviolet wavelength. Thus nanocrystals are ideal for dense multiplexing. Some important nanocrystal features that may limit certain applications include their fairly large physical size and long lifetime.

To take advantage of nanocrystal features, it is important to use properly optimized filters. Semrock offers BrightLine® filter sets specially optimized for the most popular quantum dot imaging applications. A universal set with a long-wave-pass emitter enables simultaneous imaging of multiple quantum dots by eye or with a color camera. Additionally, filter sets tailored to individual quantum dots are also available (see filter sets above). Best of all, these filters share the incredible "no burn-out" reliability of all BrightLine filters, an ideal match for highly photostable quantum dot nanocrystals!

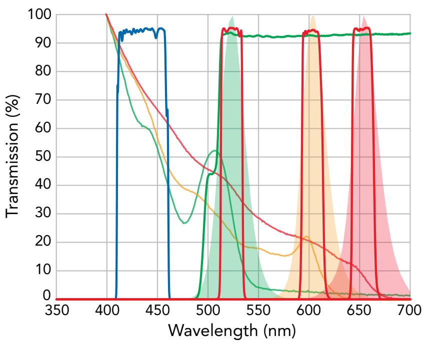


Figure 2. A universal exciter provides superior excitation efficiency while avoiding the excitation of DAPI and undesirable autofluorescence. This filter is combined with a dichroic beamsplitter with extremely wide reflection and transmission bands for maximum flexibility, and narrow, highly transmitting emission filters matched to each of the most important Qdot wavelengths.

TECHNICAL NOTE

Ultraviolet (UV) Fluorescence Applications

Many biological molecules of interest naturally fluoresce when excited by shorter wavelength UV light. This "intrinsic fluorescence" can be a powerful tool as labeling with extrinsic fluorophores is not required. One important application is the direct fluorescence imaging of aromatic amino acids including tryptophan, tyrosine, and phenylalanine, which are building blocks for proteins. The aromatic rings in these molecules give rise to strong fluorescence excitation peaks in the 260 to 280 nm range. Another application is DNA quantitation. Purines and pyrimidines – bases for nucleic acids like DNA and RNA – have strong absorption bands in the 260 to 280 nm range.

Semrock's UV BrightLine fluorescence filters offer a powerful tool for direct fluorescence imaging. These unique UV filters are reliable "no burn-out" and offer performance nearly comparable to visible and near-IR filters. Figure 1 shows the spectrum of a high-reliability 280 nm BrightLine excitation filter with the highest commercially available transmission (> 65%), remarkably steep edges, and wideband blocking across the entire UV and visible spectrum. This spectrum is directly compared to a traditional and inferior metal-dielectric filter. In one example system, this filter difference was shown to provide over 100x improvement in signal-to-noise ratio.

Figure 2 shows the spectra from a UV filter set designed for imaging tryptophan, overlaid on the absorption and emission spectra for that amino acid. Note the nearly ideal overlap and high transmission of all three filters in this set.

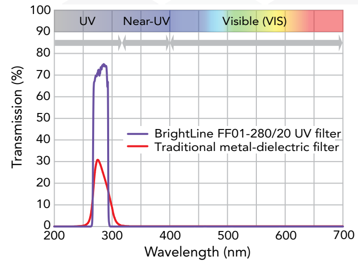


Figure 1. BrightLine FF01-280/20-25 filter

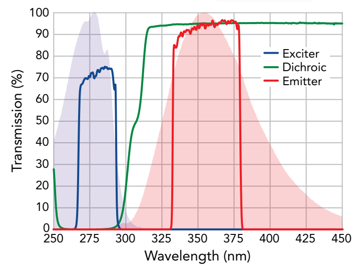
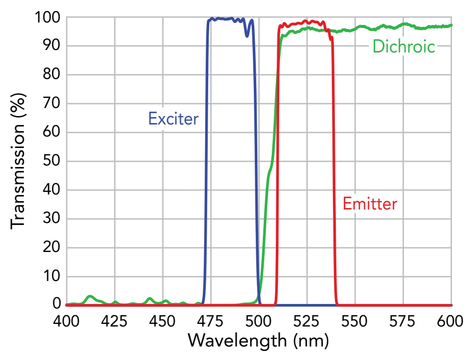


Figure 2. TRP-A single-band fluorescence filter set is ideal for imaging tryptophan (see filter set above).

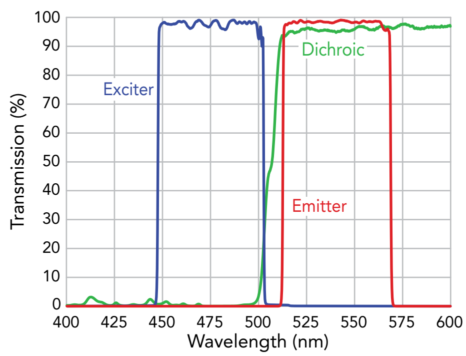
ACTUAL MEASURED DATA

What you see is what you get. The published spectra for our filters are actual measured data from actual finished parts, not theory and not a design estimate only to be made under ideal conditions. Our strict manufacturing control and advanced metrology capabilities ensure that the filter you receive meets the spectral specifications you expect.

Highest Contrast FITC-2024B Set



Highest Brightness FITC-5050A Set



INDIVIDUAL & FILTER SET PACKAGING

Semrock utilizes individual PET-G packaging for standard-size catalog filters. This packaging allows Semrock to produce cleaner parts, reduce potential defects caused by shipping & handling, and utilize 100% recyclable materials.

Custom size filters in low volume will be packaged in envelopes lined with cleanroom grade, non-abrasive, resin-free, non-woven fabric.

Learn more at about our packaging at www.idex-hs.com/packaging

BrightLine® FISH & Dense Multiplexing Information

APPLICATION NOTE

Crosstalk in FISH and Densely Multiplexed Imaging

When using multiple fluorophores with densely spaced spectra, rapid and accurate results rely on the ability to readily distinguish the fluorescence labels from one another. This dense multiplexing of images is particularly important when doing Fluorescence in Situ Hybridization (FISH) measurements. Thus, it is critical to minimize crosstalk, or the signal from an undesired fluorophore relative to that of a desired fluorophore. The table below quantifies crosstalk values for neighboring fluorophores when using a given BrightLine FISH filter set. Values are determined from the overlap of typical, normalized fluorophore spectra, the filter design spectra, and an intense metal halide lamp.

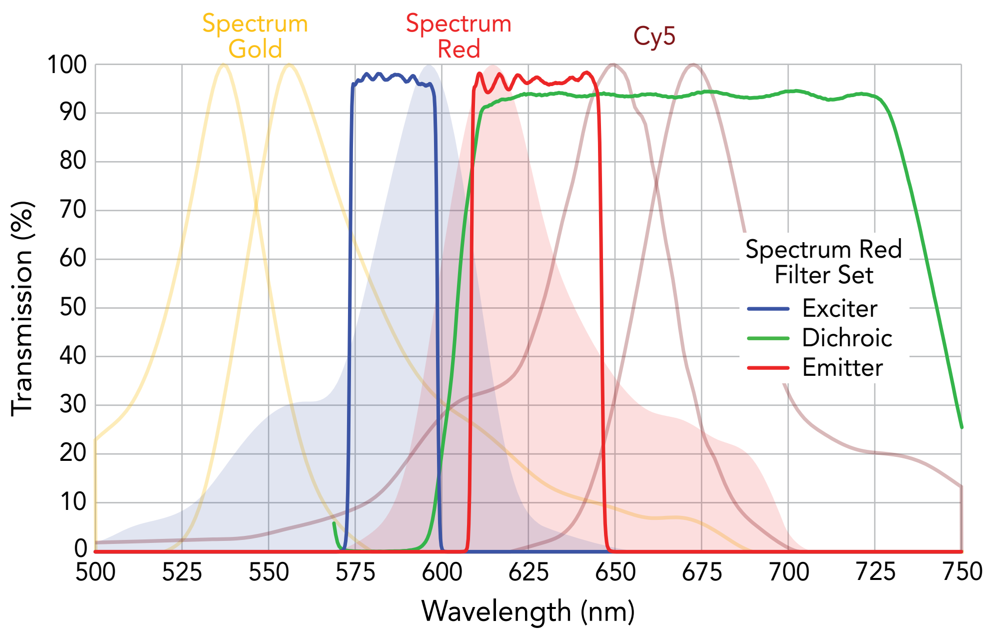
Fluorophore / Filter Set	Relative Fluorophore Contributions for Each Filter Set								
	DAPI	SpAqua	SpGreen	SpGold	SpOrange	SpRed	Cy5 / FRed	Cy5.5	Cy7
DAPI	100%	30%	0%						
SpAqua	0%	100%	1%	0%					
SpGreen	0%	0%	100%	3%	0%				
SpGold		0%	2%	100%	49%	1%			
SpOrange			0%	36%	100%	11%	0%		
SpRed				0%	15%	100%	1%	0%	
Cy5 / FRed					0%	12%	100%	53%	1%
Cy5.5						0%	53%	100%	6%
Cy7							0%	12%	100%

Grey combinations are not recommended

As an example, when imaging a sample labeled with the SpectrumGreen™, SpectrumGold™, and SpectrumRed™ fluorophores using the SpectrumGold filter set, the undesired SpectrumGreen signal will be less than 2% of the desired SpectrumGold signal, and the SpectrumRed signal will be less than 1%.

Amazing Spectra that Minimize Crosstalk

These BrightLine filter sets are meticulously optimized to maximize brightness for popular fluorophores, while simultaneously minimizing unnecessary background as well as crosstalk with adjacent fluorophores. The graph below shows an example of the filter spectra for the SpectrumRed filter set (blue, green, and red solid lines), as well as the absorption and emission curves for SpectrumGold, SpectrumRed, and Cy5™ (left to right). Crosstalk is kept to only a few percent or less, as quantified in the table above.



BrightLine® Single-band Sets for FISH & Dense Multiplexing

PathVysion® assay control sample with CEP 17 and HER-2/neu probes (100X oil-immersion objective).

Help Ease the Upstream Battle Against Cancer with BrightLine FISH Fluorescence Filter Sets

Fluorescence In Situ Hybridization, or FISH, is an exciting fluorescence imaging technique that enables clinical-scale genetic screening based on molecular diagnostics. Semrock pioneered hard-coated BrightLine filters that are significantly brighter than and have superior contrast to older, soft-coated fluorescence filters, thus offering faster and more accurate measurements. Independent evaluations have shown that FISH images can be obtained in as little as one half the exposure time using BrightLine filters. And yet the inherent manufacturability of Semrock's patented ion-beam-sputtered filters actually allows them to be priced lower than soft-coated FISH filter sets.

Switching to BrightLine filters is the simplest and least expensive way to dramatically increase the quality of your FISH images.

Full Spectrum of Solutions

Examples of popular assays using BrightLine FISH filter sets

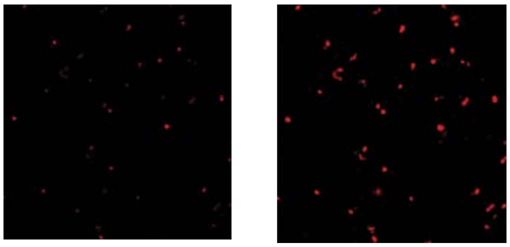
Single-band Filter Sets	Assay	Purpose
DAPI, SpGr, SpOr	PathVysion®	Detects amplification of the HER-2 gene for screening and prognosis of breast cancer
DAPI, SpAqua, SpGr, SpOr	AneuVysion®	Used as an aid in prenatal diagnosis of chromosomal abnormalities
DAPI, SpAqua, SpGr, SpGold, SpRed	UroVysion™	Aid for initial diagnosis of bladder carcinoma and subsequent monitoring for tumor recurrence in previously diagnosed patients
DAPI, SpAqua, SpGr, SpGold, SpRed, Cy5	M-FISH	Permits the simultaneous visualization of all human (or mouse) chromosomes in different colors for karyotype analysis

PRODUCT NOTE

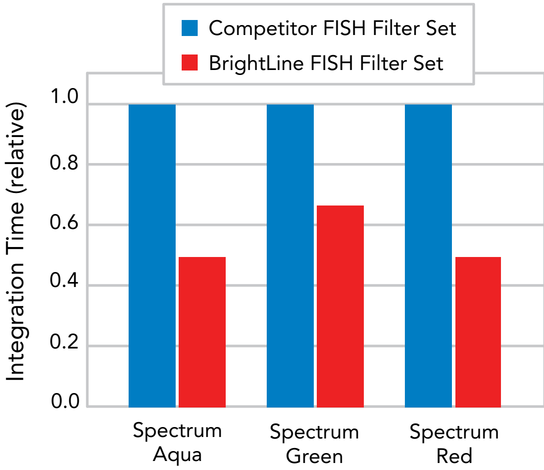
Can Better Fluorescence Filters Really Make a Difference?

BrightLine "no-burn-out" filters have been tested widely in both research and clinical fields over many years of use. Extensive independent testing has also been performed with BrightLine FISH filter sets. A few examples of results are shown here. Whether you are finding and analyzing metaphase spreads or scoring cells by spot counting, significantly improve the speed and accuracy of your FISH analysis with BrightLine filter sets.

Competitor filter set   BrightLine filter set



Side-by-side independent comparison using equal exposure times of images achieved with competitor filter sets (left) and BrightLine filter sets (right), of a human tumor hybridized with CEP 3 probe in Spectrum Red (part of Vysis UroVysion™ assay, 400X magnification). Photo courtesy of Tina Bocker Edmonston, M.D., Thomas Jefferson University.



BrightLine filters allow shorter integration times for faster imaging – especially for automated tasks like metaphase finding. This independent industry test compares integration times required by BrightLine FISH filter sets to those of competitor filter sets. The automated system, based on a Zeiss Axio Imager microscope, found metaphase spreads with identical image intensities.

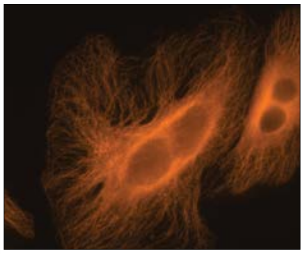
BrightLine® Single-band Sets for FISH & Dense Multiplexing

Filter Set / Primary Fluorophores	Excitation (CWL/BW)	Emission (CWL/BW)	Dichroic (Edge)	Filter Set Part Numbers / –ZERO Set Part Numbers	Base Price / –ZERO Price
SpAqua-C **SpectrumAqua™**, DEAC	438/24	483/32	458 nm	**SpAqua-C-000** SpAqua-C-000-ZERO	**$1055** $1164
SpGr-B **SpectrumGreen™**, FITC, Alexa Fluor® 488	494/20	527/20	506 nm	**SpGr-B-000** SpGr-B-000-ZERO	**$1080** $1189
SpGold-B **SpectrumGold™**, Alexa Fluor® 532	534/20	572/28	552 nm	**SpGold-B-000** SpGold-B-000-ZERO	**$1080** $1189
SpOr-B **SpectrumOrange™**, Cy3™, Rhodamine, Alexa Fluor® 555	543/22	586/20	562 nm	**SpOr-B-000** SpOr-B-000-ZERO	**$1040** $1149
SpRed-B **SpectrumRed™**, Texas Red, Alexa Fluor® 668 & 594	586/20	628/32	605 nm	**SpRed-B-000** SpRed-B-000-ZERO	**$1040** $1149

Filter Specifications on page 36
"–ZERO" denotes zero pixel shift performance (see page 38)

NOTE: For DAPI , Cy5™, Cy5.5™, or Cy7™ sets, refer to pages 18-19.

Qdot® Single-band Filter Sets



Cell image courtesy of Thermo Fisher Scientific.

These single-band filter sets are specially optimized for brilliant, dense multi-color detection with Molecular Probes® (Thermo Fisher Scientific) quantum dot nanocrystals. The highly transmitting, deep-blue exciter achieves maximum quantum dot excitation efficiency while virtually eliminating any DAPI or Hoechst excitation. And with the no burn-out reliability shared by all BrightLine® filters, the permanent performance of these sets will outlast even your quantum dots!

Filter Set / Primary Fluorophores	Excitation (CWL/BW)	Emission (CWL/BW)	Dichroic (Edge)	Filter Set Part Numbers / –ZERO Set Part Numbers	Base Price / –ZERO Price
QDLP-C *(Longpass)* **Qdot® 525, 565, 585, 605, 625, 655, 705, & 800 Nanocrystals** *Versatile and high brightness longpass filter set for viewing multiple Qdots*	435/40	500/LP	510 nm	**QDLP-C-000**	**$1085**
QD525-C **Qdot® 525 Nanocrystals**	435/40	525/15	510 nm	**QD525-C-000** QD525-C-000-ZERO	**$1155** $1264
QD605-C **Qdot® 605 Nanocrystals**	435/40	605/15	510 nm	**QD605-C-000** QD605-C-000-ZERO	**$1130** $1239
QD625-C **Qdot® 625 Nanocrystals**	435/40	625/15	510 nm	QD625-C-000 QD625-C-000-ZERO	**$1160** $1269
QD655-C **Qdot® 655 Nanocrystals**	435/40	655/15	510 nm	**QD655-C-000** QD655-C-000-ZERO	**$1130** $1239

Filter Specifications on page 36
"–ZERO" denotes zero pixel shift performance (see page 38)

BrightLine® FRET Single-band Sets

These filter sets offer our simplest solution for dual-wavelength FRET imaging.
Also see our multiband "Sedat" filter sets for high-performance FRET imaging starting on page 30.

Filter Set / Primary Fluorophores	Excitation (CWL/BW)	Emission (CWL/BW)	Dichroic (Edge)	Filter Set Part Numbers / –ZERO Set Part Numbers	Base Price / –ZERO Price
FRET-BFP/GFP-B Blue: BFP, DAPI, Hoechst, Alexa Fluor® 350 Green: GFP, (EGFP), FITC, Cy2™, Alexa Fluor® 488	387/11	Em1: 447/60 Em2: 520/35	409 nm	**FRET-BFP/GFP-B-000** FRET-BFP/GFP-B-000-ZERO	**$1430** $1539
FRET-CFP/YFP-C Cyan: CFP, CyPet, AmCyan Yellow: YFP, YPet, Venus	438/24	Em1: 483/32 Em2: 542/27	458 nm	**FRET-CFP/YFP-C-000** FRET-CFP/YFP-C-000-ZERO	**$1430** $1539
FRET-GFP/RFP-D Green: GFP, (EGFP), FITC, Cy2™, Alexa Fluor® 488 Red: mRFP1, mCherry, mStrawberry, dTomato, DsRed, TRITC, Cy3™	472/30	Em1: 520/35 Em2: 641/75	495 nm	**FRET-GFP/RFP-D-000** FRET-GFP/RFP-D-000-ZERO	**$1430** $1539
FRET-CY3/CY5-A Yellow: Cy3™, Alexa Fluor® 555 Red: Cy5™, Alexa Fluor® 647	531/40	Em1: 593/40 Em2: 676/29	562 nm	**FRET-CY3/CY5-A-000** FRET-CY3/CY5-A-000-ZERO	**$1430** $1539

Filter Specifications on page 36
"–ZERO" denotes zero pixel shift performance (see page 38)

Filter Set and imaging dichroic options for common FRET fluorophore pairs

Start with a FRET fluorophore pair	For imaging with emission filter wheel only, using a FRET single-band filter set	For imaging utilizing emission signal splitting, add an image splitting dichroic	For imaging with excitation and emission filter wheels, "Sedat" multiband filter sets	For imaging with excitation filter wheel and emission signal splitting, add image splitting dichroic
BFP/GFP	FRET-BFP/GFP-B	FRET-BFP/GFP-B FF484-FDi01-25x36	DA/FI-2X2M-B	DA/FI-2X2M-B FF484-FDi01-25x36
CFP/YFP	FRET-CFP/YFP-C	FRET-CFP/YFP-C FF509-FDi01-25x36	CFP/YFP-2X2M-B	CFP/YFP-2X2M-B FF509-FDi01-25x36
GFP/RFP	FRET-GFP/RFP-C	FRET-GFP/RFP-C FF580-FDi01-25x36	FITC/TxRed-2X2M-B	FITC/TxRed-2X2M-B FF580-FDi01-25x36
Cy3/Cy5	FRET-Cy3/Cy5-A	FRET-Cy3/Cy5-A FF662-FDi01-25x36	Cy3/Cy5-2X2M-B	Cy3/Cy5-2X2M-B FF662-FDi01-25x36

Image splitting dichroics are listed on page 63

CUBES PAGE 37

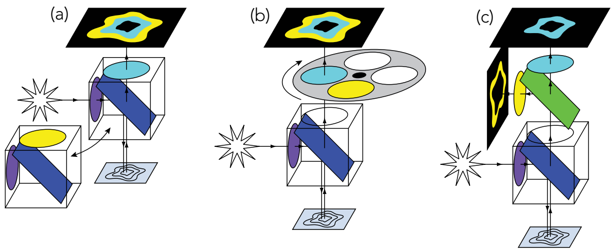
BrightLine® FRET Single-band Sets

TECHNICAL NOTE

Optical Filter Configurations for FRET

The classical approach to FRET measurements involves changing filter cubes (see Figure (a) and page 24 for filters and more information on FRET). For example, in the acceptor-photobleaching method, a donor-specific cube is first used to collect the emission from the donor (e.g., CFP). Then a filter cube for the acceptor is used to visualize and photobleach the acceptor (e.g., YFP). Intensity measurements of the donor before and then again after photobleaching the acceptor are used to calculate FRET efficiency. Steep spectral edges of the filters ensure that only the acceptor is photobleached and minimize the signal contamination due to bleedthrough in multiply labeled FRET samples. This technique suffers from several drawbacks, including: slow speed (changing filter cubes takes typically a second or more) and imaging artifacts (due to the movement of the filter turret and other vibrations).

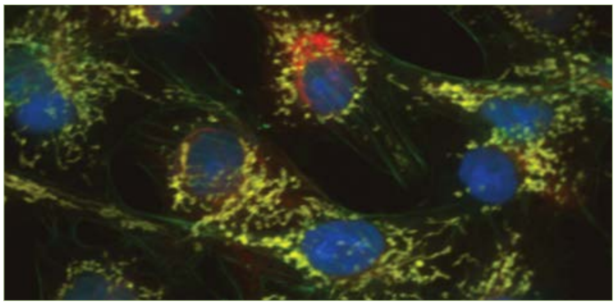
The most popular approach to FRET imaging, shown in Figure (b), is often called the FRET-cube method. A single-band exciter and a single-edge dichroic beamsplitter, each specific to the donor, are placed in a cube in the microscope turret, and a filter wheel with single-band emission filters is used to select the emission from either the donor or the acceptor. Filter wheels cause minimal vibrations and have much faster switching times (as low as tens of ms) compared to filter turrets, and are therefore better suited for live-cell FRET applications.



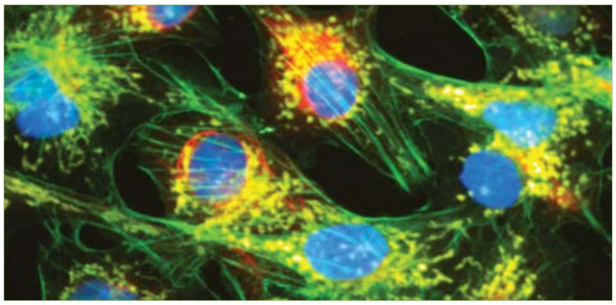
Many researchers prefer to utilize a Sedat filter set configuration (see page 35 for filters). This approach provides additional flexibility in the visualization of the sample as well as to perform control experiments – such as finding regions or samples labeled with only the donor or acceptor and collection of pure spectral contributions from each. The added flexibility also enables the donor photobleaching method for calculation of FRET efficiency.

However, the most demanding FRET applications, such as live-cell imaging and imaging of single molecules may require "simultaneous" imaging of the emission signal from both the donor and the acceptor. Figure (c) shows a configuration for simultaneous imaging, in which an image-splitting dichroic beamsplitter (see page 63) placed in the emission channel of the microscope is used to separate the signals from the donor and the acceptor and steer them onto two different CCDs or two distinct regions of the same CCD. Since there are no moving parts, motion-based imaging artifacts are also eliminated.

TECHNICAL NOTE



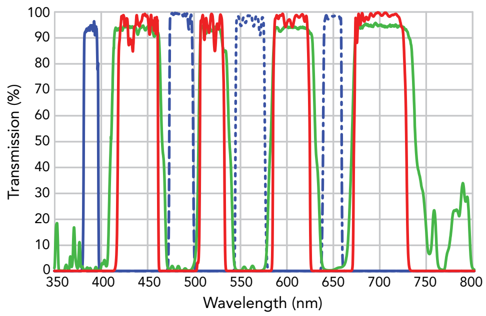
Leading Competitor's Quad-band "Pinkel" Filter Set



Semrock BrightLine Quad-band "Pinkel" Filter Set

Multicolor Fluorescence: Four Times Brighter and Twice the Contrast

Comparison images of Rat Mesangial Cells: labeled with Hoechst, Alexa 488, MitoTracker Red and Cy5 using the Semrock Quad-band DA/FI/TR/Cy5-4X-B "Pinkel" filter set on an Olympus BX61WI-DSU Spinning Disk Confocal Microscope. Images courtesy of Mike Davidson – Molecular Expressions.



DA/FI/TR/Cy5-4X-B "Pinkel" Set Spectra

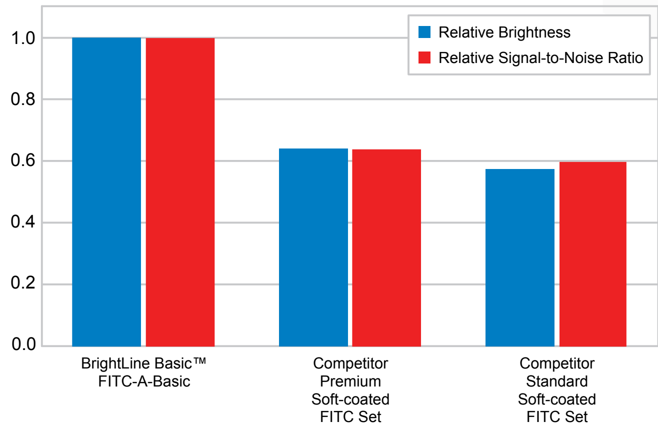
This four color, quad-band, filter set is designed for high speed, sequential imaging of DAPI, FITC, TRITC, and Cy5. The complete, 6-filter set is comprised of 1 quad-band dichroic beamsplitter, 1 quad-band emitter, and 4 single-band exciters. All six filters are 'no burn out' hard-coated in design that will provide consistent, high performance. This set is also available in a 'Sedat' version, that replaces the single quad-band emitter with four single-band emitters. Both our Sedat and Pinkel sets are designed for the single-band filters to be installed in filter wheels.

BrightLine® Basic™ Best-value Single-band Sets

How can You do Great Research on a Tight Budget? BrightLine Basic Fluorescence Filter Sets! Hard-coated Performance at Soft-coated Prices.

These value-priced single-band filter sets combine the proven durability of BrightLine research sets with optical performance that exceeds premium soft-coated fluorescence filters, yet are offered at soft-coated prices. In fact, BrightLine Basic filter sets are brighter than soft-coated filter sets of comparable contrast, but don't burn out, further lowering the total cost of ownership. Ideal for routine applications that require cost-effective, high volume capabilities and no burn-out such as: clinical microscopy (mycological and fungal staining, immunofluorescent testing), routine analysis, and education.

Measured data taken on an Olympus BX microscope using a 40X objective and a QImaging Retiga camera. Sample is Thermo Fisher Scientific FluoCells #2 sample (BODIPY FL fluorophore).



BrightLine® (Highest Performance) set compared to BrightLine Basic (Best Value) set

Semrock's highest-performance BrightLine filter sets offer the best fluorescence filters available, while the value-priced BrightLine Basic filter sets provide a high level of performance and same proven durability at an outstanding price.

BrightLine Filter Set	BrightLine Basic Filter Set	BrightLine Filter Set Compared to BrightLine Basic Filter Set*
$825	$625	
DAPI-1160B	BFP-A-Basic	>10% higher brightness; >10% higher contrast (using BFP)
DAPI-5060C		Several times brighter; comparable contrast (using BFP)
CFP-2432C	CFP-A-Basic	Tens of percent higher brightness; comparable contrast
GFP-3035D	GFP-A-Basic	Tens of percent higher contrast; brightness slightly lower
FITC-3540C	FITC-A-Basic	>10% higher brightness; >10% higher contrast
YFP-2427B	YFP-A-Basic	Tens of percent higher brightness; comparable contrast
TRITC-B	TRITC-A-Basic	Tens of percent higher brightness and contrast; Basic set intentionally designed for traditional deep-red TRITC emission
TXRED-4040C	TXRED-A-Basic	>10% higher brightness; >10% higher contrast
Cy5-4040C	Cy5-A-Basic	> 5% higher brightness; comparable contrast (using Alexa Fluor® 647)

- Only sets which have corresponding BrightLine and BrightLine Basic sets are listed.
- Brightness is based on relative throughput using the primary fluorophore and assuming typical metal-halide lamp and CCD camera spectral responses.
- Contrast is the signal-to-noise ratio (SNR), assuming the background noise is dominated by broadband autofluorescence (as is typically the case in moderate to higher fluorophore concentration samples).

* Actual results may vary depending on instrumentation and the exact sample preparation, which can substantially impact the spectra and relative intensities of the fluorophore and background.

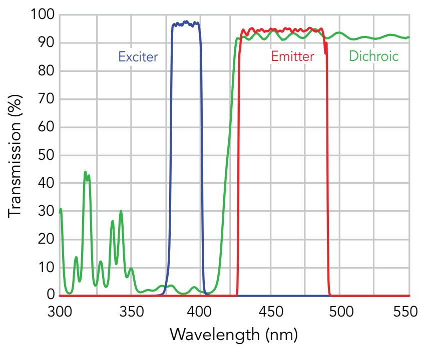
BrightLine® Basic™ Best-value Single-band Sets

Filter Set / Primary Fluorophores	Excitation (CWL/BW)	Emission (CWL/BW)	Dichroic (Edge)	Filter Set Part Numbers	Base Price
BFP-A-Basic **BFP**, DAPI, Hoechst, AMCA, Alexa Fluor® 350	390/18	460/60	416 nm	**BFP-A-Basic-000**	**$935**
CFP-A-Basic **CFP**, AmCyan, SYTOX Blue, BOBO-1, PO-PRO-1	434/17	479/40	452 nm	**CFP-A-Basic-000**	**$915**
WGFP-A-Basic **wtGFP**	445/45	510/42	482 nm	**WGFP-A-Basic-000**	**$915**
GFP-A-Basic **GFP**, (EGFP), DiO, Cy2™, YOYO-1, YO-PRO-1	469/35	525/39	497 nm	**GFP-A-Basic-000**	**$915**
FITC-A-Basic **FITC**, rsGFP, Bodipy, 5-FAM, Fluo-4, Alexa Fluor® 488	475/35	530/43	499 nm	**FITC-A-Basic-000**	**$945**
FITC-LP01-Clinical *(Longpass)* **FITC**, Acridine Orange *Immunofluorescent clinical tests*	475/28	515/LP	500 nm	**FITC-LP01-Clinical-000**	**$945**
YFP-A-Basic **YFP**, Calcium Green-1, Eosin, Fluo-3, Rhodamine 123	497/16	535/22	516 nm	**YFP-A-Basic-000**	**$915**
TRITC-A-Basic **TRITC**, dTomato, Alexa Fluor® 546	542/20	620/52	570 nm	**TRITC-A-Basic-000**	**$915**
Cy3.5-A-Basic **Cy3.5™**, mStrawberry	565/24	620/52	585 nm	**CY3.5-A-Basic-000**	**$915**
TXRED-A-Basic **Texas Red®**, mCherry, 5-ROX, Alexa Fluor® 568, mRFP1	559/34	630/69	585 nm	**TXRED-A-Basic-000**	**$915**
Cy5-A-Basic **Cy5™**, Alexa Fluor® 647, SpectrumFRed	630/38	694/44	655 nm	**Cy5-A-Basic-000**	**$915**

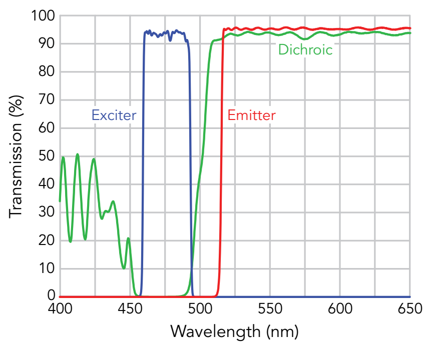
Filter Specifications on page 36

CUBES PAGE 37

BFP-A Basic Spectra



FITC-LP01-Clinical Spectra



TECHNICAL NOTE

BrightLine® LED-Optimized Fluorescence Filter Sets

Over the past decade, LED-based light engines have largely replaced gas-discharge lamps (or arc lamps) for fluorescence imaging because LEDs enable faster channel switching, deliver discrete output wavelengths, consume less energy, and offer significantly longer lifetimes. An important factor to consider in this change in excitation technology is that the spectral signature and energy distribution of LED light engines differ from those of arc lamps. This is illustrated in Figure 1.

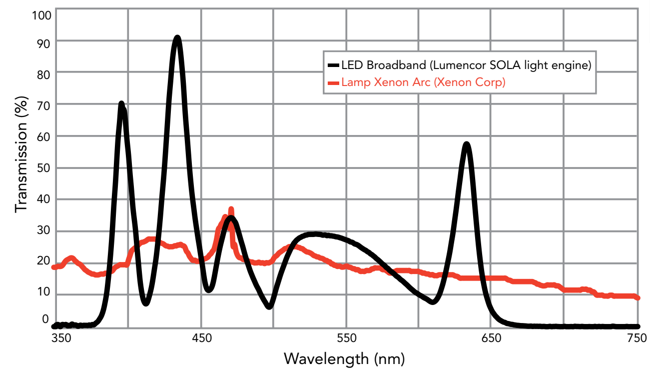


Figure 1: "Comparison of the spectra of a Xenon arc lamp with a Broadband LED light engine"

Because traditional filter sets are tuned to match the output spectra of arc lamps, the mismatch between the illumination spectra of the new LED lamps with the transmission spectra of the traditional filter sets causes a reduction in the brightness of the illumination reaching the fluorophores. As an example, consider the case of the DA/FI/TR/Cy5-4X-B (traditional) quad-band filter set. The excitation filters in this set are optimized for the output spectrum of Xenon (Xe) or Mercury (Hg) arc lamps. When the light source is changed to an LED light engine of similar brightness, the overall transmitted energy through the four excitation channels is reduced, and the excitation intensity is extremely low within the Cy5 band.

BrightLine LED-based Light Engine Filter Set Solutions

To address the loss of transmitted energy caused by spectrum mismatch, Semrock developed a new generation of filter sets that match the excitation filters to the unique spectral peaks of the most popular LED-based light engines on the market today. Take, for example, the Cy5 channel of the previously mentioned quad-band set. Figure 2 shows the improvement of transmitted energy when, for an LED light engine, the selected excitation filter is changed from the FF01-650/13 (traditional Cy5 exciter) to the corresponding FF01-635/18 (LED Cy5 exciter). It can be seen that the peak for the FF01-635/18 has been centered over the LED peak.

Designing new excitation filters for the LED-optimized sets has resulted in improvement of the transmitted signal for the DAPI and TRITC bands by 35% each in comparison to the traditional sets. Most importantly, the signal within the Cy5 band is restored, with an improvement of 750%.

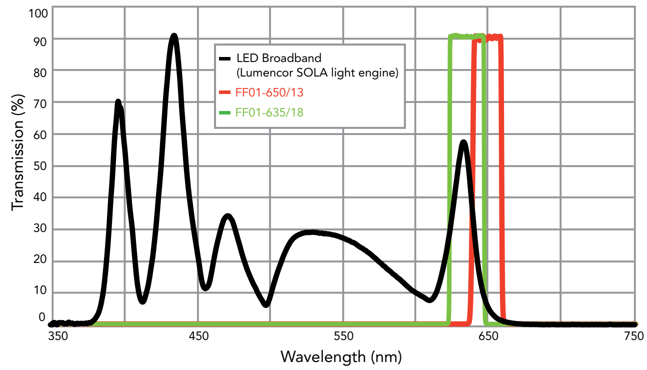


Figure 2: "SearchLight™ simulation comparing the transmission through a FF01-650/13 (Cy5 exciter of traditional multiband filter set) and a FF01-635/18 (Cy5 exciter of the multiband set optimized for LED Light Engines) when illuminated by a typical LED light engine."

The Semrock BrightLine Benefit

The new generation of LED-optimized BrightLine filter sets offers several benefits over traditional multiband filter sets:

Excellent Signal Quality: Excitation filters are spectrally positioned to deliver the brightest signal and the best signal-to-noise ratio in the industry.

Reduced Complexity and Cost: Common excitation filters can be used for both single-band and corresponding multiband configurations. This interchangeability provides a seamless transition between single-band and multiband imaging when configuring the excitation filters into the LED-based light engine and can also provide significant cost savings.

Wide Selection: The BrightLine LED filter set family includes over twenty filter sets, supporting single-band, full multiband, Pinkel, and Sedat configurations. The filter sets include penta-band (5 channel), quad-band (4-channel), and triple-band (3 channel) configurations for the most popular fluorophores.

Affordable Eight-Color Imaging: The penta-band LED-DA/FI/TR/Cy5/Cy7-5X-A and triple-band LED-CFP/YFP/mCherry-3X-A filter sets have complementary channels that provide an easy off-the-shelf solution to image eight fluorophores within a sample. The separation among all eight channels of the penta- and triple-band filters makes eight-color imaging easy and affordable (Figure 3).

(continued)

(continued from previous page)

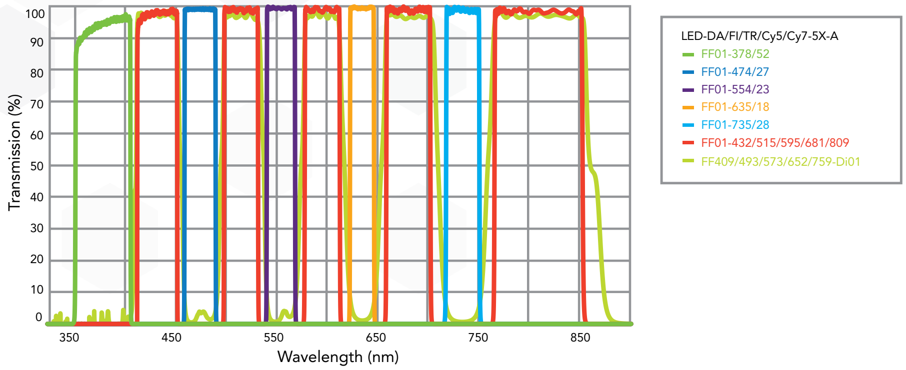
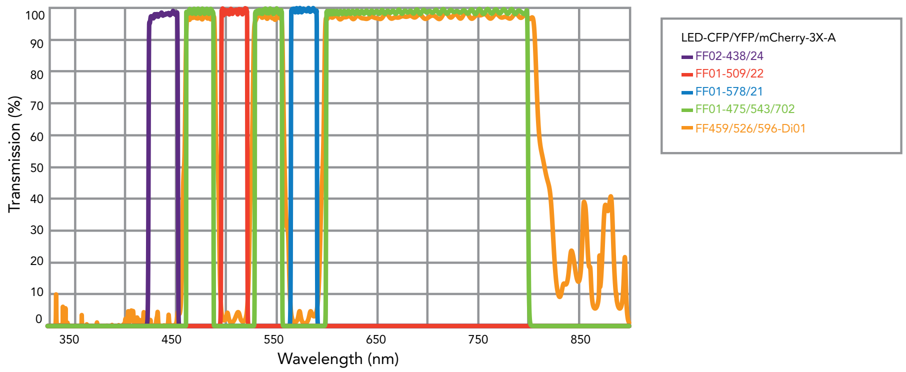


Figure 3: SearchLight™ simulation demonstrating the compatibility of the LED-DA/FI/TR/Cy5/Cy7-5XA (penta-band LED set) and the LED-CFP/YFP/mCherry-3X-A (triple-band LED set)



PRODUCT NOTE

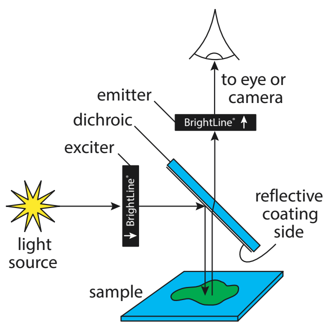
Orientation of Filters

Because of the durability of Semrock filters, you can easily populate filter cubes, filter sliders, and filter wheels yourself without fear of damaging the filters. To maximize intended transmission and blocking and to minimize autofluorescence, filters must always be oriented so that light is incident on a specific surface of the filter. This note describes the correct orientation for the different filter types.

Orienting Housed Excitation and Emission Filters

Semrock exciter and emitter filters mounted in housings feature an alignment arrow on the housing; see the illustrations below. Orient such a filter so that the arrow points in the direction of light propagation. For microscopes, the exciter filter arrow should point away from the light source and toward the dichroic beamsplitter, and the emitter filter arrow should point away from the dichroic beamsplitter and toward the eye, detector, or camera.

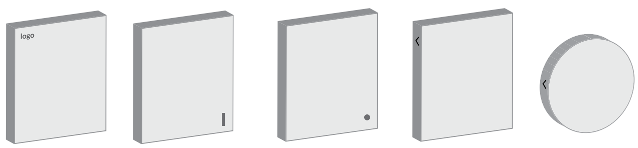
Dichroic beamsplitters are rarely mounted in housings. See below for guidance.



Orienting Dichroic Beamsplitters and Other Unhoused Optical Filters

Dichroic beamsplitters and other unhoused optical filters feature orientation marks that identify the coated surface upon which light must be incident. An orientation mark is placed either on the front surface of the filter, or on the edge of the filter as a caret (^) mark. The different types of orientation marks are shown in the following drawings along with the corresponding orientation guidance.

Semrock logo: The logo is on the surface facing the incident light.
Line: A short line is on the surface facing the incident light. The line may be easier to see if viewed at an oblique angle.
Dot: A small dot is on the surface facing the incident light. The dot may be easier to see if viewed at an oblique angle.
Caret: A caret on the edge of the filter points in the direction of light travel. When the viewer faces the surface that receives the incident light, the caret points away from the viewer.
CAUTION: A number of dichroic beamsplitters have coatings on both surfaces. Always use the above instructions to identify the coated surface that should face the incident light! If you encounter any ambiguity or difficulty, please contact Semrock for assistance in identifying the surface orientation.



BrightLine® Single-band & Multiband LED Filter Sets

Semrock started with the spectra of the most popular LED-based light engines on the market today to design this family of filter sets. These sets deliver significant fluorescence signal improvements when compared to using traditional filter sets designed for standard broadband light sources such as mercury or xenon arc lamps. These filter sets are optimized to simultaneously deliver the brightest signal and the highest signal-to-noise ratio (contrast) available for imaging a range of fluorophores with LED-based light engines.

- Spectrally aligned to popular LED-based light engines
- 10s to 100s of percent more signal per channel compared to traditional light source sets when used with LED-based light engines

BrightLine Single-band LED Filter Sets

Filter Set / Primary Fluorophores	Excitation (CWL/BW)	Emission (CWL/BW)	Dichroic (Edge)	Filter Set Part Numbers / –ZERO Set Part Numbers	Base Price /–ZERO Price
LED-DAPI-B DAPI, Alexa Fluor® 405, BFP, Pacific Blue™	378/52	447/60	409 nm	**LED-DAPI-B-000** LED-DAPI-B-000-ZERO	**$1055** $1164
LED-CFP-A CFP (ECFP), Cerulean, SYTOX Blue, TagCFP	438/24	483/32	458 nm	**LED-CFP-A-000** LED-CFP-A-000-ZERO	**$1055** $1164
LED-mTFP-A mTFP1 (Teal), CFP (ECFP), ATTO 425, TagCFP	442/42	494/34	470 nm	**LED-mTFP-A-000** LED-mTFP-A-000-ZERO	**$1055** $1164
LED-FITC-A FITC (Fluorescein), GFP (EGFP), Cy2™, 5-FAM	474/27	525/45	495 nm	**LED-FITC-A-000** LED-FITC-A-000-ZERO	**$1055** $1164
LED-YFP-A YFP (EYFP), Venus, Fluo-3, Rhodamine 123	509/22	544/24	526 nm	**LED-YFP-A-000** LED-YFP-A-000-ZERO	**$1130** $1239
LED-Venus-A Venus, YFP (EYFP), Alexa Fluor® 405, 6-JOE	513/13	544/24	526 nm	**LED-Venus-A-000** LED-Venus-A-000-ZERO	**$1175** $1284
LED-TRITC-A TRITC, SpectrumOrange, dTomato, mTangerine	554/23	609/54	573 nm	**LED-TRITC-A-000** LED-TRITC-A-000-ZERO	**$1055** $1164
LED-mCherry-A mCherry, TexasRed, mKate, mRFP1	578/21	641/75	596 nm	**LED-mCherry-A-000** LED-mCherry-A-000-ZERO	**$1130** $1239
LED-Cy5-A Cy5™, Alexa Fluor® 647, APC	635/18	680/42	652 nm	**LED-Cy5-A-000** LED-Cy5-A-000-ZERO	**$1130** $1239
LED-Cy7-A Cy7™, Alexa Fluor® 750, ATTO 740, DiR	735/28	809/81	757 nm	**LED-Cy7-A-000** LED-Cy7-A-000-ZERO	**$1055** $1164

Filter Specifications on page 36
"–ZERO" denotes zero pixel shift performance (see page 38)

"Pinkel" Multiband LED Filter Sets – single-band exciters, one triple- or quad-band emitter, and one multiedge beamsplitter

Filter Set / Primary Fluorophores	Single-band Excitation (CWL/BW)	Multiband Emission (CWL/BW)	Multiedge Dichroic (Edge)	Filter Set Part Numbers	Base Price /–ZERO Price
LED-DA/FI/TX-3X-B *(Triple-band Pinkel Set)* Blue: DAPI, BFP (EBFP), Alexa Fluor® 405 Green: FITC (Fluorescein), GFP (EGFP), Cy2™ Red: Texas Red, mCherry, 5-ROX	 Ex1: 378/52 Ex2: 474/27 Ex3: 575/25	 432/36 523/46 702/196	 409 nm 493 nm 596 nm	**LED-DA/FI/TX-3X-B-000** LED-DA/FI/TX-3X-B-000-ZERO	**$2185** $2294
LED-CFP/YFP/mCherry-3X-A *(Triple-band Pinkel Set)* Cyan: CFP (ECFP), Cerulean, SYTOX Blue, TagCFP Yellow: YFP (EYFP), Venus, Fluo-3, Rhodamine 123 Red: mCherry, TexasRed, mKate, mRFP1	 Ex1: 438/24 Ex2: 509/22 Ex3: 578/21	 475/22 543/22 702/197	 459 nm 526 nm 596 nm	**LED-CFP/YFP/mCherry-3X-A-000** LED-CFP/YFP/mCherry-3X-A-000-ZERO	**$2185** $2294
LED-DA/FI/TR/Cy5-4X-B *(Quad-band Pinkel Set)* Blue: DAPI, BFP (EBFP), Alexa Fluor® 405 Green: FITC (Fluorescein), GFP (EGFP), Alexa Fluor® 488 Orange: TRITC, DsRed, dTomato, mRFP Red: Cy5™, APC, Alexa Fluor® 647	 Ex1: 378/52 Ex2: 474/27 Ex3: 554/23 Ex4: 635/18	 432/36 515/30 595/31 730/139	 409 nm 493 nm 573 nm 652 nm	**LED-DA/FI/TR/Cy5-4X-B-000** LED-DA/FI/TR/Cy5-4X-B-000-ZERO	**$2780** $2889
LED-DA/FI/TR/Cy5/Cy7-5X-A *(Penta-band Pinkel Set)* Blue: DAPI, BFP (EBFP), Alexa Fluor® 405 Green: FITC (Fluorescein), GFP (EGFP), Alexa Fluor® 488 Orange: TRITC, DsRed, dTomato, mRFP Red: Cy5™, APC, Alexa Fluor® 647 Far Red: Cy7™, DiR, Alexa Fluor® 750	 Ex1: 378/52 Ex2: 474/27 Ex3: 554/23 Ex4: 635/18 Ex5: 735/28	 432/36 515/30 595/31 681/40 809/80	 409 nm 493 nm 573 nm 652 nm 759 nm	**LED-DA/FI/TR/Cy5/Cy7-5X-A-000** LED-DA/FI/TR/Cy5/Cy7-5X-A-000-ZERO	**$3365** $3474

BrightLine® Multiband LED Filter Sets

EXPANDED LED SETS

Full Multiband LED Filter Sets – multiband exciter, emitter and beamsplitter

Filter Set / Primary Fluorophores	Multiband Excitation (CWL/BW)	Multiband Emission (CWL/BW)	Multiedge Dichroic (Edge)	Filter Set Part Numbers	Base Price /–ZERO Price
CELESTA-DA/FI/TR/Cy5/Cy7-A *(Penta-band Full Multiband)* Blue: DAPI, BFP (EBFP), Alexa Fluor® 405 Green: FITC (Fluorescein), GFP (EGFP), Alexa Fluor® 488 Orange: TRITC, DsRed, dTomato, mRFP Red: Cy5™, APC, Alexa Fluor® 647 Deep Red: Cy7™, DiR, Alexa Fluor® 750	391/44 477/12 549/16 638.5/17 741/32	441/30 511/26 592.5/37 684/34 817/66	421 nm 491 nm 567 nm 659 nm 776 nm	**CELESTA-DA/FI/TR/Cy5/Cy7-A-000** CELESTA-DA/FI/TR/Cy5/Cy7-A-000-ZERO	**$2565** $2674
CELESTA-CFP/YFP-A *(Dual-band Full Multiband)* Cyan: CFP (ECFP), Cerulean, SYTOX Blue, TagCFP Yellow: YFP (EYFP), Eosin, Fluo-3, Alexa Fluor® 514	449/20 520/20	484/22 561/30	471 nm 539 nm	**CELESTA-CFP/YFP-A-000** CELESTA-CFP/YFP-A-000-ZERO	**$1515** $1624
LED-DA/FI/TX-A *(Triple-band Full Multiband)* Blue: DAPI, BFP (EBFP), Alexa Fluor® 405 Green: FITC (Fluorescein), GFP (EGFP), Cy2™ Red: Texas Red, mCherry, 5-ROX	378/52 474/27 575/25	432/36 523/46 702/196	409 nm 493 nm 596 nm	**LED-DA/FI/TX-A-000** LED-DA/FI/TX-A-000-ZERO	**$1590** $1699
LED-CFP/YFP/mCherry-A *(Triple-band Full Multiband)* Cyan: CFP (ECFP), Cerulean, SYTOX Blue, TagCFP Yellow: YFP (EYFP), Eosin, Fluo-3, Rhodamine 123 Red: mCherry, TexasRed, mKate, mRFP1	438/24 509/22 578/21	475/22 543/22 702/197	459 nm 526 nm 596 nm	**LED-CFP/YFP/mCherry-A-000** LED-CFP/YFP/mCherry-A-000-ZERO	**$1590** $1699
LED-DA/FI/TR/Cy5-B *(Quad-band Full Multiband)* Blue: DAPI, BFP, Alexa Fluor® 405 Green: FITC (Fluorescein), GFP (EGFP), Alexa Fluor® 488 Orange: TRITC, DsRed, dTomato, mRFP Red: Cy5™, APC, Alexa Fluor® 647	378/52 474/27 554/23 635/18	432/36 515/30 595/31 730/139	409 nm 493 nm 573 nm 652 nm	**LED-DA/FI/TR/Cy5-B-000** LED-DA/FI/TR/Cy5-B-000-ZERO	**$1920** $2029
LED-DA/FI/TR/Cy5/Cy7-A *(Penta-band Full Multiband)* Blue: DAPI, BFP (EBFP), Alexa Fluor® 405 Green: FITC (Fluorescein), GFP (EGFP), Alexa Fluor® 488 Orange: TRITC, DsRed, dTomato, mRFP Red: Cy5™, APC, Alexa Fluor® 647 Deep Red: Cy7™, DiR, Alexa Fluor® 750	378/50 474/25 554/21 635/16 735/26	432/36 515/30 595/31 681/40 809/80	409 nm 493 nm 573 nm 652 nm 759 nm	**LED-DA/FI/TR/Cy5/Cy7-A-000** LED-DA/FI/TR/Cy5/Cy7-A-000-ZERO	**$2235** $2344

"Sedat" Multiband LED Filter Sets – single-band exciters and emitters, and one multiedge beamsplitter

Filter Set / Primary Fluorophores	Single-band Excitation (CWL/BW)	Single-band Emission (CWL/BW)	Multiedge Dichroic (Edge)	Filter Set Part Numbers	Base Price
LED-DA/FI/TX-3X3M-B *(Triple-band Sedat Set)* Blue: DAPI, BFP (EBFP), Alexa Fluor® 405 Green: FITC (Fluorescein), GFP (EGFP), Cy2™ Red: Texas Red, mCherry, 5-ROX	Ex1: 378/52 Ex2: 474/27 Ex3: 575/25	Em1: 432/36 Em2: 525/40 Em3: 641/75	409 nm 493 nm 596 nm	**LED-DA/FI/TX-3X3M-B-000**	**$2810**
LED-CFP/YFP/mCherry-3X3M-A *(Triple-band Sedat Set)* Cyan: CFP (ECFP), Cerulean, SYTOX Blue, TagCFP Yellow: YFP (EYFP), Eosin, Fluo-3, Rhodamine 123 Red: mCherry, TexasRed, mKate, mRFP1	Ex1: 438/24 Ex2: 509/22 Ex3: 578/21	Em1: 482/25 Em2: 544/24 Em3: 641/75	459 nm 526 nm 596 nm	**LED-CFP/YFP/mCherry-3X3M-A-000**	**$2780**
LED-DA/FI/TR/Cy5-4X4M-B *(Quad-band Sedat Set)* Blue: DAPI, BFP (EBFP), Alexa Fluor® 405 Green: FITC (Fluorescein), GFP (EGFP), Alexa Fluor® 488 Orange: TRITC, DsRed, dTomato, mRFP Red: Cy5™, APC, Alexa Fluor® 647	Ex1: 378/52 Ex2: 474/27 Ex3: 554/23 Ex4: 635/18	Em1: 432/36 Em2: 515/30 Em3: 595/31 Em4: 698/70	409 nm 493 nm 573 nm 652 nm	**LED-DA/FI/TR/Cy5-4X4M-B-000**	**$3640**
LED-DA/FI/TR/Cy5/Cy7-5X5M-A *(Penta-band Sedat Set)* Blue: DAPI, BFP (EBFP), Alexa Fluor® 405 Green: FITC (Fluorescein), GFP (EGFP), Alexa Fluor® 488 Orange: TRITC, DsRed, dTomato, mRFP Red: Cy5™, APC, Alexa Fluor® 647 Far Red: Cy7™, DiR, Alexa Fluor® 750	Ex1: 378/52 Ex2: 474/27 Ex3: 554/23 Ex4: 635/18 Ex5: 735/28	Em1: 432/36 Em2: 515/30 Em3: 595/31 Em4: 680/42 Em5: 809/81	409 nm 493 nm 573 nm 652 nm 759 nm	**LED-DA/FI/TR/Cy5/Cy7-5X5M-A-000**	**$4495**

See spectra graphs and ASCII data for these filter sets at www.idex-hs.com/optical-filter-sets by selecting "LED-Based Light Engines" under Light Sources in the left-hand menu

BrightLine® Multiband Fluorescence Sets

TECHNICAL NOTE

Multiband Filter Set Configurations

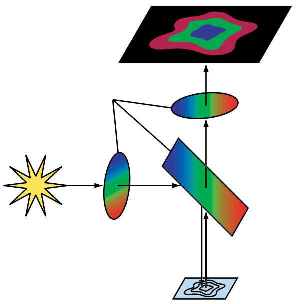
The ability to label multiple, distinct objects of interest in a single sample greatly enhances the power of fluorescence imaging. One way to achieve high-quality images of such samples has been to take multiple photographs while switching single-band filter cubes between photographs, and then later to combine these photographs electronically. Limitations to this approach historically included "pixel shift" among the multiple monochrome images, and the speed with which a complete multicolor image could be captured. Semrock solved the problem of "pixel shift" with its BrightLine ZERO™ technology, and the single-band filter cube approach remains the best technique for achieving images with the highest contrast and lowest bleedthrough possible. But with the increasing demand for high-speed imaging, especially for live-cell real-time analysis using fluorescent protein labels, there is a need for an alternative to the single-band filter cube approach that does not sacrifice too much image fidelity. Semrock's advanced multiband optical filter technology brings simultaneous multicolor imaging to a new level.

There are three types of multiband filter sets for simultaneous multicolor imaging. The "full multiband" configuration uses all multiband filters – exciter, emitter, and dichroic beamsplitter – and is ideal for direct visualization, such as locating areas of interest on a sample. This approach is quick and easy to implement, and is compatible with all standard fluorescence microscopes. However, it requires a color camera for electronic imaging and cannot eliminate fluorophore bleedthrough. The "Pinkel" configuration uses single-band exciters in a filter wheel with multiband emitter and dichroic filters. It offers an economical way to achieve very high-speed, high-contrast, simultaneous multi-color imaging. This approach is based on a monochrome CCD camera, which is less expensive and offers better resolution and noise performance than color cameras. While bleedthrough is reduced relative to the full-multiband approach, some bleedthrough is still possible since all emission bands are imaged simultaneously. The "Sedat" configuration uses single-band exciters and single-band emitters in synchronized filter wheels, with a multiband dichroic beamsplitter. This approach provides the best image fidelity for high-speed simultaneous multi-color imaging, though it requires a larger investment in system hardware.

In fact, Semrock is your only source of "full multiband" quad-band filter sets and the unique penta "Pinkel" and "Sedat" set.

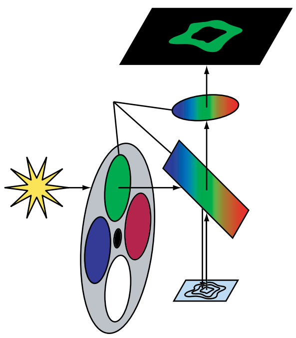
"Full Multiband" Configuration

(Multiband exciter, multiband emitter, & multiband dichroic)



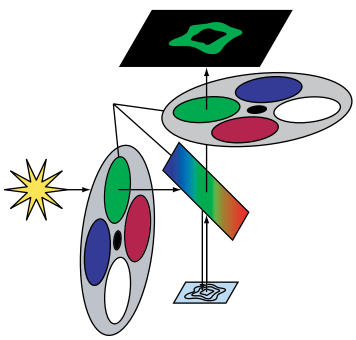
"Pinkel" Configuration

(Multiband emitter, multiband dichroic, & single-band exciters)



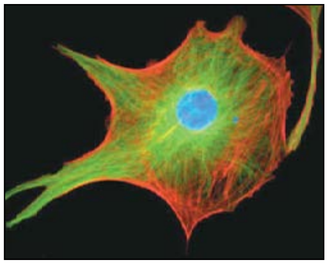
"Sedat" Configuration

(Multiband dichroic, single-band exciters, & single-band emitters)



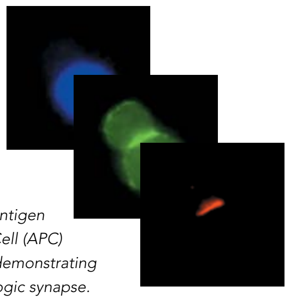
"Full Multiband" Image

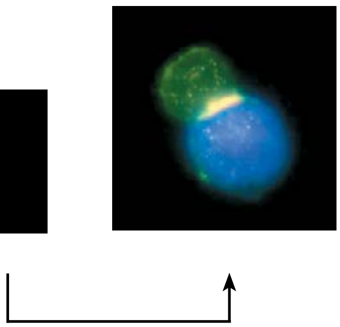
Multi-color image captured with a color CCD camera



"Pinkel" and "Sedat" Composite Image

Single-color images are combined electronically to produce one high-fidelity, multi-color image





T-Cell and Antigen Presenting Cell (APC) conjugates demonstrating an immunologic synapse. Samples courtesy of Beth Graf and Dr. Jim Miller at the University of Rochester Medical Center

BrightLine® Multiband Fluorescence Sets

Full Multiband Filter Sets – multiband exciter, emitter and beamsplitter

Filter Set / Primary Fluorophores	Multiband Excitation (CWL/BW)	Multiband Emission (CWL/BW)	Multiedge Dichroic (Edge)	Filter Set Part Numbers	Base Price
BRFLD-A			409 nm	**BRFLD-A-000**	**$680**
DA/FI-A *(Dual-band Full Multiband)*				**DA/FI-A-000**	**$1415**
Blue: DAPI, Hoechst, AMCA, BFP, Alexa Fluor® 350	387/11	433/38	403 nm		
Green: FITC, GFP, rsGFP, Bodipy, Alexa Fluor® 488	480/29	530/40	502 nm		
GFP/DsRed-A *(Dual-band Full Multiband)*				GFP/DsRed-A-000	**$1415**
Green: GFP, rsGFP, FITC, Alexa Fluor® 488	468/34	512/23	493 nm		
Red: DsRed, TRITC, Cy3™, Texas Red®, Alexa Fluor® 568 & 594	553/26	630/91	574 nm		
FITC/TxRed-A *(Dual-band Full Multiband)*				**FITC/TxRed-A-000**	**$1415**
Green: FITC, GFP, rsGFP, Bodipy, Alexa Fluor® 488	479/38	524/29	505 nm		
Red: Texas Red®, mCherry, Alexa Fluor® 568 & 594	585/27	628/33	606 nm		
Cy3/Cy5-A *(Dual-band Full Multiband)*				**Cy3/Cy5-A-000**	**$1415**
Yellow: Cy3™, DsRed, Alexa Fluor® 555	534/36	577/24	560 nm		
Red: Cy5™, SpectrumFRed™, Alexa Fluor® 647 & 660	635/31	690/50	659 nm		
DA/FI/TR-A *(Triple-band Full Multiband)*				**DA/FI/TR-A-000**	**$1590**
Blue: DAPI, Hoechst, AMCA, BFP, Alexa Fluor® 350	387/11	433/36	403 nm		
Green: FITC, GFP, rsGFP, Bodipy, Alexa Fluor® 488	478/24	517/23	497 nm		
Orange: TRITC, DsRed, Cy3™, Alexa Fluor® 555	555/19	613/61	574 nm		
DA/FI/TX-B *(Triple-band Full Multiband)*				**DA/FI/TX-B-000**	**$1590**
Blue: DAPI, Hoechst, AMCA, BFP, Alexa Fluor® 350	407/14	457/22	436 nm		
Green: FITC, GFP, rsGFP, Bodipy, Alexa Fluor® 488	494/20	530/20	514 nm		
Red: Texas Red®, MitoTracker Red, Alexa Fluor® 568 & 594	576/20	628/28	604 nm		
DA/FI/TR/Cy5-A *(Quad-band Full Multiband)*				**DA/FI/TR/Cy5-A-000**	**$1920**
Blue: DAPI, Hoechst, AMCA, BFP, Alexa Fluor® 350	387/11	440/40	410 nm		
Green: FITC, GFP, rsGFP, Bodipy, Alexa Fluor® 488	485/20	521/21	504 nm		
Orange: TRITC, DsRed, Cy3™, Alexa Fluor® 555	559/25	607/34	582 nm		
Red: Texas Red®, MitoTracker Red, Alexa Fluor® 568 & 594	649/13	700/45	669 nm		

Filter Specifications on page 36

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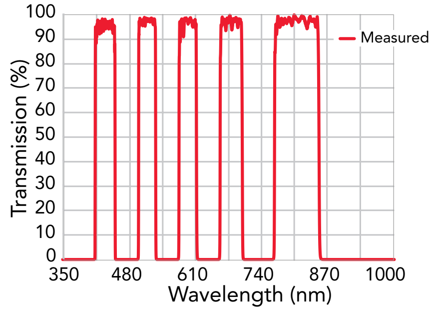
PRODUCT NOTE

Semrock manufactures multiband fluorescence filters with passband, edge steepness, and blocking performance that rival the best single-band filters, and all with the superior, "no burn-out" durability of hard coatings. In fact, every filter in every BrightLine filter set, including these multiband sets, is made with our durable hard-coating sputtered technology.

Semrock always provides:

- The highest transmission, blocking and edge steepness for dazzling visual and digital imaging.
- Hard, dielectric coatings for every filter, including UV exciters for "no burn-out" performance.
- Spectrally complex filters are a specialty. The world's best five color multiband set and a large selection of quad-, triple-, and dual-band sets are also available.



Graph above shows typical measured transmission of the FF01-432/515/595/681/809 filter

BrightLine® Multiband Fluorescence Sets

"Pinkel" Multiband Filter Sets – single-band exciters, one dual-, triple-, quad-, or penta-band emitter and one multiedge beamsplitter

Filter Set / Primary Fluorophores	Single-band Excitation (CWL/BW)	Multiband Emission (CWL/BW)	Multiedge Dichroic (Edge)	Filter Set Part Numbers	Base Price
DA/FI-2X-B *(Dual-band Pinkel Set)* Blue: DAPI, Hoechst, AMCA, BFP, Alexa Fluor® 350 Green: FITC, GFP, rsGFP, Bodipy, Alexa Fluor® 488	Ex1: 387/11 Ex2: 485/20	433/38 530/40	403 nm 502 nm	DA/FI-2X-B-000	$1675
GFP/DsRed-2X-A *(Dual-band Pinkel Set)* Green: GFP, rsGFP, FITC, Alexa Fluor® 488 Red: DsRed, TRITC, Cy3™, Texas Red®, Alexa Fluor® 568 & 594	Ex1: 470/22 Ex2: 556/20	512/23 630/91	493 nm 574 nm	GFP/DsRed-2X-A-000	$1675
FITC/TxRed-2X-B *(Dual-band Pinkel Set)* Green: FITC, GFP, rsGFP, Bodipy, Alexa Fluor® 488 Red: Texas Red®, mCherry, Alexa Fluor® 568 & 594	Ex1: 485/20 Ex2: 586/20	524/29 628/33	505 nm 606 nm	FITC/TxRed-2X-B-000	$1660
Cy3/Cy5-2X-B *(Dual-band Pinkel Set)* Yellow: Cy3™, DsRed, Alexa Fluor® 555 Red: Cy5™, SpectrumFRed™, Alexa Fluor® 647 & 660	Ex1: 534/30 Ex2: 628/40	577/24 690/50	560 nm 659 nm	Cy3/Cy5-2X-B-000	$1705
DA/FI/TR-3X-A *(Triple-band Pinkel Set)* Blue: DAPI Green: FITC (Fluorescein), GFP (EGFP) Orange: TRITC (Tetramethylrhodamine)	Ex1: 387/11 Ex2: 480/17 Ex3: 556/20	433/36 517/23 613/61	403 nm 497 nm 574 nm	DA/FI/TR-3X-A-000	$2185
DA/FI/TX-3X-C *(Triple-band Pinkel Set)* Blue: DAPI, Hoechst, AMCA, BFP, Alexa Fluor® 350 Green: FITC, GFP, rsGFP, BoDipy, Alexa Fluor® 488 Red: Texas Red®, MitoTracker Red, Alexa Fluor® 568 & 594	Ex1: 387/11 Ex2: 494/20 Ex3: 575/25	457/22 530/20 628/28	436 nm 514 nm 604 nm	DA/FI/TX-3X-C-000	$2210
DA/FI/TR/Cy5-4X-B *(Quad-band Pinkel Set)* Blue: DAPI, Hoechst, AMCA, Alexa Fluor® 350 Green: FITC, GFP, rsGFP, Bodipy, AlexaFluor® 488 Orange: TRITC, Cy3™, Texas Red®, Alexa Fluor® 568 & 594 Red: Cy5™, APC, TOTO-3, TO-PRO-3, Alexa Fluor® 647 & 660	Ex1: 387/11 Ex2: 485/20 Ex3: 560/25 Ex4: 650/13	440/40 521/21 607/34 700/45	410 nm 504 nm 582 nm 669 nm	DA/FI/TR/Cy5-4X-B-000	$2780
DA/FI/TR/Cy5/Cy7-5X-A *(Penta-band Pinkel Set)* Blue: DAPI, Hoechst, AMCA, Alexa Fluor® 350 Green: FITC, GFP, rsGFP, Bodipy, AlexaFluor® 488 Orange: TRITC, Cy3™, Texas Red®, Alexa Fluor® 568 & 594 Red: Cy5™, APC, TOTO-3, TO-PRO-3, Alexa Fluor® 647 & 660 Far Red: Cy7™	Ex1: 387/11 Ex2: 485/20 Ex3: 560/25 Ex4: 650/13 Ex5: 740/13	440/40 521/21 607/34 694/35 809/81	408 nm 504 nm 581 nm 667 nm 762 nm	DA/FI/TR/Cy5/Cy7-5X-A-000	$3445
LF405/488/532/635-4X-A *(Quad-band Pinkel Set)* Blue: DAPI, BFP (EBFP) Green: FITC (Fluorescein), GFP (EGFP) Orange: mCherry (RFP), mRFP1 Red: Cy5™	390/40 482/18 532/3 640/14	445.8/32.5 510.5/16 581.5/63 703/80	422.3 nm 497.8 nm 541.6 nm 655.9 nm	LF405/488/532/635-4X-A-000	$2970
LF405/488/561/635-4X-A *(Quad-band Pinkel Set)* Blue: DAPI, BFP (EBFP) Green: FITC (Fluorescein), GFP (EGFP) Orange: mCherry (RFP), mRFP1 Red: Cy5™	390/40 482/18 563/9 640/14	446/32.5 523.5/42 600/35.5 677/27.5	426.3 nm 498.3 nm 575.4 nm 655.3 nm	LF405/488/561/635-4X-A-000	$2985
LF488/561-2X-B *(Dual-band Pinkel Set)* Green: FITC (Fluorescein), GFP (EGFP) Orange: mCherry (RFP), mRFP1	482/18 563/9	523/40 610/52	500 nm 575.5 nm	LF488/561-2X-B-000	$1870

Filter Specifications on page 36

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BrightLine® Multiband Fluorescence Sets

"Sedat" Multiband Filter Sets – single-band exciters and emitters and one multiedge beamsplitter

Filter Set / Primary Fluorophores	Single-band Excitation (CWL/BW)	Single-band Emission (CWL/BW)	Multiedge Dichroic (Edge)	Filter Set Part Numbers	Base Price
DA/FI-2X2M-B *(Dual-band Sedat Set)* Blue: DAPI, Hoechst, AMCA, BFP, Alexa Fluor® 350 Green: FITC, GFP, rsGFP, Bodipy, Alexa Fluor® 488	Ex1: 387/11 Ex2: 485/20	Em1: 435/40 Em2: 531/40	403 nm 502 nm	**DA/FI-2X2M-B-000**	**$1935**
GFP/DsRed-2X2M-C *(Dual-band Sedat Set)* Green: GFP, rsGFP, FITC, Alexa Fluor® 488 Red: DsRed, TRITC, Cy3™, Texas Red®, Alexa Fluor® 568 & 594	Ex1: 470/22 Ex2: 556/20	Em1: 514/30 Em2: 617/73	493 nm 574 nm	**GFP/DsRed-2X2M-C-000**	**$1935**
FITC/TxRed-2X2M-B *(Dual-band Sedat Set)* Green: FITC, GFP, rsGFP, BoDipy, Alexa Fluor® 488 Red: Texas Red®, mCherry, Alexa Fluor® 568 & 594	Ex1: 485/20 Ex2: 586/20	Em1: 536/40 Em2: 628/32	505 nm 606 nm	**FITC/TxRed-2X2M-B-000**	**$1920**
Cy3/Cy5-2X2M-B *(Dual-band Sedat Set)* Yellow: Cy3™, DsRed, Alexa Fluor® 555 Red: Cy5™, SpectrumFRed™, Alexa Fluor® 647 & 660	Ex1: 534/30 Ex2: 628/40	Em1: 585/40 Em2: 692/40	560 nm 659 nm	**Cy3/Cy5-2X2M-B-000**	**$1965**
DA/FI/TR-3X3M-C *(Triple-band Sedat Set)* Blue: DAPI Green: FITC (Fluorescein), GFP (EGFP) Orange: TRITC (Tetramethylrhodamine)	Ex1: 387/11 Ex2: 480/17 Ex3: 556/20	Em1: 435/40 Em2: 520/28 Em3: 617/73	403 nm 497 nm 574 nm	**DA/FI/TR-3X3M-C-000**	**$2780**
DA/FI/TX-3X3M-C *(Triple-band Sedat Set)* Blue: DAPI, Hoechst, AMCA, BFP, Alexa Fluor® 350 Green: FITC, GFP, rsGFP, Bodipy, Alexa Fluor® 488 Red: Texas Red®, MitoTracker Red, Alexa Fluor® 568 & 594	Ex1: 387/11 Ex2: 494/20 Ex3: 575/25	Em1: 447/60 Em2: 531/22 Em3: 624/40	436 nm 514 nm 604 nm	**DA/FI/TX-3X3M-C-000**	**$2805**
DA/FI/TR/Cy5-4X4M-C *(Quad-band Sedat Set)* Blue: DAPI, Hoechst, AMCA, Alexa Fluor® 350 Green: FITC, GFP, rsGFP, Bodipy, Alexa Fluor® 488 Orange: TRITC, Cy3™, Texas Red®, MitoTracker Red, Alexa Fluor® 568 & 594 Red: Cy5™, APC, TOTO-3, TO-PRO-3, Alexa Fluor® 647 & 660	Ex1: 387/11 Ex2: 485/20 Ex3: 560/25 Ex4: 650/13	Em1: 440/40 Em2: 525/30 Em3: 607/36 Em4: 684/24	410 nm 504 nm 582 nm 669 nm	**DA/FI/TR/Cy5-4X4M-C-000**	**$3640**
DA/FI/TR/Cy5/Cy7-5X5M-B *(Penta-band Sedat Set)* Blue: DAPI, Hoechst, AMCA, Alexa Fluor® 350 Green: FITC, GFP, Bodipy, AlexaFluor® 488 Orange: TRITC, Texas Red®, Alexa Fluor® 568 Red: Cy5™, APC, Alexa Fluor® 647 & 660 Far Red: Cy7™	Ex1: 387/11 Ex2: 485/20 Ex3: 560/25 Ex4: 650/13 Ex5: 740/13	Em1: 440/40 Em2: 525/30 Em3: 607/36 Em4: 684/24 Em5: 809/81	408 nm 504 nm 581 nm 667 nm 762 nm	**DA/FI/TR/Cy5/Cy7-5X5M-B-000**	**$4575**
LF405/488/561/635-4X4M-A *(Quad-band Full Multiband)* Blue: DAPI, BFP (EBFP) Green: FITC (Fluorescein), GFP (EGFP) Orange: mCherry (RFP), mRFP1 Red: Cy5™	390/40 482/28 563/9 640/14	445/20 525/30 605/15 676/29	426.3 nm 498.3 nm 575.4 nm 655.3 nm	**LF405/488/561/635-4X4M-A-000**	**$3845**
LF488/561-2X2M-B *(Dual-band Sedat Set)* Green: FITC (Fluorescein), GFP (EGFP) Orange: mCherry (RFP), mRFP1	482/18 563/9	525/45 609/54	500 nm 575.5 nm	**LF488/561-2X2M-B-000**	**$2130**

Filter Specifications on page 36

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BrightLine® Filter Common Specifications (for filters in sets pages 17–35)

Exciter and Emitter Specifications (except where otherwise noted)

Property	Specification	Comment
Guaranteed Transmission	> 93%	Except BrightLine Basic™ and Qdot®: > 90%; except multiband Averaged over the passband
Typical Transmission	> 97%	Except BrightLine Basic and Qdot: > 94% Averaged over the passband
Angle of Incidence	0° ± 5°	Range of angles over which optical specs are guaranteed for collimated light
Cone Half Angle	7°	Filter performance is likely to remain satisfactory up to 10° centered around the nominal Angle of Incidence
Autofluorescence	Low	
Transverse Dimensions	25.0 mm	Except Leica sizes, see www.idex-hs.com/semrock
Transverse Tolerance	+ 0.0 / - 0.1 mm	
Exciter Thickness	5.0 mm	Black-anodized aluminum ring
Emitter Thickness	3.5 mm	Black-anodized aluminum ring
Thickness Tolerance	± 0.1 mm	Black-anodized aluminum ring
Exciter Clear Aperture	> 21 mm	Except Leica filters: > 85%
Emitter Clear Aperture	> 22 mm	Except BrightLine Basic & Qdot: > 21 mm; except Leica filters: > 85%
Scratch-Dig	60-40	Except BrightLine Basic: 80-50 Measured within clear aperture
Ring Housing Material	Aluminum, black anodized	
Blocking	BrightLine filters have blocking far exceeding OD 6 (except BrightLine Basic: OD 5) as needed to ensure the blackest background, even when using modern low-noise CCD, EMCCD or CMOS cameras. The blocking is optimized for microscopy applications using our proprietary filter design software.	
Orientation	Arrow on ring indicates preferred direction of propagation of light *(see page 29)*	

Dichroic Beamsplitter Specifications (except where otherwise noted)

Property	Specification	Comment
Guaranteed Transmission	> 93%	Averaged over the specified band; except multiband and BrightLine Basic
Typical Transmission	> 97%	Averaged over the specified band; except BrightLine Basic
Reflection	> 98%	Except BrightLine Basic: > 90%; and multiband Averaged over the specified band
Angle of Incidence	45° ± 1.5°	Range of angles over which optical specs are guaranteed for collimated light
Cone Half Angle	2°	Filter performance is likely to remain satisfactory up to 3° Centered around the nominal Angle of Incidence
Autofluorescence	Ultra-low	
Transverse Dimensions	25.2 x 35.6 mm	Except Leica sizes, see www.idex-hs.com/semrock
Transverse Tolerance	± 0.1 mm	
Thickness	1.05 mm	Except where otherwise noted
Thickness Tolerance	± 0.05 mm	
Clear Aperture	> 80%	Elliptical
Surface Quality	60-40	Except BrightLine Basic: 80-50 Measured within clear aperture
Edge Chipping	Per ANSI/OEOSC OP1.002-2006, American Standard	
Orientation	Reflective coating side should face toward light source and sample *(see page 29)*	

For Laser Dichroic Specifications, see page 71

General Filter Specifications (all BrightLine filters)

Property	Specification
Coating Type	Sputtered
Reliability and Durability	Hard-coated technology with epoxy-free, single-substrate construction for unrivaled filter life span and no "burn-out" even when subjected to high light intensities for a prolonged period of time. BrightLine filters are rigorously tested and proven to MIL-STD-810F and MIL-C-48497A environmental standards.
Microscope Compatibility	All BrightLine filters are available to fit Leica, Nikon, Olympus, Zeiss, and Aperio microscopes.

See spectra graphs and ASCII data for these filter sets at www.idex-hs.com/semrock

Fluorescence Filter Cubes

See online filter installation video

	Microscope Brand / Compatible Microscopes	Semrock Cube Designation	Cube Price*	Cube Part Number	Filter Set Part Number Mounted in Cube
	Aperio				
	ScanScope FL	AMF	$479	AMF	<Set Part Number>-AMF
	Nikon				
	TE2000, 80i, 90i, 50i, 55i, Eclipse Ti, Ni, Ci, and any using the Epi-fluor Illuminator	TE2000	$409	NTE	<Set Part Number>-NTE
	E200, E400, E600, E800, E1000, TS100, TS100F, TE200, TE300, ME600L, L150A, and some Labophot, Optiphot, and Diaphot series	Quadfluor	$409	NQF	<Set Part Number>-NQF
	Olympus				
	AX70, BX, BX50, BX51, BX60, BX61, BX50/51WI, BX60/61WI, IX50, IX51, IX70, IX71, IX81	U-MF2	$459	OMF	<Set Part Number>-OMF
	Compatible with the BX53, BX63 upright microscopes and also standard beam diameter applications for the IX53, IX73, and IX83 inverted microscopes.	U-FF	$459	OFF	<Set Part Number>-OFF
	Fluorescence Filter holder for Olympus IX3 Microscopes For large beam diameter and lower tier applications in the IX73 and IX83 model microscopes. Requires a 32 mm emitter and exciter and a 32 x 44 mm dichroic beamsplitter.	IX3-FFXL	$709	OFX	<Set Part Number>-OFX
	Zeiss				
	Axio Imager, Axiostar Plus, Axioskop 40, Axio Observer, Axioplan2i, Axioplan2ie, Axiovert200, and Axioskop2 (post-2001), Axiovert 40, Axio Examiner, and Axio Scope A1	FL CUBE EC P&C	$299	ZHE	<Set Part Number>-ZHE
	Leica - BrightLine Basic™, TRP-A, QDLP-B, and Laser Fluorescence sets are not sold as –ZERO compatible sets.				
	DM-2000, DM-2500, DM-3000, DMI3000 B, DM-4000, DMI-4000 B, DM-5000, DM-5500, DM-6000 and DMI6000 B	DM-K	$389	LDMK**	<Set Part Number>-LDMK-ZERO
	DMi8	DMi8 P-cube	$459	LDMP	<Set Part Number>-LDMP-ZERO

* Cube price when purchased separately or with a set. To have your set mounted at no charge, replace "-000" in the set part number with the cube part number from above (e.g. use FITC-3540C-NTE).

** Non-standard sets: Filter sets mounted in cubes that require non-standard filter shapes and sizes may not be available.

Multi-exciter sets are also available with 32 mm diameter exciters. See website for current pricing.

NOTE

If you use a Leica microscope, all BrightLine single-band bandpass filters in "Pinkel" and "Sedat" sets come with standard 25 mm (32 mm optional) exciters and 25 mm emitters, which are packaged separately for convenient mounting in standard filter wheels. For set part numbers for Leica microscopes, see www.idex-hs.com/semrock.

BrightLine® –ZERO™ Image Registration

BrightLine –ZERO™ Fluorescence Filter Sets

Only $109 ensures exact image registration when making multi-color composite images with BrightLine® single-band sets assembled into cubes at the factory. Not sure you need this? Keep in mind that BrightLine filters do not burn out, and the –ZERO option requires no calibration or special alignment, so why not cost-effectively future-proof your system? Join your many colleagues and demand the "–ZERO option" for certified image registration. To order, just add "–ZERO" to the end of the filter set part number.

- Allows you to create spatially registered multi-color composite images
- Hard coated for durability and reliability
- Ideal for demanding applications like:
  Co-localization fluorescence measurements
  Fluorescence In Situ Hybridization (FISH)
  Comparative Genomic Hybridization (CGH)

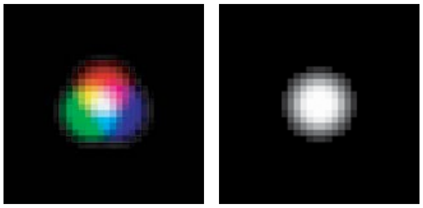
Property	Value	Comment	Price
Set-to-set Image Shift	< ± 1 pixel	Worst case image shift when interchanging BrightLine –ZERO filter sets, as measured relative to the mean image position for a large sample of filter sets. Analysis assumes collimated light in a standard microscope with a 200 mm focal length tube lens and 6.7 micron pixel size. Tested in popular microscope cubes.	+ $109 to the set price

Available as a –ZERO Set	NOT Available as a –ZERO Set
BrightLine Single-band and Longpass Sets	BrightLine Basic Sets
BrightLine LED Single-band Sets	BrightLine Laser Fluorescence Sets
BrightLine LED Full Multiband & Pinkel Sets	Brightline LED Sedat Multiband Sets
BrightLine FISH Sets	BrightLine Multiband Sets
FRET Sets	Qdot Longpass Set
Qdot Sets	Customer Selected Custom Sets

TECHNICAL NOTE

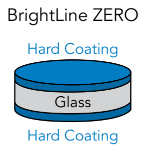
What is Pixel Shift?

Pixel shift results when a filter in an imaging path (the emitter and/or dichroic beamsplitter in a fluorescence microscope) with a non-zero wedge angle deviates the light rays to cause a shift of the image detected on a high-resolution CCD camera. When two or more images of the same object acquired using different filter sets are overlaid (in order to simultaneously view fluorescence from multiple fluorophores), any significant non-zero filter wedge angle means that the images will not be registered to identical pixels on the CCD camera. Hence, images produced by different fluorophores will not be accurately correlated or combined.

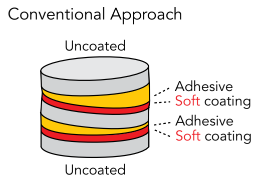


Composite images produced from conventional filter sets (above left), which typically have significant pixel shift, are distorted, whereas BrightLine ZERO pixel shift filter sets (above right) yield precise multi-color images.

Poor image registration, or pixel shift, results from the almost inevitable non-zero filter wedge angle. But low pixel shift is critical to obtain the best imaging performance when exchanging filters during any measurements that involve multiple exposures.



Semrock's advanced ion-beam-sputtering coating technology makes it possible for all BrightLine filters to be uniquely constructed from a single piece of glass, with the permanent hard coatings applied directly to the outside. This patented lower-loss and high-reliability construction inherently offers superior imaging performance. BrightLine –ZERO filter substrates are further manufactured and tested to the most exacting tolerances for certified "zero pixel shift" performance.



With older soft-coated fluorescence filters, one is forced to use multiple substrates that are typically bonded together with adhesive, generally resulting in significant wedge angle and therefore pixel shift. To improve the imaging registration, extra processing steps, alignment steps, and/or compensating optics are required, resulting in added cost. By contrast, BrightLine –ZERO filters are inherently manufacturable and thus very affordable.

BrightLine® Laser Filter and Set Reference Tables

Fluorescence Filter Sets Optimized for Lasers

*Refer to page 30 for details on multiband filter set configurations

Laser Line	Popular Fluorophores	Single-band Laser Sets: Bandpass Page 40	Single-band Laser Sets: Longpass Page 40	Multiband Laser Sets: "Full Multiband"* Page 41	Multiband Laser Sets: "Pinkel"* Page 42	Multiband Laser Sets: "Sedat"* Page 42
375 ± 3 nm 405 ± 5 nm	DAPI, BFP	LF405-C	LF405/LP-C	LF405/488/594-A LF405/488/532/635-B LF405/488/561/635-B	LF405/488/594-3X-B LF405/488/532/635-4X-B LF405/488/561/635-4X-B	LF405/488/594-3X3M-B LF405/488/561/635-4X4M-B
~ 440 nm 441.6 nm	CFP	LF442-C				
473 ± 2 nm 488 +3/–2 nm 491 nm	FITC, GFP	LF488-D	LF488/LP-D	LF488/561-B LF405/488/594-A LF405/488/532/635-B LF405/488/561/635-B	LF488/561-2X-C LF405/488/594-3X-B LF405/488/532/635-4X-B LF405/488/561/635-4X-B	LF488/561-2X2M-C LF405/488/594-3X3M-B LF405/488/561/635-4X4M-B
514.5 nm 515 nm	YFP	LF514-C				
532 nm	TRITC			LF405/488/532/635-B	LF405/488/532/635-4X-B	
559 ± 5 nm 561.4 nm 568.2 nm	RFPs (mCherry, HcRed, DsRed), Texas Red®	LF561-C	LF561/LP-D	LF488/561-B LF405/488/561/635-B	LF488/561-2X-C LF405/488/561/635-4X-B	LF488/561-2X2M-C LF405/488/561/635-4X4M-B
593.5 nm 594 ± 0.3 nm 594.1 nm	mCherry, mKate2, Alexa Fluor 594™, Texas Red®	LF594-D	LF594/LP-D	LF405/488/594-A	LF405/488/594-3X-B	LF405/488/594-3X3M-B
632.8 nm 635 +7/–0 nm 647.1 nm	Cy5™, APC, Alexa 633 & 647	LF635-C	LF635/LP-C	LF405/488/532/635-B LF405/488/561/635-B	LF488/543/635/-3X-A LF405/488/532/635-4X-B LF405/488/561/635-4X-B	LF405/488/561/635-4X4M-B

Individual Fluorescence Filters Optimized for Lasers

Laser Line	Laser Description	Single-Edge Laser Dichroics Page 70 – 72	Multiedge Laser Dichroic Page 70 & 72	Laser Combiners/ Separators Page 74	Yokogawa CSU Filters Page 75	Laser Longpass Filters Page 91
~ 375	GaN diode	●	●	●		
~ 405	GaN diode	●	●	●	●	●
~ 440	Diode	●		●	●	
441.6	HeNe gas	●		●	●	●
457.9	Ar-ion gas	●		●	●	●
~ 470	Diode	●		●	●	
473.0	Doubled DPSS	●	●	●	●	●
488.0	Ar-ion gas	●	●	●	●	●
~ 488	Doubled OPS	●	●	●	●	●
491.0	Doubled DPSS	●		●	●	●
505.0		●				●
514.5	Ar-ion gas	●		●	●	●
515.0	Doubled DPSS	●		●	●	●
532.0	Doubled DPSS	●	●	●	●	●
543.5	HeNe gas		●	●		
~559			●			
561.4	Doubled DPSS	●	●	●	●	●
568.2	Kr-ion gas	●	●	●	●	●
593.5	Doubled DPSS	●	●	●		●
594.1	HeNe gas	●	●	●		●
632.8	HeNe gas	●	●	●	●	●
~ 635	Diode	●	●	●	●	●
647.1	Kr-ion gas		●	●	●	●

Multiphoton laser fluorescence filters are available for blocking ranges of 680-1600 nm, see page 44

BrightLine® Laser Fluorescence Single-band and Longpass Filter Sets

★ INDICATES SUPER-RESOLUTION / TIRF

Designed for the unique demands of TIRF laser excitation, the dichroic beamsplitter reflection range extends down to 350 nm allowing the combined use of photoactivation, UV sources with the normal excitation laser line. Users of uncaging and super-resolution techniques will appreciate this added functionality. Maximize SNR and minimize artifacts in TIRF, confocal, PALM, STORM, SIM, and other super-resolution techniques.

Filter Set / Primary Fluorophores	Excitation (CWL/BW)	Emission (CWL/BW)	Dichroic (Laser)	Filter Set Part Numbers	Base Price
★ **LF405/LP-C** *(Longpass)* 375 & 405 nm	390/40	405/LP	405 nm	**LF405/LP-C-000**	**$1365**
★ **LF405-C** 375 & 405 nm	390/40	452/45	405 nm	**LF405-C-000**	**$1335**
★ **LF442-C** ~ 440 & 441.6 nm	448/20	482/25	442 nm	**LF442-C-000**	**$1330**
★ **LF488/LP-D** *(Longpass)* 473 & 488 nm	482/18	488/LP	488 nm	**LF488/LP-D-000**	**$1365**
★ **LF488-D** 473 & 488 nm	482/18	525/45	488 nm	**LF488-D-000**	**$1335**
★ **LF514-C** 514.5 & 515.0 nm	510/10	542/27	514 nm	**LF514-C-000**	**$1335**
★ **LF561/LP-D** 559, 561.4, & 568.2 nm	561/14	561/LP	561 nm	**LF561/LP-D-000**	**$1365**
★ **LF561-C** 559, 561.4, & 568.2 nm	561/14	609/54	561 nm	**LF561-C-000**	**$1335**
★ **LF594/LP-D** *(Longpass)* 593.5,594, 594.1 nm	591/6	594/LP	594 nm	**LF594/LP-D-000**	**$1395**
★ **LF594-D** 593.5, 594, 594.1 nm	591/6	647/57	594 nm	**LF594-D-000**	**$1365**
★ **LF635/LP-C** *(Longpass)* 632.8, 635, & 647.1 nm	640/14	635/LP	635 nm	**LF635/LP-C-000**	**$1415**
★ **LF635-C** 632.8, 635, & 647.1 nm	640/14	676/29	635 nm	**LF635-C-000**	**$1385**
LF405/LP-B *(Longpass)* 405 nm	390/40		418 nm	**LF405/LP-B-000**	**$1315**
LF405-B 405 nm	390/40	452/45	414 nm	**LF405-B-000**	**$1285**
LF442-B 442 nm	448/20	482/25	462 nm	**LF442-B-000**	**$1280**
LF488/LP-C *(Longpass)* 488 nm	482/18		495.5 nm	**LF488/LP-C-000**	**$1315**
LF488-C 488 nm	482/18	525/45	495.5 nm	**LF488-C-000**	**$1285**
LF514-B 514 nm	510/10	542/27	520 nm	**LF514-B-000**	**$1285**
LF561/LP-C *(Longpass)* 561 & 568 nm	561/14		573 nm	**LF561/LP-C-000**	**$1315**
LF561-B 561 & 568 nm	561/14	609/54	573 nm	**LF561-B-000**	**$1385**
LF594/LP-C *(Longpass)* 561 nm	591/6		599.5 nm	**LF594/LP-C-000**	**$1345**
LF594-C 594 nm	591/6	647/57	599.5 nm	**LF594-C-000**	**$1315**
LF635/LP-B *(Longpass)* 635 nm	640/14		655.8 nm	**LF635/LP-B-000**	**$1365**
★ **LF635-B** 635 nm	640/14	676/29	655.8 nm	**LF635-B-000**	**$1335**

BrightLine® Laser Fluorescence Multiband Sets

Full Multiband Filter Sets - multiband exciter, emitter and beamsplitter

Set / Laser Lines Primary Fluorophores	Multiband Excitation (CWL/BW)	Multiband Emission (CWL/BW)	Multiedge Dichroic (Laser)	Filter Set Part Numbers	Base Price
LF488/561-B *(Dual-band Full Multiband)* Green: FITC (Fluorescein), GFP (EGFP) Red: mCherry (RFP)	482/18 563/9	523/40 610/52	488 nm 561 nm	**LF488/561-B-000**	**$1590**
LF405/488/594-A *(Triple-band Full Multiband)* Blue: DAPI, BFP (EBFP) Green: FITC (Fluorescein), GFP (EGFP) Red: mCherry, Texas Red®	390/40 482/18 587/15	446/32 532/58 646/68	405 nm 488 nm 594 nm	**LF405/488/594-A-000**	**$1690**
LF405/488/532/635-B *(Quad-band Full Multiband)* Blue: DAPI Green: FITC (Fluorescein), GFP (EGFP) Orange: TRITC Red: Cy5™	390/40 482/18 532/3 640/14	446/32 510/16 581/63 703/80	405 nm 488 nm 532 nm 635 nm	**LF405/488/532/635-B-000**	**$1995**
LF405/488/561/635-B *(Quad-band Full Multiband)* Blue: DAPI, BFP (EBFP) Green: FITC (Fluorescein), GFP (EGFP) Orange: mCherry (RFP) Red: Cy5™	390/40 482/18 563/9 640/14	446/32 523/42 600/35 677/27	405 nm 488 nm 561 nm 635 nm	**LF405/488/561/635-B-000**	**$1995**
LF405/488/532/635-A *(Quad-band Full Multiband)* Blue: DAPI, BFP (EBFP) Green: FITC (Fluorescein), GFP (EGFP) Orange: mCherry (RFP), mRFP1 Red: Cy5™	390/40 482/18 532/3 640/14	445.8/32.5 510/16 581.5/63 703/80	422.3 nm 497.8 nm 541.6 nm 655.9 nm	**LF405/488/532/635-A-000**	**$1940**
LF405/488/561/635-A *(Quad-band Full Multiband)* Blue: DAPI, BFP (EBFP) Green: FITC (Fluorescein), GFP (EGFP) Orange: mCherry (RFP), mRFP1 Red: Cy5™	390/40 482/18 563.5/9 640/14	446/32.5 523.5/42 600/35.5 677/27.5	426.3 nm 498.3 nm 575.4 nm 655.3 nm	**LF405/488/561/635-A-000**	**$1940**
LF488/561-A *(Dual-band Full Multiband)* Green: FITC (Fluorescein), GFP (EGFP) Orange: mCherry (RFP), mRFP1	482/18 563.5/9	523/40 610/52	500 nm 575.5 nm	**LF488/561-A-000**	**$1535**

Filter Specifications on page 36

CUBES PAGE 37

NOTE: BrightLine Laser Fluorescence filter sets are optimized for laser excitation and inherently provide excellent image registration performance – when interchanging these sets with one another, minimal pixel shift is observed. Note that the laser filter sets are not designed to exhibit "zero pixel shift" performance when interchanging with BrightLine –ZERO™ filter sets. Images obtained with the laser filter sets exhibit excellent image registration not only with one another, but also with images obtained when no fluorescence filters are present (e.g. in DIC or other bright-field modes).

- Super-resolution / TIRF filter sets guarantee 1 λ P-V RWE filter set performance
- Filter wavelengths precisely keyed to popular laser lines, with steep transitions from laser blocking to fluorescence transmission
- Minimal reflected wavefront distortion for even large diameter illumination beams
- Exceptionally high transmission to maximize system throughput, thus reducing acquisition time
- Deep blocking at laser wavelengths to minimize noise background
- Longpass sets allow for longer wavelengths to be detected and more light to be captured

BrightLine® Laser Fluorescence Multiband Sets

"Pinkel" Multiband Laser Filter Sets - single-band exciters, multiband emitter and beamsplitter

Set / Laser Lines Primary Fluorophores	Single-band Excitation (CWL/BW)	Multiband Emission (CWL/BW)	Multiedge Dichroic (Laser)	Filter Set Part Numbers	Base Price
★ **LF488/561-2X-C** *(Dual-band Pinkel Set)* Green: FITC (Fluorescein), GFP (EGFP) Red: mCherry (RFP)	Ex1: 482/18 Ex2: 563/9	523/40 610/52	488 nm 561 nm	**LF488/561-2X-C-000**	**$1925**
LF405/488/594-3X-B *(Triple-band Pinkel Set)* Blue: DAPI, BFP (EBFP) Green: FITC (Fluorescein), GFP (EGFP) Red: mCherry, Texas Red®	Ex1: 390/40 Ex2: 482/18 Ex3: 591/6	446/32 532/58 646/68	405 nm 488 nm 594 nm	**LF405/488/594-3X-B-000**	**$2405**
★ **LF405/488/532/635-4X-B** *(Quad-band Pinkel Set)* Blue: DAPI Green: FITC (Fluorescein), GFP (EGFP) Orange: TRITC Red: Cy5™	Ex1: 390/40 Ex2: 482/18 Ex3: 532/3 Ex4: 640/14	446/32 510/16 581/63 703/80	405 nm 488 nm 532 nm 635 nm	**LF405/488/532/635-4X-B-000**	**$3025**
★ **LF405/488/561/635-4X-B** *(Quad-band Pinkel Set)* Blue: DAPI, BFP (EBFP) Green: FITC (Fluorescein), GFP (EGFP) Orange: mCherry, mRFP1 Red: Cy5™	Ex1: 390/40 Ex2: 482/18 Ex3: 563/9 Ex4: 640/14	446/32 523/42 600/35 677/27	405 nm 488 nm 561 nm 635 nm	**LF405/488/561/635-4X-B-000**	**$3040**

Filter Specifications on page 36

"Sedat" Multiband Laser Filter Sets - single-band exciters and emitters, multiedge beamsplitter

Set / Laser Lines Primary Fluorophores	Single-band Excitation (CWL/BW)	Single-band Emission (CWL/BW)	Multiedge Dichroic (Laser)	Filter Set Part Numbers	Base Price
★ **LF488/561-2X2M-C** *(Dual-band Sedat Set)* Green: FITC (Fluorescein), GFP (EGFP) Red: mCherry (RFP)	Ex1: 482/18 Ex2: 563/9	Em1: 525/45 Em2: 609/54	488 nm 561 nm	**LF488/561-2X2M-C-000**	**$2185**
LF405/488/594-3X3M-B *(Triple-band Sedat Set)* Blue: DAPI, BFP (EBFP) Green: FITC (Fluorescein), GFP (EGFP) Red: mCherry, Texas Red®	Ex1: 390/40 Ex2: 482/18 Ex3: 591/6	Em1: 445/20 Em2: 525/45 Em3: 647/57	405 nm 488 nm 594 nm	**LF405/488/594-3X3M-B-000**	**$3000**
★ **LF405/488/561/635-4X4M-B** *(Quad-band Sedat Set)* Blue: DAPI Green: FITC (Fluorescein), GFP (EGFP) Orange: Cy3™, TRITC, mOrange Red: Cy5™	Ex1: 390/40 Ex2: 482/18 Ex3: 563/9 Ex4: 640/14	Em1: 445/20 Em2: 525/30 Em3: 605/15 Em4: 676/29	405 nm 488 nm 561 nm 635 nm	**LF405/488/561/635-4X4M-B-000**	**$3900**

Filter Specifications on page 36

CUBES PAGE 37

Review our Fluorescence Multiplexing White Paper, May 2022

Selecting Filters for Fluorescence Multiplexing

The steady advances in optical thin film deposition technology over recent decades have enabled production of high performance multiband optical filters that address the increasing demand for multicolor fluorescence instrumentation. Though there is now a wide range of available catalog filters designed for a large variety of fluorophores, selecting suitable filters is often a complex process. Here we present considerations relevant to the design of such a multiplexing system. Read more at: *www.idex-hs.com/fluorescence-multiplexing*

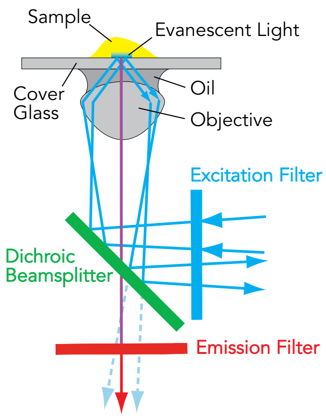
TECHNICAL NOTE

Optical Filters for Laser-based TIRF & Super-resolution Microscopes

The advent of lasers as light sources for TIRF & Super-resolution imaging imposes specific constraints on imaging systems and their components. For example, optical filters used in laser-based imaging systems have specific requirements that are unique compared to those filters used in broadband light source based instruments.

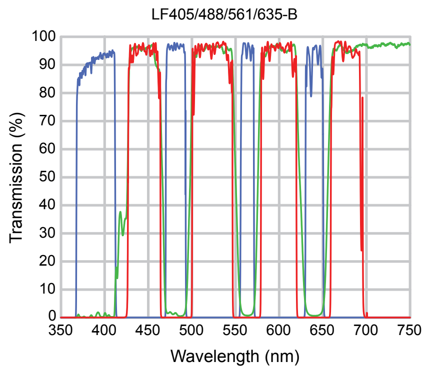
Despite varying opinions, optical source clean-up filters (excitation filters) are important for laser sources to block the unwanted light at wavelengths away from the actual laser line, including spontaneous emission observed in solid-state lasers and the plasma lines of gas lasers. Additionally, these filters should be durable enough to withstand the high intensity of laser beams. Unlike the traditional soft-coated fluorescence filters used for decades, newer hard-coated thin-film filters made with ion-beam sputtering have high laser damage threshold (LDT) ratings. High optical durability, combined with the robust environmental reliability of hard-coated filters—which are virtually impervious to thermal and humidity induced degradation—eliminates the need to ever replace the filters for most fluorescence microscopy applications.

Excitation filters for laser applications also have unique wavelength requirements. Some lasers, like gas lasers and DPSS lasers, have very precise and narrow laser lines. However, selection of a narrow laser line cleanup filter is not a good match for systems that might use multiple lasers with similar wavelengths (such as 473 nm and 488 nm for exciting GFP). The spectral output from diode and optically pumped semiconductor lasers can vary appreciably from laser to laser, with temperature, and as the lasers age. Therefore for most laser microscopy systems broader excitation filters that appear similar to those used for broadband light source (e.g., arc lamp) microscopy systems are a good solution. For example, the UV excitation band of the Semrock laser quad-band set is designed to be used with both 375 and 405 nm lasers, with the long-wavelength edge taking into account a ± 5 nm uncertainty in the wavelength of the 405 nm laser.



A typical emission filter should provide high blocking (> OD 6) at all possible laser lines that might be used with the filter set, thus ensuring the darkest background signal level, while at the same time providing excellent transmission of the emission signal. It should be noted that not all emission filters for broadband light sources provide sufficient blocking at laser lines and therefore they can lead to an appreciable compromise in imaging contrast.

Dichroics for laser applications should not only be made such that their reflection and transmission bands are compatible with the excitation and emission filters, but they also need to be coated with antireflection coatings in order to maximize transmission of the emission signal and eliminate coherent interference artifacts. Since the dichroic beamsplitter is directly exposed to the powerful excitation beam, even weak autofluorescence from the filter will contaminate the emission signal. Therefore, a substrate with ultra-low autofluorescence, such as fused silica, should be used.



The dichroic beamsplitter can have a significant impact on the image quality in certain applications, especially if the flatness (or curvature) of the dichroic is not suitable. For most laser microscope applications, the dichroic should be flat enough such that there is no noticeable shift in the focal spot of the illumination laser beam, where focal shift is typically defined by the Rayleigh range. This is critical for applications such as TIRF Confocal, PALM, STORM, SIM, and other super-resolution techniques.

Demanding applications such as imaging of single molecules using TIRF may impose unprecedented constraints on the blocking of laser beams in the emission channel while maximizing the collection of every possible photon from the fluorophores. In such situations, conventional bandpass emission filters may be replaced by a long-wave-pass filter keyed to the specific laser line. In our observation, TIRF systems even benefit from using a second emission filter in conjunction with all the filters of a laser set. The main purpose of the second filter, which should be physically separated from the first emission filter, is to ensure that higher-angle scattered excitation light does not make it through the entire imaging path to the detector.

Finally, conventional microscopy cubes can significantly compromise the flatness of the dichroic beamsplitters thereby introducing aberrations. But TIRF & super-resolution imaging systems are highly sensitive to optical wavefront distortion and demand the highest quality components for best instrument sensitivity. Our industry-leading TIRF & Super-resolution Microscopy Cubes that are guaranteed to provide 1λ P-V RWE are optimized for such high-end applications.

Overall, the designs of the excitation and emission filters as well as that of the dichroic beamsplitter should be complementary to each other to obtain the highest fidelity fluorescence visualization. Optical filters play a vital role in obtaining maximum performance from complex, expensive, laser-based microscopes and it only makes sense to invest in optical filters that match the performance of the imaging system.

Fluorophores
Single-band Sets
Multiband Sets
Cubes
Laser Sets
NLO Filters
Individual Filters
Dichroic Beamsplitters
Tunable Filters
More

BrightLine® Multiphoton Fluorescence Filters

These BrightLine multiphoton ultra-high-performance fluorescence filters serve a full range of applications, accommodating the wide range of fluorescent dyes that are the essential tools of the modern researcher. The transmission bands of the emitters are so wide that they appear clear at normal incidence. The long-wave-pass dichroic reflection bands are so wide that they look like mirrors when viewed at 45°. These filters virtually eliminate excitation laser noise at the detector. To reduce undesired fluorescence noise outside a desired band, simply add a BrightLine bandpass filter (see pages 48-56).

Laser Blocking Emission Filters

Average Transmission	Blocking Range	Glass Thickness	Filter Part Number	Price
> 93% 485 – 555 nm	OD_{avg} > 5: 300 – 474.5 nm OD_{avg} > 6: 567.5 – 1200 nm	2.0 mm	FF01-520/70-25	$1050
> 90% 350 – 650 nm	OD_{avg} > 8: 680 – 1040 nm OD_{avg} > 6: 1040 – 1080 nm	2.0 mm	FF01-680/SP-25	$1260
> 90% 350 – 690 nm	OD_{avg} > 6: 720 – 1100 nm	2.0 mm	FF01-720/SP-25	$1065
> 90% 380 – 720 nm	OD_{avg} > 6: 750 – 1100 nm	2.0 mm	FF01-750/SP-25	$1065
> 90% 380 – 740 nm	OD_{avg} > 6: 770 – 1400 nm	2.0 mm	FF01-770/SP-25	$1260
> 90% 380 – 760 nm	OD_{avg} > 6: 790 – 1400 nm	2.0 mm	FF01-790/SP-25	$1260
> 90% 380 – 860 nm	OD_{avg} > 6: 890 – 1400 nm	2.0 mm	FF01-890/SP-25	$1260
> 90% 400 – 905 nm	OD_{avg} > 6: 940 – 1600 nm	2.0 mm	FF01-940/SP-25	$1260

Long Wave Pass Dichroic Beamsplitters

Average Transmission	Average Reflection Bandwidth	Glass Thickness	Filter Part Number	Price
> 93% 680 – 1600 nm	> 98% 350 – 650 nm	1.05 mm	FF665-Di02-25x36	$630
> 93% 720 – 1600 nm	> 98% 350 – 690 nm	1.05 mm	FF705-Di01-25x36	$630
> 93% 750 – 1600 nm	> 98% 350 – 720 nm	1.05 mm	FF735-Di02-25x36	$630
> 93% 790 – 1600 nm	> 98% 350 – 760 nm	1.05 mm	FF775-Di01-25x36	$630
> 93% 892.5 – 1600 nm	> 98% 350 – 857.5 nm	1.05 mm	FF875-Di01-25x36	$630
> 93% 943.5 – 1600 nm	> 98% 350 – 906.5 nm	1.05 mm	FF925-Di01-25x36	$630

Short Wave Pass Dichroic Beamsplitters

Average Transmission	Average Reflection Bandwidth	Glass Thickness	Filter Part Number	Price
> 90% 360 – 650 nm	> 98% (s-polarization) 680 – 1080 nm > 90% (p-polarization) 700 – 1010 nm	1.05 mm	FF670-SDi01-25x36	$630
> 90% 360 – 675 nm	> 90% (avg-polarization) 725 – 1300 nm > 95% (s-polarization) 720 – 1300 nm > 85% (p-polarization) 730 – 1300 nm	1.05 mm	FF700-SDi01-25x36	$630
> 85% (avg. polarization) 370 – 690 nm > 90% (s- & p-polarizations) 400 – 410 nm	R_{avg} > 95% (avg. polarization) 750 – 875 nm R_{abs} > 99% (s- & p-polarizations) 800 – 820 nm	1.05 mm	FF720-SDi01-25x36	$630

See spectra graphs and ASCII data for these filter sets at wwww.idex-hs.com/semrock

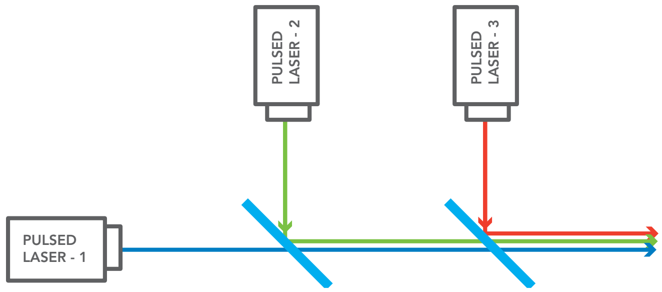
BrightLine® Multiphoton LaserMUX™ Beam Combining Filters

Multiphoton Beam Combining Filters

Average Transmission	Average Reflection Bandwidth	Glass Thickness	Filter Part Number	Price
> 93% (avg-polarization) 890 – 2100 nm > 90% (s-polarization) 890 – 2100 nm > 95% (p-polarization) 845 – 2100 nm	> 95% (avg-polarization) 670 – 815 nm > 98% (s-polarization) 670 – 849 nm > 90% (p-polarization) 670 – 815 nm	1.05 mm	FF850-Di01-t1-25x36	$790
> 93% (avg-polarization) 1022 – 2100 nm > 90% (s-polarization) 1022 – 2100 nm > 95% (p-polarization) 992 – 2100 nm	> 95% (avg-polarization) 770 – 938 nm > 98% (s-polarization) 770 – 968 nm > 90% (p-polarization) 770 – 930 nm	1.05 mm	FF980-Di01-t1-25x36	$790

PRODUCT NOTE

Our Multiphoton LaserMUX beam combiners enable deeper tissue imaging and improved contrast in multi-color and multi-modal fluorescence microscopy. The filters set new performance standards by simultaneously achieving high transmission, high reflection, and low GDD over both reflection & transmission, while maintaining minimal wavefront distortion. Ideal for combining two femtosecond pulsed laser beams, they are perfect for optogenetics and other life science applications.



BrightLine Multiphoton LaserMUX Beam Combiners can be used to combine multiple pulsed laser beams

Coherent Raman Scattering (CRS) Filters

Product Description	Avg. Transmission & Blocking Ranges		Glass Thickness	Filter Part Numbers	Price
SRS Filters					
SRS Imaging Emission Filter	T_{avg} > 93% Laser Blocking Range Laser Blocking Range	695 – 1005 nm OD_{avg} > 6: 300 – 680 nm OD_{avg} > 6: 1027.5 – 1700 nm OD_{abs} > 7: 1064 nm	2.0 mm	FF01-850/310-25	$1050
CARS Filters					
CARS Bandpass Emission Filter	T_{avg} > 93% Blocking Ranges	580 – 670 nm OD_{avg} > 5: 200 – 567 nm OD_{avg} > 6: 685 – 1400 nm OD_{abs} > 7: 800 & 1064 nm	2.0 mm	FF01-625/90-25	$1050
StopLine Notch Dichroic Beamsplitter	T_{avg} > 90% R > 98%	50 – 992 nm, 1114 – 1600 nm 1040 nm	1.05 mm	NFD01-1040-25x36	$765
StopLine Notch Dichroic Beamspiltter	T_{avg} > 90% R > 98%	350 – 1015 nm, 1140 – 1600 nm 1064 nm	1.05 mm	NFD01-1064-25x36	$765

Multiedge Confocal / Multiphoton Super-resolution / TIRF Dichroic Beamsplitters

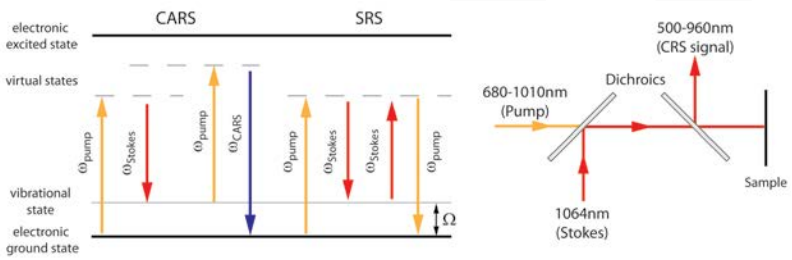
Average Transmission	Average Reflection Bandwidth	Glass Thickness	Filter Part Number	Price
≥ 92% 425 – 470 nm ≥ 92% 508 – 540 nm ≥ 92% 583 – 615 nm ≥ 92% 671 – 725 nm	> 94% (absolute) 400 – 410 nm > 94% (absolute) 483 – 493 nm > 94% (absolute) 559 – 563 nm > 94% (absolute) 635 – 647 nm > 94% (average) 800 – 1050 nm	1.05 mm 3.00 mm	Di01-R405/488/561/635/800-t1-25x36 Di01-R405/488/561/635/800-t3-25x36	$965 $1065

BrightLine® Coherent Raman Scattering (CRS) Filters

TECHNICAL NOTE

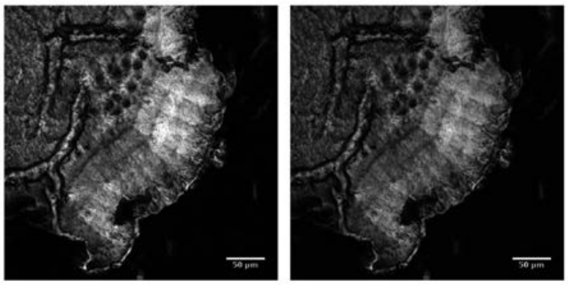
Coherent Raman Scattering (CRS, CARS and SRS)

With coherent Raman scattering (CRS) it is possible to perform highly specific, label-free chemical and biological imaging with orders of magnitude higher sensitivity at video-rate speeds compared with traditional Raman imaging. CRS is a nonlinear four-wave mixing process that is used to enhance the weak spontaneous Raman signal associated with specific molecular vibrations. Two different types of CRS that are exploited for chemical and biological imaging are coherent anti-Stokes Raman scattering (CARS) and stimulated Raman scattering (SRS).



Coherent Raman scattering energy diagrams for both CARS and SRS (left), and a schematic of a typical experimental setup (right).

In CRS, two lasers are used to excite the sample. The wavelength of a first laser (often a fixed-wavelength, 1064 nm laser) is set at the Stokes frequency, ω_{Stokes}. The wavelength of the second laser is tuned to the pump frequency, ω_{pump}. When the frequency difference $\omega_{pump} - \omega_{Stokes}$ between these two lasers matches an intrinsic molecular vibration of frequency Ω both CARS and SRS signals are generated within the sample.
In CARS, the coherent Raman signal is generated at a new, third wavelength, given by the anti-Stokes frequency $\omega_{CARS} = 2\omega_{pump} - \omega_{Stokes} = \omega_{pump} + \Omega$. In SRS there is no signal at a wavelength that is different from the laser excitation wavelengths. Instead, the intensity of the scattered light at the pump wavelength experiences a stimulated Raman loss (SRL), with the intensity of the scattered light at the Stokes wavelength experiencing a stimulated Raman gain (SRG). The key advantage of SRS microscopy over CARS microscopy is that it provides background-free chemical imaging with improved image contrast, both of which are important for biomedical imaging applications where water represents the predominant source of nonresonant background signal in the sample.



CARS Images

Coherent anti-Stokes Raman (CARS) imaging of cholesteryl palmitate. The image on the left was obtained using Semrock filter FF01-625/90. The image on the right was obtained using a fluorescence bandpass filter having a center wavelength of 650 nm and extended blocking. An analysis of the images revealed that the FF01-625/90 filter provided greater than 2.6 times CARS signal. Images courtesy of Prof. Eric Potma (UC Irvine).

Harmonic Generation Microscopy

Harmonic generation microscopy (HGM) is a label-free imaging technique that uses high-peak power ultrafast lasers to generate appreciable image contrast in biological imaging applications. Harmonic generation microscopy exploits intrinsic energy-conserving second and third order nonlinear optical effects. In second-harmonic generation (SHG) two incident photons interact at the sample to create a single emission photon having twice the energy i.e., $2\omega_i = \omega_{SHG}$. A prerequisite for SHG microscopy is that the sample must exhibit a significant degree of noncentrosymmetric order at the molecular level before an appreciable SHG signal can be generated. In third-harmonic generation (THG), three incident photons interact at the sample to create a single emission photon having three times the energy i.e., $3\omega_i = \omega_{THG}$. Both SHG and THG imaging techniques can be combined with other nonlinear optical imaging (NLO) modalities, such as multiphoton fluorescence and coherent Raman scattering imaging. Such a multimodal approach to biological imaging allows a comprehensive analysis of a wide variety of biological entities, such as individual cells, lipids, collagen fibrils, and the integrity of cell membranes at the same time.

Multiphoton Filters Common Specifications

Common Specifications

Property		Emitter	LWP Dichroic	Comment
Passband Transmission	Guaranteed	> 90%	> 93%	Averaged over any 50 nm (emitter) or 10 nm (dichroic) window within the passband. For SWP dichroic specifications, see page 44 .
	Typical	> 95%	> 95%	
Dichroic Reflection	LWP	N/A	> 98%	Averaged over any 30 nm window within the reflection band. For SWP dichroic specifications, see page 44.
Multiedge Dichroic Reflection		N/A	N/A	For multiedge dichroic specifications, values are specified as absolute or average, see page 71 for polarization dependent reflection details.
Autofluorescence		Ultra-low	Ultra-low	Fused silica substrate
Blocking		Emitter filters have exceptional blocking over the Ti:Sapphire laser range as needed to achieve superb signal-to-noise ratios even when using an extended-response PMT or a CCD camera or other silicon-based detector.		
Pulse Dispersion		LWP dichroic beamsplitters are suitable for use with 100 femtosecond Gaussian laser pulses. For SWP dichroic beamsplitters, see the Group Delay Dispersion and Polarization Technical Note at www.idex-hs.com/semrock		
Emitter Orientation		The emitter orientation does not affect its performance; therefore there is no arrow on the ring to denote a preferred orientation.		
Dichroic Orientation		For the LWP dichroic, the reflective coating side should face toward detector and sample. For the SWP dichroic, the reflective coating side should face towards the laser as shown in the diagram on page 29.		
Microscope Compatibility		These filters fit most standard-sized microscope cubes from Nikon, Olympus, and Zeiss and may also be mounted in optical bench mounts. Contact Semrock for special filter sizes.		

TECHNICAL NOTE

Multiphoton Filters

In multiphoton fluorescence microscopy, fluorescent molecules that tag targets of interest are excited and subsequently emit fluorescent photons that are collected to form an image. However, in a two-photon microscope, the molecule is not excited with a single photon as it is in traditional fluorescence microscopy, but instead, two photons, each with twice the wavelength, are absorbed simultaneously to excite the molecule.

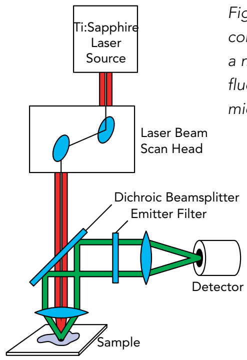


Figure 1: Typical configuration of a multiphoton fluorescence microscope

As shown in Figure 1, a typical system is comprised of an excitation laser, scanning and imaging optics, a sensitive detector (usually a photomultiplier tube), and optical filters for separating the fluorescence from the laser (dichroic beamsplitter) and blocking the laser light from the detector (emission filter).

The advantages offered by multiphoton imaging systems include: true three-dimensional imaging like confocal microscopy; the ability to image deep inside of live tissue; elimination of out-of-plane fluorescence; and reduction of photobleaching away from the focal plane to increase sample longevity. Now Semrock has brought enhanced performance to multiphoton users by introducing optical filters with ultra-high transmission in the passbands, steep transitions, and guaranteed deep blocking everywhere it is needed. Given how much investment is typically required for the excitation laser and other complex elements of multiphoton imaging systems, these filters represent a simple and inexpensive upgrade to substantially boost system performance.

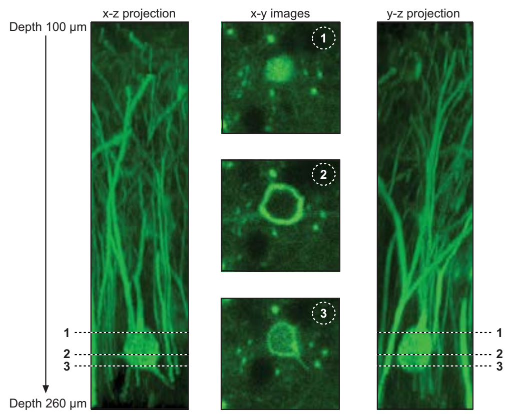
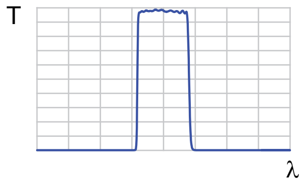


Figure 2: Exciting research using Semrock multiphoton filters demonstrates the power of fluorescent Ca^{2+} indicator proteins (FCIPs) for studying Ca^{2+} dynamics in live cells using two-photon microscopy. Three-dimensional reconstructions of a layer 2/3 neuron expressing a fluorescent protein CerTN-L15. Middle: 3 selected images (each taken at depth marked by respective number on the left and right). Image courtesy of Prof. Dr. Olga Garaschuk of the Institute of Neuroscience at the Technical University of Munich. (Modified from Heim et al., Nat. Methods, 4(2): 127-9, Feb. 2007).

BrightLine® Single-band Bandpass Filters



Semrock stocks an exceptional range of high-performance, high-reliability individual fluorescence bandpass filters that have been optimized for use in a variety of fluorescence instruments. These filters exclusively utilize our patented single-substrate construction for the highest performance and reliability.

Unless otherwise noted, all filters are housed in a standard 25 mm round black-anodized aluminum ring with thickness as indicated, and a clear aperture of at least 21 mm.

Color	Center Wavelength	Avg. Transmission and Bandwidth[1]	Housed Size (Diameter x Thickness)	Glass Thickness	Filter Part Number	Price
	254 nm	*See Mercury Line filters, page 107*			Hg01-254-25	
	257 nm	> 50% over 12 nm	25 mm x 3.5 mm	1.05 mm	FF01-257/12-25	$555
	260 nm	> 55% over 16 nm	25 mm x 3.5 mm	1.05 mm	FF01-260/16-25	$555
	280 nm	> 60% over 10 nm	25 mm x 3.5 mm	1.05 mm	FF01-280/10-25	$555
	280 nm	> 65% over 20 nm	25 mm x 5.0 mm	2.0 mm	FF01-280/20-25	$565
	285 nm	> 60% over 14 nm	25 mm x 5.0 mm	3.0 mm	FF01-285/14-25	$555
	292 nm	> 70% over 27 nm	25 mm x 3.5 mm	2.0 mm	FF01-292/27-25	$555
	300 nm	> 60% over 80 nm	25 mm x 3.5 mm	2.0 mm	FF01-300/80-25	$555
	302 nm	> 70% over 26 nm	25 mm x 3.5 mm	2.0 mm	FF01-302/26-25	$555
	315 nm	> 75% over 15 nm	25 mm x 3.5 mm	2.0 mm	FF01-315/15-25	$525
	320 nm	> 65% over 40 nm	25 mm x 5.0 mm	2.0 mm	FF02-320/40-25	$555
	334 nm	> 60% over 40 nm	25 mm x 3.5 mm	2.0 mm	FF01-334/40-25	$555
	340 nm	> 75% over 12 nm	25 mm x 3.5 mm	2.0 mm	FF01-340/12-25	$525
	340 nm	> 75% over 22 nm	25 mm x 3.5 mm	1.05 mm	FF01-340/22-25	$525
	340 nm	> 75% over 26 nm	25 mm x 5.0 mm	2.0 mm	FF01-340/26-25	$400
	355 nm	> 80% over 40 nm	25 mm x 3.5 mm	2.0 mm	FF01-355/40-25	$375
	356 nm	> 85% over 30 nm	25 mm x 5.0 mm	2.0 mm	FF01-356/30-25	$420
	357 nm	> 75% over 44 nm	25 mm x 3.5 mm	2.0 mm	FF01-357/44-25	$375
	360 nm	> 90% over 23 nm	25 mm x 3.5 mm	2.0 mm	FF01-360/23-25	$435
	365 nm	*See Mercury Line filters, page 107*			Hg01-365-25	
	370 nm	> 90% over 6 nm	25 mm x 5.0 mm	3.0 mm	FF01-370/6-25	$455
	370 nm	> 90% over 10 nm	25 mm x 5.0 mm	3.0 mm	FF01-370/10-25	$455
	370 nm	> 90% over 36 nm	25 mm x 5.0 mm	2.0 mm	FF01-370/36-25	$375
	375 nm	> 80% over 110 nm	25 mm x 3.5 mm	2.0 mm	FF01-375/110-25	$455
	377 nm	> 85% over 50 nm	25 mm x 5.0 mm	3.5 mm	FF01-377/50-25	$375
	378 nm	> 85% over 52 nm	25 mm x 5.0 mm	2.0 mm	FF01-378/52-25	$375
	379 nm	> 90% over 34 nm	25 mm x 5.0 mm	2.0 mm	FF02-379/34-25	$375
	380 nm	> 80% over 14 nm	25 mm x 5.0 mm	3.5 mm	FF01-380/14-25	$435
	385 nm	> 90% over 26 nm	25 mm x 3.5 mm	2.0 mm	FF01-385/26-25	$455
	386 nm	> 90% over 23 nm	25 mm x 5.0 mm	2.0 mm	FF01-386/23-25	$435
	387 nm	> 90% over 11 nm	25 mm x 5.0 mm	2.0 mm	FF01-387/11-25	$375
	389 nm	> 93% over 38 nm	25 mm x 5.0 mm	2.0 mm	FF01-389/38-25	$420
	390 nm	> 90% over 18 nm	25 mm x 5.0 mm	2.0 mm	FF01-390/18-25	$315
	390 nm	> 93% over 40 nm	25 mm x 5.0 mm	2.0 mm	FF01-390/40-25	$405
	392 nm	> 93% over 23 nm	25 mm x 5.0 mm	2.0 mm	FF01-392/23-25	$375
	395 nm	> 85% over 11 nm	25 mm x 3.5 mm	2.0 mm	FF01-395/11-25	$420
	400 nm	> 90% over 12 nm	25 mm x 3.5 mm	2.0 mm	FF01-400/12-25	$455
	400 nm	> 90% over 40 nm	25 mm x 3.5 mm	2.0 mm	FF01-400/40-25	$435
	403 nm	*See VersaChrome Edge™ filters, page 82*			FF01-403/95-25	

[1] Bandwidth is the minimum width over which the average transmission exceeds the specified passband transmission; see Technical Note on page 57.

(continued)

For graphs, ASCII data and blocking information, go to www.idex-hs.com/semrock

BrightLine® Single-band Bandpass Filters

Color	Center Wavelength	Avg. Transmission and Bandwidth[1]	Housed Size (Diameter x Thickness)	Glass Thickness	Filter Part Number	Price
	405 nm	*See Laser Diode Clean-Up filters, page 101*			LD01-405/10-25	
	405 nm	> 87% over 10 nm	25 mm x 5.0 mm	3.5 mm	FF01-405/10-25	$405
	405 nm	> 90% over 150 nm	25 mm x 3.5 mm	2.0 mm	FF01-405/150-25	$455
	406 nm	> 85% over 15 nm	25 mm x 3.5 mm	2.0 mm	FF01-406/15-25	$375
	414 nm	> 90% over 46 nm	25 mm x 3.5 mm	2.0 mm	FF01-414/46-25	$345
	415 nm	> 90% over 10 nm	25 mm x 3.5 mm	2.0 mm	FF01-415/10-25	$435
	417 nm	> 90% over 60 nm	25 mm x 5.0 mm	2.0 mm	FF01-417/60-25	$405
	420 nm	> 90% over 5 nm	25 mm x 5.0 mm	3.5 mm	FF01-420/5-25	$475
	420 nm	> 90% over 10 nm	25 mm x 3.5 mm	2.0 mm	FF01-420/10-25	$405
	425 nm	> 90% over 26 nm	25 mm x 5.0 mm	3.5 mm	FF01-425/26-25	$375
	427 nm	> 93% over 10 nm	25 mm x 5.0 mm	2.0 mm	FF01-427/10-25	$405
	432 nm	> 93% over 32 nm	25 mm x 3.5 mm	2.0 mm	FF01-432/36-25	$375
	433 nm	> 93% over 24 nm	25 mm x 3.5 mm	2.0 mm	FF01-433/24-25	$400
	434 nm	> 90% over 17 nm	25 mm x 5.0 mm	2.0 mm	FF01-434/17-25	$315
	435 nm	> 90% over 40 nm	25 mm x 5.0 mm	2.0 mm	FF02-435/40-25	$375
	438 nm	> 93% over 24 nm	25 mm x 5.0 mm	2.0 mm	FF02-438/24-25	$375
	439 nm	*See Laser Diode Clean-Up filters, page 101*			LD01-439/8-25	
	439 nm	> 93% over 154 nm	25 mm x 5.0 mm	2.0 mm	FF01-439/154-25	$400
	440 nm	> 93% over 40 nm	25 mm x 3.5 mm	2.0 mm	FF01-440/40-25	$375
	442 nm	> 93% over 42 nm	25 mm x 5.0 mm	2.0 mm	FF01-442/42-25	$375
	445 nm	> 93% over 20 nm	25 mm x 5.0 mm	2.0 mm	FF01-445/20-25	$375
	445 nm	> 90% over 40 nm	25 mm x 3.5 mm	2.0 mm	FF01-445/40-25	$375
	445 nm	> 90% over 45 nm	25 mm x 5.0 mm	2.0 mm	FF01-445/45-25	$315
	447 nm	> 93% over 60 nm	25 mm x 3.5 mm	2.0 mm	FF02-447/60-25	$375
	448 nm	> 93% over 20 nm	25 mm x 5.0 mm	2.0 mm	FF01-448/20-25	$400
	450 nm	> 90% over 70 mm	25 mm x 3.5 mm	2.0 mm	FF01-450/70-25	$375
	451 nm	*See VersaChrome Edge™ filters, page 82*			FF01-451/106-25	
	452 nm	> 93% over 45 nm	25 mm x 3.5 mm	2.0 mm	FF01-452/45-25	$375
	457 nm	> 90% over 50 nm	25 mm x 5.0 mm	3.5 mm	FF01-457/50-25	$345
	458 nm	> 90% over 64 nm	25 mm x 3.5 mm	2.0 mm	FF01-458/64-25	$420
	460 nm	> 90% over 14 nm	25 mm x 5.0 mm	3.0 mm	FF01-460/14-25	$375
	460 nm	> 90% over 60 nm	25 mm x 3.5 mm	2.0 mm	FF01-460/60-25	$315
	460 nm	> 90% over 80 nm	25 mm x 5.0 mm	2.0 mm	FF02-460/80-25	$375
	461 nm	> 90% over 5 nm	25 mm x 3.5 mm	2.0 mm	FF01-461/5-25	$345
	465 nm	> 90% over 30 nm	25 mm x 5.0 mm	3.5 mm	FF01-465/30-25	$345
	466 nm	> 90% over 5 nm	25 mm x 5.0 mm	3.5 mm	FF01-466/5-25	$455
	466 nm	> 93% over 40 nm	25 mm x 5.0 mm	2.0 mm	FF01-466/40-25	$375
	469 nm	> 90% over 35 nm	25 mm x 5.0 mm	2.0 mm	FF01-469/35-25	$315
	470 nm	> 93% over 22 nm	25 mm x 5.0 mm	2.0 mm	FF01-470/22-25	$375
	470 nm	> 90% over 28 nm	25 mm x 5.0 mm	3.5 mm	FF01-470/28-25	$455
	470 nm	> 93% over 100 nm	25 mm x 5.0 mm	2.0 mm	FF02-470/100-25	$375
	472 nm	> 93% over 30 nm	25 mm x 5.0 mm	2.0 mm	FF02-472/30-25	$375
	473 nm	> 90% over 10 nm	25 mm x 3.5 mm	2.0 mm	FF01-473/10-25	$375
	474 nm	> 93% over 23 nm	25 mm x 5.0 mm	2.0 mm	FF01-474/23-25	$405
	474 nm	> 93% over 27 nm	25 mm x 5.0 mm	2.0 mm	FF01-474/27-25	$375
	475 nm	> 92% over 23 nm	25 mm x 3.5 mm	2.0 mm	FF01-475/23-25	$435

[1] Bandwidth is the minimum width over which the average transmission exceeds the specified passband transmission; see Technical Note on page 57.

(continued)

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BrightLine® Single-band Bandpass Filters

Color	Center Wavelength	Avg. Transmission and Bandwidth[1]	Housed Size (Diameter x Thickness)	Glass Thickness	Filter Part Number	Price
	475 nm	> 90% over 28 nm	25 mm x 5.0 mm	2.0 mm	FF01-475/28-25	$375
	475 nm	> 90% over 35 nm	25 mm x 5.0 mm	2.0 mm	FF01-475/35-25	$315
	475 nm	> 90% over 42 nm	25 mm x 5.0 mm	3.5 mm	FF01-475/42-25	$345
	475 nm	> 93% over 50 nm	25 mm x 5.0 mm	2.0 mm	FF02-475/50-25	$375
	479 nm	> 90% over 40 nm	25 mm x 3.5 mm	2.0 mm	FF01-479/40-25	$315
	480 nm	> 92% over 17 nm	25 mm x 3.5 mm	2.0 mm	FF01-480/17-25	$375
	482 nm	> 93% over 18 nm	25 mm x 5.0 mm	2.0 mm	FF02-482/18-25	$405
	482 nm	> 93% over 25 nm	25 mm x 3.5 mm	2.0 mm	FF01-482/25-25	$375
	482 nm	> 93% over 35 nm	25 mm x 5.0 mm	2.0 mm	FF01-482/35-25	$375
	483 nm	> 93% over 32 nm	25 mm x 3.5 mm	2.0 mm	FF01-483/32-25	$375
	485 nm	> 93% over 20 nm	25 mm x 5.0 mm	2.0 mm	FF02-485/20-25	$375
	488 nm	> 90% over 6 nm	25 mm x 3.5 mm	2.0 mm	FF01-488/6-25	$405
	488 nm	> 93% over 10 nm	25 mm x 3.5 mm	2.0 mm	FF01-488/10-25	$405
	488 nm	> 93% over 50 nm	25 mm x 3.5 mm	2.0 mm	FF01-488/50-25	$455
	490 nm	> 93% over 60 nm	25 mm x 3.5 mm	2.0 mm	FF01-490/60-25	$405
	494 nm	> 93% over 20 nm	25 mm x 5.0 mm	2.0 mm	FF01-494/20-25	$400
	494 nm	> 93% over 34 nm	25 mm x 3.5 mm	2.0 mm	FF01-494/34-25	$375
	494 nm	> 90% over 41 nm	25 mm x 5.0 mm	3.5 mm	FF01-494/41-25	$375
	497 nm	> 90% over 16 nm	25 mm x 5.0 mm	2.0 mm	FF01-497/16-25	$315
	500 nm	> 93% over 15 nm	25 mm x 5.0 mm	2.0 mm	FF01-500/15-25	$450
	500 nm	> 93% over 24 nm	25 mm x 5.0 mm	3.5 mm	FF01-500/24-25	$400
	503 nm	> 93% over 40 nm	25 mm x 3.5 mm	2.0 mm	FF01-503/40-25	$455
	504 nm	> 93% over 12 nm	25 mm x 5.0 mm	2.0 mm	FF01-504/12-25	$375
	505 nm	*See VersaChrome Edge™ filters, page 82*			FF01-505/119-25	
	509 nm	> 93% over 22 nm	25 mm x 5.0 mm	2.0 mm	FF01-509/22-25	$375
	510 nm	> 93% over 10 nm	25 mm x 5.0 mm	2.0 mm	FF02-510/10-25	$405
	510 nm	> 93% over 20 nm	25 mm x 5.0 mm	2.0 mm	FF03-510/20-25	$405
	510 nm	> 90% over 42 nm	25 mm x 3.5 mm	2.0 mm	FF01-510/42-25	$315
	510 nm	> 93% over 84 nm	25 mm x 3.5 mm	2.0 mm	FF01-510/84-25	$375
	511 nm	> 90% over 20 nm	25 mm x 3.5 mm	2.0 mm	FF01-511/20-25	$435
	512 nm	> 92% over 25 nm	25 mm x 3.5 mm	2.0 mm	FF01-512/25-25	$420
	513 nm	> 93% over 13 nm	25 mm x 5.0 mm	2.0 mm	FF01-513/13-25	$420
	513 nm	> 90% over 17 nm	25 mm x 3.5 mm	2.0 mm	FF01-513/17-25	$375
	514 nm	> 93% over 3 nm	25 mm x 5.0 mm	2.0 mm	FF01-514/3 -25	$405
	514 nm	> 93% over 30 nm	25 mm x 3.5 mm	2.0 mm	FF01-514/30-25	$375
	514 nm	> 93% over 44 nm	25 mm x 3.5 mm	1.05 mm	FF01-514/44-25	$375
	515 nm	> 93% over 30 nm	25 mm x 3.5 mm	2.0 mm	FF01-515/30-25	$375
	517 nm	> 90% over 20 nm	25 mm x 5.0 mm	3.5 mm	FF01-517/20-25	$375
	520 nm	> 93% over 5 nm	25 mm x 3.5 mm	2.0 mm	FF01-520/5-25	$420
	520 nm	> 93% over 15 nm	25 mm x 5.0 mm	2.0 mm	FF01-520/15-25	$455
	520 nm	> 93% over 28 nm	25 mm x 3.5 mm	2.0 mm	FF02-520/28-25	$375
	520 nm	> 93% over 35 nm	25 mm x 3.5 mm	2.0 mm	FF01-520/35-25	$375
	520 nm	> 90% over 44 nm	25 mm x 3.5 mm	2.0 mm	FF01-520/44-25	$345
	520 nm	> 90% over 60 nm	25 mm x 3.5 mm	2.0 mm	FF01-520/60-25	$435
	520 mm	*See Multiphoton filters, page 44*			FF01-520/70-25	

(continued)

[1] Bandwidth is the minimum width over which the average transmission exceeds the specified passband transmission; see Technical Note on page 57

For graphs, ASCII data and blocking information, go to www.idex-hs.com/semrock

BrightLine® Single-band Bandpass Filters

Color	Center Wavelength	Avg. Transmission and Bandwidth[1]	Housed Size (Diameter x Thickness)	Glass Thickness	Filter Part Number	Price
	523 nm	> 93% over 20 nm	25 mm x 3.5 mm	2.0 mm	FF01-523/20-25	$400
	524 nm	> 93% over 24 nm	25 mm x 3.5 mm	2.0 mm	FF01-524/24-25	$405
	525 nm	> 90% over 15 nm	25 mm x 3.5 mm	2.0 mm	FF01-525/15-25	$400
	525 nm	> 90% over 30 nm	25 mm x 3.5 mm	2.0 mm	FF01-525/30-25	$375
	525 nm	> 90% over 39 nm	25 mm x 3.5 mm	2.0 mm	FF01-525/39-25	$315
	525 nm	> 90% over 40 nm	25 mm x 5.0 mm	2.0 mm	FF02-525/40-25	$405
	525 nm	> 93% over 45 nm	25 mm x 3.5 mm	2.0 mm	FF01-525/45-25	$375
	525 nm	> 93% over 50 nm	25 mm x 3.5 mm	2.0 mm	FF03-525/50-25	$375
	527 nm	> 93% over 20 nm	25 mm x 3.5 mm	2.0 mm	FF01-527/20-25	$375
	529 nm	> 90% over 24 nm	25 mm x 5.0 mm	2.0 mm	FF02-529/24-25	$455
	530 nm	> 90% over 11 nm	25 mm x 5.0 mm	3.5 mm	FF01-530/11-25	$375
	530 nm	> 90% over 43 nm	25 mm x 3.5 mm	2.0 mm	FF01-530/43-25	$315
	530 nm	> 90% over 55 nm	25 mm x 3.5 mm	2.0 mm	FF01-530/55-25	$405
	531 nm	> 93% over 22 nm	25 mm x 5.0 mm	2.0 mm	FF02-531/22-25	$375
	531 nm	> 93% over 40 nm	25 mm x 5.0 mm	2.0 mm	FF01-531/40-25	$375
	531 nm	> 94% over 46 nm	25 mm x 3.5 mm	2.0 mm	FF01-531/46-25	$435
	531 nm	> 93% over 3 nm	25 mm x 5.0 mm	2.0 mm	FF01-532/3-25	$405
	532 nm	> 90% over 18 nm	25 mm x 3.5 mm	2.0 mm	FF01-532/18-25	$455
	534 nm	> 93% over 20 nm	25 mm x 5.0 mm	2.0 mm	FF01-534/20-25	$400
	534 nm	> 93% over 30 nm	25 mm x 5.0 mm	2.0 mm	FF02-534/30-25	$405
	534 nm	> 90% over 42 nm	25 mm x 3.5 mm	2.0 mm	FF01-534/42-25	$405
	535 nm	> 90% over 22 nm	25 mm x 3.5 mm	2.0 mm	FF01-535/22-25	$315
	535 nm	> 90% over 50 nm	25 mm x 3.5 mm	1.05 mm	FF01-535/50-25	$375
	535 nm	> 93% over 150 nm	25 mm x 3.5 mm	2.0 mm	FF01-535/150-25	$455
	536 nm	> 93% over 40 nm	25 mm x 3.5 mm	2.0 mm	FF01-536/40-25	$375
	537 nm	> 90% over 26 nm	25 mm x 5.0 mm	3.0 mm	FF01-537/26-25	$345
	538 nm	> 90% over 40 nm	25 mm x 3.5 mm	2.0 mm	FF01-538/40-25	$375
	539 nm	> 90% over 30 nm	25 mm x 3.5 mm	2.0 mm	FF01-539/30-25	$455
	540 nm	> 93% over 15 nm	25 mm x 5.0 mm	2.0 mm	FF01-540/15-25	$420
	540 nm	> 93% over 50 nm	25 mm x 3.5 mm	2.0 mm	FF01-540/50-25	$375
	540 nm	> 93% over 80 nm	25 mm x 3.5 mm	2.0 mm	FF01-540/80-25	$435
	542 nm	> 90% over 20 nm	25 mm x 5.0 mm	2.0 mm	FF01-542/20-25	$315
	542 nm	> 93% over 27 nm	25 mm x 3.5 mm	2.0 mm	FF01-542/27-25	$375
	543 nm	> 93% over 22 nm	25 mm x 5.0 mm	3.5 mm	FF01-543/22-25	$375
	544 nm	> 93% over 24 nm	25 mm x 3.5 mm	2.0 mm	FF01-544/24-25	$375
	545 nm	> 90% over 55 nm	25 mm x 3.5 mm	2.0 mm	FF01-545/55-25	$405
	546 nm	> 90% over 6 nm	25 mm x 3.5 mm	2.0 mm	FF01-546/6-25	$420
	549 nm	> 90% over 12 nm	25 mm x 3.5 mm	2.0 mm	FF01-549/12-25	$455
	549 nm	> 90% over 15 nm	25 mm x 5.0 mm	3.5 mm	FF01-549/15-25	$455
	549 nm	> 93% over 17 nm	25 mm x 3.5 mm	2.0 mm	FF01-549/17-25	$375
	550 nm	> 90% over 32 nm	25 mm x 3.5 mm	2.0 mm	FF01-550/32-25	$375
	550 nm	> 90% over 49 nm	25 mm x 3.5 mm	2.0 mm	FF01-550/49-25	$345
	550 nm	> 92% over 88 nm	25 mm x 3.5 mm	2.0 mm	FF01-550/88-25	$375
	550 nm	> 90% over 200 nm	25 mm x 3.5 mm	2.0 mm	FF01-550/200-25	$455
	554 nm	> 93% over 23 nm	25 mm x 5.0 mm	2.0 mm	FF01-554/23-25	$375

(continued)

[1] Bandwidth is the minimum width over which the average transmission exceeds the specified passband transmission; see Technical Note on page 57.

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BrightLine® Single-band Bandpass Filters

Color	Center Wavelength	Avg. Transmission and Bandwidth[1]	Housed Size (Diameter x Thickness)	Glass Thickness	Filter Part Number	Price
	556 nm	> 93% over 20 nm	25 mm x 5.0 mm	2.0 mm	FF01-556/20-25	$375
	558 nm	> 90% over 20 nm	25 mm x 5.0 mm	3.5 mm	FF01-558/20-25	$455
	559 nm	> 90% over 34 nm	25 mm x 5.0 mm	2.0 mm	FF01-559/34-25	$315
	560 nm	> 93% over 14 nm	25 mm x 5.0 mm	2.0 mm	FF01-560/14-25	$455
	560 nm	> 93% over 25 nm	25 mm x 5.0 mm	2.0 mm	FF01-560/25-25	$375
	560 nm	> 90% over 94 nm	25 mm x 3.5 mm	2.0 mm	FF01-560/94-25	$435
	561 nm	> 93% over 4 nm	25 mm x 5.0 mm	3.5 mm	FF01-561/4-25	$420
	561 nm	> 93% over 14 nm	25 mm x 5.0 mm	2.0 mm	FF01-561/14-25	$405
	562 nm	> 93% over 40 nm	25 mm x 5.0 mm	2.0 mm	FF01-562/40-25	$375
	563 nm	> 93% over 9 nm	25 mm x 5.0 mm	2.0 mm	FF01-563/9-25	$420
	565 nm	> 90% over 24 nm	25 mm x 5.0 mm	2.0 mm	FF01-565/24-25	$315
	565 nm	*See VersaChrome Edge™ filters, page 82*			FF01-565/133-25	
	567 nm	> 95% over 15 nm	25 mm x 3.5 mm	2.0 mm	FF01-567/15-25	$405
	571 nm	> 93% over 72 nm	25 mm x 3.5 mm	2.0 mm	FF01-571/72-25	$420
	572 nm	> 92% over 15 nm	25 mm x 3.5 mm	2.0 mm	FF01-572/15-25	$405
	572 nm	> 93% over 28 nm	25 mm x 3.5 mm	2.0 mm	FF01-572/28-25	$375
	575 nm	> 90% over 15 nm	25 mm x 5.0 mm	3.5 mm	FF01-575/15-25	$405
	575 nm	> 93% over 25 nm	25 mm x 5.0 mm	2.0 mm	FF03-575/25-25	$375
	575 nm	> 93% over 59 nm	25 mm x 3.5 mm	2.0 mm	FF01-575/59-25	$345
	578 nm	> 93% over 21 nm	25 mm x 5.0 mm	2.0 mm	FF01-578/21-25	$375
	578 nm	> 90% over 105 nm	25 mm x 3.5 mm	2.0 mm	FF01-578/105-25	$375
	579 nm	> 90% over 34 nm	25 mm x 3.5 mm	2.0 mm	FF01-579/34-25	$375
	580 nm	> 93% over 14 nm	25 mm x 5.0 mm	2.0 mm	FF01-580/14-25	$455
	580 nm	> 90% over 23 nm	25 mm x 3.5 mm	2.0 mm	FF01-580/23-25	$345
	582 nm	> 90% over 15 nm	25 mm x 3.5 mm	2.0 mm	FF01-582/15-25	$345
	582 nm	> 93% over 64 nm	25 mm x 3.5 mm	2.0 mm	FF01-582/64-25	$435
	582 nm	> 90% over 75 nm	25 mm x 5.0 mm	2.0 mm	FF01-582/75-25	$375
	583 nm	> 92% over 22 nm	25 mm x 3.5 mm	2.0 mm	FF01-583/22-25	$400
	585 nm	> 93% over 29 nm	25 mm x 5.0 mm	2.0 mm	FF01-585/29-25	$375
	585 nm	> 90% over 40 nm	25 mm x 3.5 mm	2.0 mm	FF01-585/40-25	$375
	586 nm	> 90% over 15 nm	25 mm x 5.0 mm	2.0 mm	FF02-586/15-25	$455
	586 nm	> 93% over 20 nm	25 mm x 3.5 mm	2.0 mm	FF01-586/20-25x3.5	$380
	586 nm	> 93% over 20 nm	25 mm x 5.0 mm	2.0 mm	FF01-586/20-25x5	$380
	587 nm	> 90% over 35 nm	25 mm x 5.0 mm	3.0 mm	FF01-587/35-25	$455
	589 nm	> 93% over 15 nm	25 mm x 5.0 mm	2.0 mm	FF01-589/15-25	$355
	589 nm	> 93% over 18 nm	25 mm x 3.5 mm	1.05 mm	FF01-589/18-25	$435
	590 nm	> 93% over 20 nm	25 mm x 5.0 mm	3.5 mm	FF01-590/20-25	$455
	590 nm	> 93% over 36 nm	25 mm x 3.5 mm	2.0 mm	FF01-590/36-25	$455
	591 nm	> 93% over 6 nm	25 mm x 5.0 mm	2.0 mm	FF01-591/6-25	$435
	592 nm	> 93% over 8 nm	25 mm x 5.0 mm	3.5 mm	FF01-592/8-25	$420
	593 nm	> 93% over 40 nm	25 mm x 3.5 mm	2.0 mm	FF01-593/40-25	$375
	593 nm	> 94% over 46 nm	25 mm x 3.5 mm	2.0 mm	FF01-593/46-25	$405
	595 nm	> 93% over 31 nm	25 mm x 3.5 mm	2.0 mm	FF01-595/31-25	$375
	598 nm	> 93% over 25 nm	25 mm x 3.5 mm	2.0 mm	FF01-598/25-25	$455
	600 nm	> 93% over 14 nm	25 mm x 5.0 mm	2.0 mm	FF01-600/14-25	$455

[1] Bandwidth is the minimum width over which the average transmission exceeds the specified passband transmission; see Technical Note on page 57.

(continued)

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BrightLine® Single-band Bandpass Filters

Color	Center Wavelength	Avg. Transmission and Bandwidth[1]	Housed Size (Diameter x Thickness)	Glass Thickness	Filter Part Number	Price
	600 nm	> 93% over 37 nm	25 mm x 3.5 mm	2.0 mm	FF01-600/37-25	$375
	600 nm	> 93% over 52 nm	25 mm x 3.5 mm	2.0 mm	FF01-600/52-25	$375
	605 nm	> 90% over 15 nm	25 mm x 3.5 mm	2.0 mm	FF01-605/15-25	$375
	605 nm	> 90% over 64 nm	25 mm x 3.5 mm	2.0 mm	FF01-605/64-25	$375
	607 nm	> 93% over 36 nm	25 mm x 3.5 mm	2.0 mm	FF01-607/36-25	$375
	607 nm	> 92% over 70 nm	25 mm x 3.5 mm	2.0 mm	FF01-607/70-25	$405
	609 nm	> 93% over 54 nm	25 mm x 3.5 mm	2.0 mm	FF01-609/54-25	$375
	609 nm	> 94% over 57 nm	25 mm x 3.5 mm	2.0 mm	FF01-609/57-25	$375
	609 nm	> 93% over 62 nm	25 mm x 3.5 mm	2.0 mm	FF01-609/62-25	$435
	609 nm	> 93% over 181 nm	25 mm x 3.5 mm	2.0 mm	FF01-609/181-25	$405
	612 nm	> 90% over 69 nm	25 mm x 3.5 mm	2.0 mm	FF01-612/69-25	$435
	615 nm	> 90% over 20 nm	25 mm x 5.0 mm	2.0 mm	FF02-615/20-25	$455
	615 nm	> 90% over 24 nm	25 mm x 3.5 mm	2.0 mm	FF01-615/24-25	$375
	615 nm	> 90% over 45 nm	25 mm x 3.5 mm	2.0 mm	FF01-615/45-25	$375
	617 nm	> 90% over 73 nm	25 mm x 5.0 mm	2.0 mm	FF02-617/73-25	$375
	618 nm	> 93% over 50 nm	25 mm x 5.0 mm	2.0 mm	FF01-618/50-25	$405
	620 nm	> 93% over 14 nm	25 mm x 5.0 mm	2.0 mm	FF01-620/14-25	$455
	620 nm	> 90% over 52 nm	25 mm x 3.5 mm	2.0 mm	FF01-620/52-25	$315
	623 nm	> 90% over 24 nm	25 mm x 5.0 mm	3.5 mm	FF01-623/24-25	$455
	623 nm	> 93% over 32 nm	25 mm x 3.5 mm	2.0 mm	FF01-623/32-25	$455
	624 nm	> 93% over 40 nm	25 mm x 3.5 mm	2.0 mm	FF01-624/40-25	$375
	625 nm	> 90% over 15 nm	25 mm x 3.5 mm	2.0 mm	FF01-625/15-25	$405
	625 nm	> 93% over 26 nm	25 mm x 5.0 mm	3.5 mm	FF01-625/26-25	$455
	625 mm	*See Multiphoton filters, page 45*			FF01-625/90-25	
	628 nm	> 93% over 32 nm	25 mm x 3.5 mm	2.0 mm	FF01-628/32-25	$375
	628 nm	> 93% over 40 nm	25 mm x 5.0 mm	2.0 mm	FF02-628/40-25	$375
	629 nm	> 90% over 56 nm	25 mm x 3.5 mm	2.0 mm	FF01-629/56-25	$345
	630 nm	> 90% over 20 nm	25 mm x 3.5 mm	2.0 mm	FF01-630/20-25	$375
	630 nm	> 90% over 38 nm	25 mm x 5.0 mm	2.0 mm	FF01-630/38-25	$315
	630 nm	> 90% over 69 nm	25 mm x 3.5 mm	2.0 mm	FF01-630/69-25	$315
	630 nm	> 92% over 92 nm	25 mm x 3.5 mm	2.0 mm	FF01-630/92-25	$405
	631 nm	> 90% over 36 nm	25 mm x 3.5 mm	1.05 mm	FF01-631/36-25	$435
	632 nm	> 93% over 22 nm	25 mm x 5.0 mm	2.0 mm	FF02-632/22-25	$375
	632 nm	*See VersaChrome Edge™ filters, page 82*			FF01-632/148-25	
	635 nm	> 93% over 18 nm	25 mm x 5.0 mm	2.0 mm	FF01-635/18-25	$375
	636 nm	> 90% over 8 nm	25 mm x 3.5 mm	2.0 mm	FF01-636/8-25	$405
	637 nm	> 93% over 7 nm	25 mm x 3.5 mm	2.0 mm	FF01-637/7-25	$405
	640 nm	*See Laser Diode Clean-Up filters, page 101*			LD01-640/8-25	
	640 nm	> 93% over 14 nm	25 mm x 5.0 mm	2.0 mm	FF01-640/14-25	$455
	640 nm	> 90% over 20 nm	25 mm x 3.5 mm	2.0 mm	FF01-640/20-25	$420
	640 nm	> 90% over 40 nm	25 mm x 5.0 mm	3.5 mm	FF01-640/40-25	$435
	641 nm	> 93% over 75 nm	25 mm x 3.5 mm	2.0 mm	FF02-641/75-25	$375
	642 nm	> 93% over 10 nm	25 mm x 5.0 mm	3.5 mm	FF01-642/10-25	$405
	647 nm	> 92% over 57 nm	25 mm x 3.5 mm	2.0 mm	FF01-647/57-25	$375
	650 nm	> 93% over 13 nm	25 mm x 5.0 mm	2.0 mm	FF01-650/13-25	$375

(continued)

[1] Bandwidth is the minimum width over which the average transmission exceeds the specified passband transmission; see Technical Note on page 57.

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BrightLine® Single-band Bandpass Filters

Color	Center Wavelength	Avg. Transmission and Bandwidth[1]	Housed Size (Diameter x Thickness)	Glass Thickness	Filter Part Number	Price
	650 nm	> 95% over 60 nm	25 mm x 3.5 mm	2.0 mm	FF01-650/60-25	$455
	650 nm	> 93% over 100 nm	25 mm x 5.0 mm	2.0 mm	FF02-650/100-25	$345
	650 nm	> 93% over 150 nm	25 mm x 5.0 mm	3.5 mm	FF01-650/150-25	$435
	655 nm	> 90% over 15 nm	25 mm x 3.5 mm	2.0 mm	FF01-655/15-25	$375
	655 nm	> 93% over 40 nm	25 mm x 5.0 mm	2.0 mm	FF02-655/40-25	$375
	660 nm	> 93% over 13 nm	25 mm x 5.0 mm	2.0 mm	FF01-660/13-25	$455
	660 nm	> 90% over 30 nm	25 mm x 3.5 mm	2.0 mm	FF01-660/30-25	$405
	660 nm	> 90% over 52 nm	25 mm x 3.5 mm	2.0 mm	FF01-660/52-25	$375
	661 nm	> 93% over 11 nm	25 mm x 3.5 mm	2.0 mm	FF01-661/11-25	$375
	661 nm	> 90% over 20 nm	25 mm x 5.0 mm	3.5 mm	FF01-661/20-25	$455
	662 nm	> 93% over 11 nm	25 mm x 3.5 mm	2.0 mm	FF01-662/11-25	$435
	665 nm	> 93% over 150 nm	25 mm x 3.5 mm	2.0 mm	FF01-665/150-25	$455
	670 nm	> 95% over 30 nm	25 mm x 3.5 mm	2.0 mm	FF01-670/30-25	$375
	673 nm	> 90% over 11 nm	25 mm x 3.5 mm	2.0 mm	FF01-673/11-25	$375
	675 nm	> 90% over 67 nm	25 mm x 5.0 mm	2.0 mm	FF02-675/67-25	$435
	676 nm	> 90% over 29 nm	25 mm x 3.5 mm	2.0 mm	FF01-676/29-25	$375
	676 nm	> 94% over 37 nm	25 mm x 3.5 mm	2.0 mm	FF01-676/37-25	$375
	679 nm	> 90% over 41 nm	25 mm x 3.5 mm	2.0 mm	FF01-679/41-25	$435
	680 nm	> 93% over 13 nm	25 mm x 5.0 mm	2.0 mm	FF01-680/13-25	$455
	680 nm	> 90% over 22 nm	25 mm x 5.0 mm	3.5 mm	FF01-680/22-25	$400
	680 nm	> 93% over 42 nm	25 mm x 3.5 mm	2.0 mm	FF01-680/42-25	$375
	681 nm	> 90% over 24 nm	25 mm x 3.5 mm	1.05 mm	FF01-681/24-25	$345
	684 nm	> 93% over 24 nm	25 mm x 5.0 mm	2.0 mm	FF02-684/24-25	$375
	685 nm	> 90% over 10 nm	25 mm x 5.0 mm	2.0 mm	FF01-685/10-25	$420
	685 nm	> 93% over 40 nm	25 mm x 5.0 mm	2.0 mm	FF02-685/40-25	$375
	690 nm	> 90% over 8 nm	25 mm x 3.5 mm	2.0 mm	FF01-690/8-25	$435
	692 nm	> 93% over 40 nm	25 mm x 3.5 mm	2.0 mm	FF01-692/40-25	$375
	694 nm	> 90% over 44 nm	25 mm x 3.5 mm	2.0 mm	FF01-694/44-25	$315
	697 nm	> 90% over 58 nm	25 mm x 3.5 mm	1.05 mm	FF01-697/58-25	$375
	698 nm	> 93% over 70 nm	25 mm x 3.5 mm	2.0 mm	FF01-698/70-25	$375
	700 nm	> 93% over 13 nm	25 mm x 5.0 mm	2.0 mm	FF01-700/13-25	$455
	708 nm	> 93% over 75 nm	25 mm x 5.0 mm	2.0 mm	FF01-708/75-25	$375
	709 nm	*See VersaChrome Edge™ filters, page 82*			FF01-709/167-25	
	710 nm	> 93% over 40 nm	25 mm x 5.0 mm	3.5 mm	FF01-710/40-25	$375
	711 nm	> 90% over 25 nm	25 mm x 5.0 mm	3.5 mm	FF01-711/25-25	$525
	716 nm	> 93% over 40 nm	25 mm x 3.5 mm	2.0 mm	FF01-716/40-25	$375
	719 nm	> 93% over 60 nm	25 mm x 3.5 mm	2.0 mm	FF01-719/60-25	$375
	720 nm	> 93% over 13 nm	25 mm x 5.0 mm	2.0 mm	FF01-720/13-25	$455
	720 nm	> 90% over 24 nm	25 mm x 3.5 mm	2.0 mm	FF01-720/24-25	$405
	725 nm	> 93% over 40 nm	25 mm x 5.0 mm	3.5 mm	FF01-725/40-25	$375
	730 nm	> 93% over 39 nm	25 mm x 3.5 mm	2.0 mm	FF01-730/39-25	$455
	731 nm	> 90% over 137 nm	25 mm x 3.5 mm	1.05 mm	FF01-731/137-25	$455
	732 nm	> 90% over 68 nm	25 mm x 3.5 mm	2.0 mm	FF01-732/68-25	$455
	735 nm	> 93% over 28 nm	25 mm x 5.0 mm	2.0 mm	FF01-735/28-25	$375
	740 nm	> 93% over 13 nm	25 mm x 5.0 mm	2.0 mm	FF01-740/13-25	$455

[1] Bandwidth is the minimum width over which the average transmission exceeds the specified passband transmission; see Technical Note on page 57.

(continued)

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BrightLine® Single-band Bandpass Filters

Color	Center Wavelength	Avg. Transmission and Bandwidth[1]	Housed Size (Diameter x Thickness)	Glass Thickness	Filter Part Number	Price
	747 nm	> 93% over 33 nm	25 mm x 5.0 mm	2.0 mm	FF01-747/33-25	$375
	755 nm	> 93% over 35 nm	25 mm x 5.0 mm	3.5 mm	FF01-755/35-25	$425
	760 nm	> 93% over 12 nm	25 mm x 5.0 mm	2.0 mm	FF01-760/12-25	$455
	766 nm	> 90% over 13 nm	25 mm x 3.5 mm	2.0 mm	FF01-766/13-25	$425
	769 nm	> 93% over 41 nm	25 mm x 5.0 mm	2.0 mm	FF01-769/41-25	$375
	775 nm	> 93% over 46 nm	25 mm x 3.5 mm	2.0 mm	FF01-775/46-25	$405
	775 nm	> 90% over 140 nm	25 mm x 3.5 mm	2.0 mm	FF01-775/140-25	$455
	780 nm	> 93% over 12 nm	25 mm x 5.0 mm	2.0 mm	FF01-780/12-25	$455
	785 mm	*See Laser Diode Clean-Up filters, page 101*			LD01-785/10-25	
	785 nm	> 94% over 62 nm	25 mm x 3.5 mm	2.0 mm	FF01-785/62-25	$435
	786 nm	> 93% over 22 nm	25 mm x 3.5 mm	2.0 mm	FF01-786/22-25	$375
	792 nm	> 93% over 64 nm	25 mm x 3.5 mm	2.0 mm	FF01-792/64-25	$525
	794 nm	> 90% over 32 nm	25 mm x 3.5 mm	2.0 mm	FF01-794/32-25	$455
	794 nm	> 93% over 160 nm	25 mm x 5.0 mm	2.0 mm	FF01-794/160-25	$375
	795 nm	> 93% over 150 nm	25 mm x 3.5 mm	2.0 mm	FF01-795/150-25	$425
	795 nm	*See VersaChrome Edge™ filters, page 82*			FF01-795/188-25	
	800 nm	> 93% over 12 nm	25 mm x 5.0 mm	2.0 mm	FF01-800/12-25	$455
	809 nm	> 93% over 81 nm	25 mm x 3.5 mm	2.0 mm	FF02-809/81-25	$375
	810 nm	> 90% over 10 nm	25 mm x 3.5 mm	2.0 mm	FF01-810/10-25	$455
	819 nm	> 90% over 44 nm	25 mm x 3.5 mm	2.0 mm	FF01-819/44-25	$435
	820 nm	> 93% over 12 nm	25 mm x 5.0 mm	2.0 mm	FF01-820/12-25	$475
	832 nm	> 93% over 37 nm	25 mm x 3.5 mm	2.0 mm	FF01-832/37-25	$405
	835 nm	> 93% over 70 nm	25 mm x 3.5 mm	2.0 mm	FF01-835/70-25	$455
	840 nm	> 93% over 12 nm	25 mm x 5.0 mm	2.0 mm	FF01-840/12-25	$455
	842 nm	> 90% over 56 nm	25 mm x 3.5 mm	2.0 mm	FF01-842/56-25	$455
	850 nm	> 90% over 10 nm	25 mm x 3.5 mm	2.0 mm	FF01-850/10-25	$475
	850 nm	*See Multiphoton filters, page 45*			FF01-850/310-25	
	857 nm	> 90% over 30 nm	25 mm x 3.5 mm	1.05 mm	FF01-857/30-25	$435
	860 nm	> 93% over 11 nm	25 mm x 5.0 mm	2.0 mm	FF01-860/11-25	$475
	880 nm	> 93% over 11 nm	25 mm x 5.0 mm	2.0 mm	FF01-880/11-25	$475
	893 nm	*See VersaChrome Edge™ filters, page 82*			FF01-893/209-25	
	900 nm	> 93% over 11 nm	25 mm x 5.0 mm	2.0 mm	FF01-900/11-25	$475
	900 nm	> 90% over 32 nm	25 mm x 3.5 mm	2.0 mm	FF01-900/32-25	$455
	920 nm	> 93% over 10 nm	25 mm x 5.0 mm	2.0 mm	FF01-920/10-25	$475
	935 nm	> 93% over 170 nm	25 mm x 3.5 mm	2.0 mm	FF01-935/170-25	$525
	940 nm	> 90% over 10 nm	25 mm x 3.5 mm	2.0 mm	FF01-940/10-25	$525
	975 nm	*See Laser Diode Clean-Up filters, page 101*			LD01-975/10-25	
	1001 nm	*See VersaChrome Edge™ filters, page 82*			FF01-1001/234-25	
	1055 nm	> 93% over 70 nm	25 mm x 3.5 mm	2.0 mm	FF01-1055/70-25	$525
	1064 nm	> 90% over 5 nm	25 mm x 3.5 mm	2.0 mm	FF01-1064/5-25	$455
	1074 nm	> 90% over 14 nm	25 mm x 3.5 mm	2.0 mm	FF01-1072/14-25	$525
	1535 nm	*See Near-IR Bandpass filters, page 102*			NIR01-1535/3-25	
	1538 nm	> 93% over 82 nm	25 mm x 5.0 mm	3.0 mm	FF01-1538/82-25	$525
	1550 nm	*See Near-IR bandpass filters, page 102*			NIR01-1550/3-25	
	1570 nm	*See Near-IR bandpass filters, page 102*			NIR01-1570/3-25	

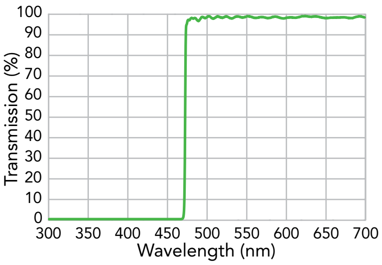
(continued)

[1] Bandwidth is the minimum width over which the average transmission exceeds the specified passband transmission; see Technical Note on page 57.

For graphs, ASCII data and blocking information, go to www.idex-hs.com/semrock

BrightLine® Long / Short pass Single-edge Filters

Actual Measured Data
FF01-519/LP-25



Semrock stocks an exceptional range of high-performance, high-reliability individual fluorescence edge filters that have been optimized for use in a variety of fluorescence instruments. These filters exclusively utilize our patented single-substrate construction for the highest performance and reliability. For additional offerings, see EdgeBasic™ long-wave-pass and short-wave-pass filters, page 82.

Unless otherwise noted, all filters are housed in a standard 25 mm round black-anodized aluminum ring with thickness as indicated, and a clear aperture of at least 21 mm. Parts with a "/LP" in the part number are long-wave-pass edge filters and parts with a "/SP" are short-wave-pass edge filters.

Edge Color	Edge Wavelength	Avg. Transmission / Passband	Housed Size (Diameter x Thickness)	Glass Thickness	Filter Part Number	Price
	274 nm	> 85% 277 – 358 nm	25 mm x 3.5 mm	2.0 mm	FF01-267/LP-25	$530
	280 nm	> 75% 282 – 560 nm	25 mm x 3.5 mm	1.05 mm	FF01-272/LP-25	$530
	272 nm	> 35% 245 – 270 nm	25 mm x 3.5 mm	2.0 mm	FF01-276/SP-25	$560
	294 nm	> 70% 255 – 290 nm	25 mm x 3.5 mm	1.05 mm	FF01-300/SP-25	$530
	306 nm	> 85% 308 – 420 nm	25 mm x 5.0 mm	2.0 mm	FF01-300/LP-25	$405
	304 nm	> 70% 250 – 300 nm	25 mm x 3.5 mm	2.0 mm	FF01-311/SP-25	$455
	347 nm	> 90% 350 – 500 nm	25 mm x 3.5 mm	2.0 mm	FF01-341/LP-25	$455
	378 nm	> 70% 320 – 370 nm	25 mm x 3.5 mm	2.0 mm	FF01-390/SP-25	$530
	388 nm	> 93% 390 – 930 nm	25 mm x 3.5 mm	2.0 mm	FF01-380/LP-25	$455
	415 nm	> 93% 417 – 1100 nm	25 mm x 3.5 mm	2.0 mm	FF02-409/LP-25	$375
	421 nm	> 90% 350 – 419 nm	25 mm x 5.0 mm	3.5 mm	FF01-424/SP-25	$455
	437 nm	> 90% 439 – 900 nm	25 mm x 3.5 mm	2.0 mm	FF01-430/LP-25	$455
	430 nm	> 93% 380 – 427 nm	25 mm x 5.0 mm	3.5 mm	FF01-440/SP-25	$455
	460 nm	> 93% 350 – 458 nm	25 mm x 3.5 mm	2.0 mm	FF01-468/SP-25	$455
	483 nm	> 90% 400 – 480 nm	25 mm x 5.0 mm	3.0 mm	FF01-492/SP-25	$455
	492 nm	> 93% 400 – 490 nm	25 mm x 3.5 mm	2.0 mm	FF01-498/SP-25	$455
	501 nm	> 93% 503 – 1100 nm	25 mm x 3.5 mm	2.0 mm	FF01-496/LP-25	$375
	515 nm	> 90% 519 – 700 nm	25 mm x 3.5 mm	2.0 mm	FF01-500/LP-25	$330
	522 nm	> 90% 525 – 800 nm	25 mm x 3.5 mm	2.0 mm	FF01-515/LP-25	$375
	530 nm	> 92% 534 – 653 nm	25 mm x 3.5 mm	2.0 mm	FF01-519/LP-25	$405
	522 nm	> 90% 380 – 520 nm	25 mm x 3.5 mm	2.0 mm	FF01-533/SP-25	$405
	541 nm	> 93% 400 – 538 nm	25 mm x 3.5 mm	1.05 mm	FF01-546/SP-25	$375
	601 nm	> 93% 604 – 1100 nm	25 mm x 3.5 mm	2.0 mm	FF01-593/LP-25	$375
	638 nm	> 85% 360 – 634 nm	25 mm x 3.5 mm	1.05 mm	FF01-650/SP-25	$455
	654 nm	*See Multiphoton filters, page 44*			FF01-680/SP-25	
	690 nm	> 93% 697 – 900 nm	25 mm x 3.5 mm	2.0 mm	FF01-685/LP-25	$405
	681 nm	> 93% 400 – 678 nm	25 mm x 3.5 mm	2.0 mm	FF02-694/SP-25	$455
	723 nm	> 93% 725 – 1200 nm	25 mm x 3.5 mm	2.0 mm	FF01-715/LP-25	$455
	706 nm	> 93% 450 – 700 nm	25 mm x 3.5 mm	2.0 mm	FF01-715/SP-25	$455
	696 nm	*See Multiphoton filters, page 44*			FF01-720/SP-25	
	754 nm	> 90% 761 – 850 nm	25 mm x 3.5 mm	2.0 mm	FF01-736/LP-25	$405
	729 nm	> 93% 392 – 725 nm	25 mm x 3.5 mm	1.05 mm	FF01-745/SP-25	$455
	727 nm	*See Multiphoton filters, page 44*			FF01-750/SP-25	
	748 nm	> 93% 550 – 745.5 nm	25 mm x 3.5 mm	2.0 mm	FF01-758/SP-25	$405
	715 nm	> 90% 425 – 675 nm	25 mm x 3.5 mm	1.05 mm	FF01-760/SP-25	$405

(continued)

BrightLine® Long / Short pass Single-edge Filters

Edge Color	Edge Wavelength	Avg. Transmission / Passband	Housed Size (Diameter x Thickness)	Glass Thickness	Filter Part Number	Price
	747 nm	*See Multiphoton filters, page 44*			FF01-770/SP-25	
	761 nm	> 93% 481 – 756 nm	25 mm x 3.5 mm	2.0 mm	FF01-775/SP-25	$455
	785 nm	> 93% 789 – 1200 nm	25 mm x 3.5 mm	2.0 mm	FF01-776/LP-25	$375
	765 nm	*See Multiphoton filters, page 44*			FF01-790/SP-25	
	835 nm	> 95% 485 – 831 nm	25 mm x 3.5 mm	2.0 mm	FF01-842/SP-25	$455
	875 nm	*See Multiphoton filters, page 44*			FF01-890/SP-25	
	910 nm	*See Multiphoton filters, page 44*			FF01-940/SP-25	
	938 nm	> 90% 600 – 935 nm	25 mm x 3.5 mm	2.0 mm	FF01-945/SP-25	$455
	912 nm	> 90% 430 – 908 nm	25 mm x 3.5 mm	2.0 mm	FF01-950/SP-25	$455
	1002 nm	> 90% 400 – 1000 nm	25 mm x 3.5 mm	2.0 mm	FF01-1010/SP-25	$405
	1304 nm	> 93% 800 – 1290 nm	25 mm x 3.5 mm	2.0 mm	FF01-1326/SP-25	$1065
	1550 nm	> 93% 1560 – 2000 nm	25 mm x 3.5 mm	2.0 mm	FF01-1535/LP-25	$530

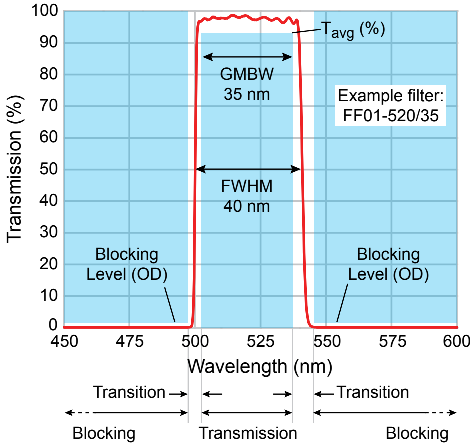
TECHNICAL NOTE

What Does "Bandwidth" Mean?

Semrock uses a "manufacturable specification" approach to define the bandwidth of our BrightLine bandpass filters. We believe this approach more accurately reflects the performance of the filter in an optical system.

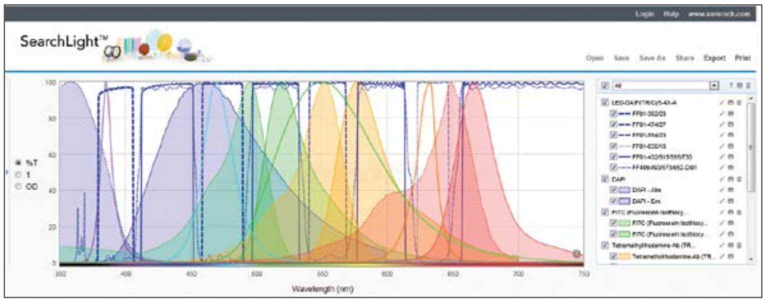
As shown in the diagram, the filter spectrum (red line) must lie within the unshaded regions. The average transmission must exceed the specification T_{avg} (%) in the Transmission Region, which has a certain center wavelength (CWL) and a width called the Guaranteed Minimum Bandwidth (GMBW). The filter part number has the form FF01-{CWL}/{GMBW}.

The transmission must lie below the blocking level specifications (OD) in the Blocking Regions. The precise shape of the spectrum is unspecified in the Transition regions. However, typically the filter passband has a Full Width at Half Maximum (FWHM) that is about 1% of the CWL wider than the GMBW bandwidth, or FWHM ~ GMBW + 0.01 x CWL. So, for the example shown in the diagram, the FF01-520/35 filter has a GMBW of 35 nm and a FWHM of 35 nm + 1% of 520 nm, or 40 nm.



SEARCHLIGHT

SearchLight allows fluorescence microscope users and optical instrument designers to predetermine the optimal fluorophore, light source, detector, and optical filter combinations for their microscope or system. By removing the guesswork and hours of searching multiple sources for spectral data, SearchLight users will be able to eliminate trial-and-error headaches and work more efficiently. Users may select from an extensive collection of preloaded spectra or upload their own spectral data in this free and openly accessible tool. Users can also save and share their data securely.



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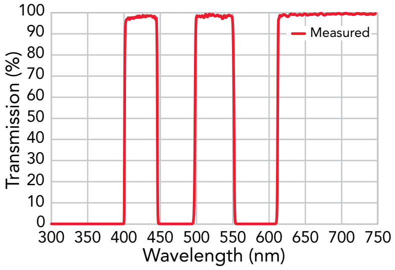
BrightLine® Multiband Bandpass Filters

Actual Measured Data
FF01-425/527/685-25



Semrock offers a unique selection of individual high-performance multiband fluorescence bandpass filters that have been optimized for use in a variety of fluorescence instruments. These filters all utilize our exclusively single-substrate, low-autofluorescence glass construction. All filters are housed in a standard 25 mm round black-anodized aluminum ring with thickness as indicated, and have a clear aperture of at least 21 mm. These filters have extremely high transmission, steep and well-defined edges, and outstanding blocking between the passbands.

Center Wavelength	Avg. Transmission / Bandwidth[1]	Housed Size (Diameter x Thickness)	Glass Thickness	Filter Part Number	Price
Dual-band Filters					
387 nm 480 nm	> 80% over 11 nm > 90% over 29 nm	25 mm x 5.0 mm	2.0 mm	FF01-387/480-25	$490
416 nm 501 nm	> 90% over 25 nm > 90% over 18 nm	25 mm x 5.0 mm	3.5 mm	FF01-416/501-25	$490
433 nm 530 nm	> 90% over 38 nm > 90% over 40 nm	25 mm x 3.5 mm	2.0 mm	FF01-433/530-25	$490
449 nm 520 nm	> 90% over 20 nm > 90% over 20 nm	25 mm x 5.0 mm	2.0 mm	FF01-449/520-25	$530
468 nm 553 nm	> 90% over 34 nm > 90% over 24 nm	25 mm x 5.0 mm	3.5 mm	FF01-468/553-25	$490
479 nm 585 nm	> 90% over 38 nm > 90% over 27 nm	25 mm x 5.0 mm	3.5 mm	FF01-479/585-25	$490
482 nm 563.5 nm	> 93% over 18 nm > 93% over 9 nm	25 mm x 5.0 mm	2.0 mm	FF01-482/563-25	$490
484 nm 561 nm	> 90% over 22 nm > 90% over 30 nm	25 mm x 3.5 mm	2.0 mm	FF01-484/561-25	$530
512 nm 630 nm	> 90% over 23 nm > 90% over 91 nm	25 mm x 3.5 mm	2.0 mm	FF01-512/630-25	$490
523 nm 610 nm	> 93% over 40 nm > 93% over 52 nm	25 mm x 3.5 mm	2.0 mm	FF01-523/610-25	$490
524 nm 628 nm	> 90% over 29 nm > 90% over 33 nm	25 mm x 3.5 mm	2.0 mm	FF01-524/628-25	$490
527 nm 645 nm	> 90% over 42 nm > 90% over 49 nm	25 mm x 3.5 mm	2.0 mm	FF01-527/645-25	$490
534 nm 635 nm	> 90% over 36 nm > 90% over 31 nm	25 mm x 5.0 mm	3.5 mm	FF01-534/635-25	$490
577 nm 690 nm	> 90% over 24 nm > 90% over 50 nm	25 mm x 3.5 mm	2.0 mm	FF01-577/690-25	$490

[1] Bandwidth is the minimum width over which the average transmission exceeds the specified passband transmission; see Technical Note on page 57.

(continued)

Using a Sutter Filter Wheel?

All Semrock "Pinkel" and "Sedat" sets are now available with Sutter threaded rings compatible with Sutter filter wheels. The threaded ring replaces the standard filter housing and also the cup/retaining ring system in the filter wheel. The result is reduced weight for maximum filter wheel speed. See our website for particular Sutter set part numbers when ordering: www.idex-hs.com/sutter-threaded-rings

BrightLine® Multiband Bandpass Filters

Center Wavelength	Avg. Transmission / Bandwidth[1]	Housed Size (Diameter x Thickness)	Glass Thickness	Filter Part Number	Price
Triple-band Filters					
378 nm 474 nm 575 nm	> 85% over 52 nm > 93% over 26.5 nm > 93% over 25 nm	25 mm x 5.0 mm	2.0 mm	FF01-378/474/575-25	$530
387.5 nm 478 nm 555.5 nm	> 80% over 11 nm > 90% over 24 nm > 90% over 19 nm	25 mm x 5.0 mm	2.0 mm	FF01-387/478/555-25	$530
390 nm 482 nm 587 nm	> 85% over 40 nm > 93% over 18 nm > 93% over 15 nm	25 mm x 5.0 mm	2.0 mm	FF01-390/482/587-25	$530
407 nm 494 nm 576 nm	> 80% over 14 nm > 85% over 20 nm > 85% over 20 nm	25 mm x 5.0 mm	2.0 mm	FF01-407/494/576-25	$530
422 nm 503 nm 572 nm	> 90% over 30 nm > 90% over 18 nm > 90% over 18 nm	25 mm x 5.0 mm	2.0 mm	FF01-422/503/572-25	$530
432 nm 523 nm 702 nm	> 93% over 36 nm > 93% over 46 nm > 93% over 196 nm	25 mm x 3.5 mm	2.0 mm	FF01-432/523/702-25	$530
432 nm 516.5 nm 614.5 nm	> 90% over 36 nm > 90% over 23 nm > 90% over 61 nm	25 mm x 3.5 mm	2.0 mm	FF01-433/517/613-25	$530
438 nm 509 nm 578 nm	> 93% over 24 nm > 93% over 21.9 nm > 93% over 21.2 nm	25 mm x 5.0 mm	2.0 mm	FF01-438/509/578-25	$530
446 nm 532 nm 646 nm	> 93% over 32.5 nm > 93% over 58.5 nm > 93% over 68 nm	25 mm x 3.5 mm	2.0 mm	FF01-446/532/646-25	$530
457 nm 530 nm 628 nm	> 80% over 22 nm > 85% over 20 nm > 85% over 28 nm	25 mm x 3.5 mm	2.0 mm	FF01-457/530/628-25	$530
465 nm 537 nm 623 nm	> 90% over 30 nm > 90% over 20 nm > 90% over 50 nm	25 mm x 3.5 mm	2.0 mm	FF01-465/537/623-25	$530
475 nm 543 nm 702 nm	> 93% over 22 nm > 93% over 22 nm > 93% over 197 nm	25 mm x 3.5 mm	2.0 mm	FF01-475/543/702-25	$530
515 nm 588 nm 700 nm	> 93% over 23 nm > 93% over 55.5 nm > 93% over 70 nm	25 mm x 3.5 mm	2.0 mm	FF01-515/588/700-25	$530
Quad-band Filters					
378 nm 474 nm 554 nm 635 nm	> 85% over 52 nm > 93% over 26.5 nm > 93% over 23 nm > 93% over 18 nm	25 mm x 5.0 mm	2.0 mm	FF01-378/474/554/635-25	$640
387 nm 485 nm 559.5 nm 649.5 nm	> 85% over 11 nm > 90% over 20 nm > 90% over 25 nm > 90% over 13 nm	25 mm x 5.0 mm	2.0 mm	FF01-387/485/559/649-25	$640

[1] Bandwidth is the minimum width over which the average transmission exceeds the specified passband transmission; see Technical Note on page 57.

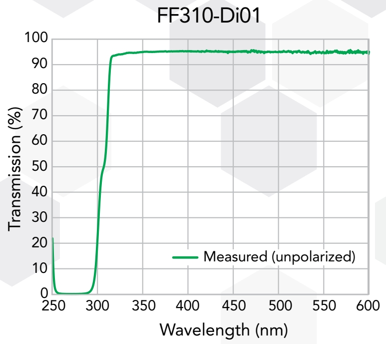
(continued)

BrightLine® Multiband Bandpass Filters

Center Wavelength	Avg. Transmission / Bandwidth[1]	Housed Size (Diameter x Thickness)	Glass Thickness	Filter Part Number	Price
Quad-band Filters					
390 nm 482 nm 532 nm 640 nm	> 85% over 40 nm > 90% over 18 nm > 90% over 3 nm > 90% over 14 nm	25 mm x 5.0 mm	2.0 mm	FF01-390/482/532/640-25	$640
390 nm 482 nm 563.5 nm 640 nm	> 85% over 40 nm > 90% over 18 nm > 90% over 9 nm > 90% over 14 nm	25 mm x 5.0 mm	2.0 mm	FF01-390/482/563/640-25	$640
432 nm 515 nm 595 nm 730 nm	> 85% over 36 nm > 93% over 30 nm > 93% over 31 nm > 93% over 139 nm	25 mm x 3.5 mm	2.0 mm	FF01-432/515/595/730-25	$640
440 nm 521 nm 607 nm 700 nm	> 90% over 40 nm > 90% over 21 nm > 90% over 34 nm > 90% over 45 nm	25 mm x 3.5 mm	2.0 mm	FF01-440/521/607/700-25	$640
446.8 nm 510.5 nm 581.5 nm 703 nm	> 93% over 32.5 nm > 93% over 16 nm > 93% over 63 nm > 93% over 80 nm	25 mm x 3.5 mm	2.0 mm	FF01-446/510/581/703-25	$640
446 nm 523 nm 600 nm 677 nm	> 90% over 32.5 nm > 90% over 42 nm > 90% over 35.5 nm > 90% over 27.5 nm	25 mm x 3.5 mm	2.0 mm	FF01-446/523/600/677-25	$640
Penta-band Filter					
378 nm 474 nm 554 nm 635 nm 735 nm	> 85% over 52 nm > 90% over 26.5 nm > 90% over 23 nm > 90% over 18 nm > 90% over 28 nm	25 mm x 5.0 mm	3.5 mm	FF01-378/474/554/635/735-25	$745
391 nm 477 nm 549 nm 638.5 nm 741 nm	> 85% over 44 nm > 90% over 12 nm > 90% over 16 nm > 90% over 17 nm > 90% over 32 nm	25 mm x 5.0 mm	3.5 mm	FF01-391/477/549/639/741-25	$855
432 nm 515 nm 595 nm 681 nm 809 nm	> 93% over 36 nm > 93% over 30.5 nm > 93% over 31 nm > 93% over 40 nm > 93% over 81 nm	25 mm x 3.5 mm	2.0 mm	FF01-432/515/595/681/809-25	$745
440 nm 520.5 nm 606.5 nm 694.5 nm 809 nm	> 90% over 40 nm > 90% over 21 nm > 90% over 34 nm > 90% over 34.5 nm > 90% over 81 nm	25 mm x 3.5 mm	2.0 mm	FF01-440/521/607/694/809-25	$745
441 nm 511 nm 592.5 nm 684 nm 817 nm	> 85% over 30 nm > 90% over 26 nm > 90% over 37 nm > 90% over 34 nm > 90% over 66 nm	25 mm x 3.5 mm	2.0 mm	FF01-441/511/593/684/817-25	$855
Eleven-band Filter					
376 nm 384 nm 394 nm 404 nm 412.2 nm 423.6 nm 434.7 nm 443.6 nm 455 nm 468 nm 478 nm	> 80% @ 376 nm > 80% @ 384 nm > 80% @ 394 nm > 80% @ 404 nm > 90% @ 412.2 nm > 90% @ 423.6 nm > 90% @ 434.7 nm > 90% @ 443.6 nm > 90% @ 455 nm > 90% @ 468 nm > 90% @ 478 nm	25 mm x 5.0 mm	3.5 mm	FF01-CH2O-25	$1125

[1] Bandwidth is the minimum width over which the average transmission exceeds the specified passband transmission; see Technical Note on page 57.

BrightLine® Single-edge Dichroic Beamsplitters



Single-edge General Purpose Dichroic Beamsplitters

(polarization-insensitive; for use at 45°)

Most beamsplitters are long-wave-pass (LWP) filters (reflect shorter wavelengths and transmit longer wavelengths).

Semrock offers a wide range of polarization-insensitive dichroic beamsplitters that exhibit steep edges with very high and flat reflection and transmission bands. More complete reflection and transmission mean less stray light for lower background and improved signal-to-noise ratio. These filters are optimized for fluorescence microscopes and instrumentation, and may also be used for a variety of other applications that require beam combining and separation based on wavelength. All Semrock filters are made with our reliable hard-coating technology and utilize high-optical-quality, ultralow-autofluorescence glass substrates. These filters are excellent for epifluorescence, flow cytometry, and diverse fluorescence imaging applications.

Color	Nominal Edge Wavelength	Avg. Reflection Band	Avg. Transmission Band	Size (L x W)	Glass Thickness	Filter Part Number	Price
	310 nm	> 98% 255 – 295 nm	> 90% 315 – 600 nm	25.2 x 35.6 mm	1.05 mm	FF310-Di01-25x36	$525
	347 nm	> 97% 240 – 325 nm	> 93% 380 – 800 nm	25.2 x 35.6 mm	1.05 mm	FF347-Di01-25x36	$525
	365 nm	> 94% 230 – 360 nm	> 90% 370 – 508 nm	25.2 x 35.6 mm	1.05 mm	FF365-Di01-25x36	$525
	376 nm	> 98% 327 – 371 nm	> 93% 381 – 950 nm	25.2 x 35.6 mm	1.05 mm	FF376-Di01-25x36	$305
	390 nm	> 95% 335 – 375 nm	> 90% 399 – 500 nm	25.2 x 35.6 mm	1.05 mm	FF390-Di01-25x36	$380
	409 nm	> 98% 327 – 404 nm	> 93% 415 – 950 nm	25.2 x 35.6 mm	1.05 mm	FF409-Di03-25x36	$305
	414 nm	> 98% 327 – 409 nm	> 93% 420 – 950 nm	25.2 x 35.6 mm	1.05 mm	FF414-Di01-25x36	$305
	416 nm	> 90% 360 – 407 nm	> 90% 425 – 575 nm	25.2 x 35.6 mm	1.05 mm	FF416-Di01-25x36	$305
	435 nm	> 98% 394 – 406 nm	> 90% 449 – 687 nm	25.2 x 35.6 mm	1.05 mm	FF435-Di01-25x36	$305
	452 nm	> 90% 423 – 445 nm	> 90% 460 – 610 nm	25.2 x 35.6 mm	1.05 mm	FF452-Di01-25x36	$285
	458 nm	> 98% 350 – 450 nm	> 93% 467 – 950 nm	25.2 x 35.6 mm	1.05 mm	FF458-Di02-25x36	$305
	470 nm	> 98% 350 – 462.5 nm	> 93% 477 – 950 nm	25.2 x 35.6 mm	1.05 mm	FF470-Di01-25x36	$305
	482 nm	> 90% 415 – 470 nm	> 90% 490 – 720 nm	25.2 x 35.6 mm	1.05 mm	FF482-Di01-25x36	$285
	495 nm	> 98% 350 – 488 nm	> 93% 502 – 950 nm	25.2 x 35.6 mm	1.05 mm	FF495-Di03-25x36	$305
	496 nm	> 98% 512 – 900 nm	> 93% 400 – 480 nm	25.2 x 35.6 mm	2.0 mm	FF496-SDi01-25x36x2.0	$380
	497 nm	> 90% 452 – 490 nm	> 90% 505 – 800 nm	25.2 x 35.6 mm	1.05 mm	FF497-Di01-25x36	$285
	499 nm	> 90% 470 – 490 nm	> 90% 508 – 675 nm	25.2 x 35.6 mm	1.05 mm	FF499-Di01-25x36	$315
	500 nm	> 98% 485 – 491 nm	> 90% 510 – 825 nm	25.2 x 35.6 mm	1.05 mm	FF500-Di01-25x36	$380
	505 nm	> 98% 513 – 725 nm	> 90% 446 – 500 nm	25.2 x 35.6 mm	1.05 mm	FF505-SDi01-25x36	$380
	506 nm	> 98% 350 – 500 nm	> 93% 513 – 950 nm	25.2 x 35.6 mm	1.05 mm	FF506-Di03-25x36	$305
	509 nm	> 94% 230 – 502 nm	> 90% 513 – 830 nm	25.2 x 35.6 mm	1.05 mm	FF509-Di01-25x36	$525
	510 nm	> 98% 327 – 488 nm	> 93% 515 – 950 nm	25.2 x 35.6 mm	1.05 mm	FF510-Di02-25x36	$380
	516 nm	> 90% 490 – 510 nm	> 90% 520 – 700 nm	25.2 x 35.6 mm	1.05 mm	FF516-Di01-25x36	$285
	518 nm	> 98% 400 – 512 nm	> 93% 523 – 690 nm	25.2 x 35.6 mm	1.05 mm	FF518-Di01-25x36	$305
	520 nm	> 98% 350 – 512 nm	> 93% 528 – 950 nm	25.2 x 35.6 mm	1.05 mm	FF520-Di02-25x36	$305
	526 nm	> 98% 350 – 519.5 nm	> 93% 532 – 950 nm	25.2 x 35.6 mm	1.05 mm	FF526-Di01-25x36	$380
	535 nm	> 90% 539 – 840 nm	> 95% 524 – 532 nm	25.2 x 35.6 mm	1.05 mm	FF535-SDi01-25x36	$380
	552 nm	> 98% 350 – 544 nm	> 93% 558 – 950 nm	25.2 x 35.6 mm	1.05 mm	FF552-Di02-25x36	$305
	555 nm	> 98% 493 – 548 nm	> 90% 562 – 745 nm	25.2 x 35.6 mm	1.05 mm	FF555-Di03-25x36	$305
	556 nm	> 97% 561 – 950 nm	> 93% 480 – 552 nm	25.2 x 35.6 mm	1.05 mm	FF556-SDi01-25x36	$380
	560 nm	> 98% 485 – 545 nm	> 90% 570 – 825 nm	25.2 x 35.6 mm	1.05 mm	FF560-Di01-25x36	$380
	562 nm	> 98% 350 – 555 nm	> 93% 569 – 950 nm	25.2 x 35.6 mm	1.05 mm	FF562-Di03-25x36	$305
	570 nm	> 90% 525 – 556 nm	> 90% 580 – 650 nm	25.2 x 35.6 mm	1.05 mm	FF570-Di01-25x36	$285
	573 nm	> 98% 350 – 566 nm	> 93% 580 – 950 nm	25.2 x 35.6 mm	1.05 mm	FF573-Di01-25x36	$305
	585 nm	> 90% 533 – 580 nm	> 90% 595 – 800 nm	25.2 x 35.6 mm	1.05 mm	FF585-Di01-25x36	$285
	593 nm	> 98% 350 – 585 nm	> 93% 601 – 950 nm	25.2 x 35.6 mm	1.05 mm	FF593-Di03-25x36	$305
	596 nm	> 98% 350 – 588.6 nm	> 93% 603 – 950 nm	25.2 x 35.6 mm	1.05 mm	FF596-Di01-25x36	$380
	605 nm	> 98% 350 – 596 nm	> 93% 612 – 950 nm	25.2 x 35.6 mm	1.05 mm	FF605-Di02-25x36	$305

(continued)

BrightLine® Single-edge Dichroic Beamsplitters

Color	Nominal Edge Wavelength	Avg. Reflection Band	Avg. Transmission Band	Size (L x W)	Glass Thickness	Filter Part Number	Price
	614 nm	> 97% 635 – 700 nm	> 70% 244 – 300 nm > 90% 300 – 594 nm	25.2 x 35.6 mm	2.0 mm	FF614-SDi01-25x36x2.0	$525
	624 nm	> 95% 528 – 610 nm	> 93% 630 – 750 nm	25.2 x 35.6 mm	2.0 mm	FF624-Di01-25x36x2.0	$380
	625 nm	> 98% 635 – 850 nm	> 90% 400 – 620 nm	25.2 x 35.6 mm	1.05 mm	FF625-SDi01-25x36	$380
	635 nm	> 94% 507 – 622 nm	> 90% 636 – 830 nm	25.2 x 35.6 mm	1.05 mm	FF635-Di01-25x36	$380
	647 nm	> 94% 667 – 1010 nm	> 93% 360 – 640 nm	25.2 x 35.6 mm	1.05 mm	FF647-SDi01-25x36	$380
	648 nm	> 98% 400 – 629 nm	> 90% 658 – 700 nm	25.2 x 35.6 mm	1.05 mm	FF648-Di01-25x36	$380
	649 nm	> 98% 500 – 642 nm	> 90% 654 – 825 nm	25.2 x 35.6 mm	1.05 mm	FF649-Di01-25x36	$380
	650 nm	> 98% 500 – 640 nm	> 90% 660 – 825 nm	25.2 x 35.6 mm	1.05 mm	FF650-Di01-25x36	$380
	652 nm	> 98% 350 – 644 nm	> 93% 659.5 – 950 nm	25.2 x 35.6 mm	1.05 mm	FF652-Di01-25x36	$380
	654 nm	> 95% 660 – 850 nm	> 93% 490 – 650 nm	25.2 x 35.6 mm	1.05 mm	FF654-SDi01-25x36	$380
	655 nm	> 98% 470 – 645 nm	> 90% 665 – 726 nm	25.2 x 35.6 mm	1.05 mm	FF655-Di01-25x36	$285
	660 nm	> 98% 350 – 651 nm	> 93% 669 – 950 nm	25.2 x 35.6 mm	1.05 mm	FF660-Di02-25x36	$305
	665 nm	*See Multiphoton filters, page 44*				FF665-Di02-25x36	
	670 nm	*Short-wave-pass; See Multiphoton filters, page 44*				FF670-SDi01-25x36	
	677 nm	> 98% 400 – 658 nm	> 90% 687 – 830 nm	25.2 x 35.6 mm	1.05 mm	FF677-Di01-25x36	$380
	685 nm	> 98% 350 – 676 nm	> 93% 695 – 939 nm	25.2 x 35.6 mm	1.05 mm	FF685-Di02-25x36	$305
	695 nm	> 98% 450 – 680 nm	> 90% 710 – 850 nm	25.2 x 35.6 mm	1.05 mm	FF695-Di01-25x36	$380
	697 nm	> 97% 705 – 900 nm	> 93% 532 – 690 nm	25.2 x 35.6 mm	1.05 mm	FF697-SDi01-25x36	$305
	700 nm	> 97% 532 – 690 nm	> 93% 705 – 800 nm	25.2 x 35.6 mm	1.05 mm	FF700-Di01-25x36	$305
	700 nm	*Short-wave-pass; See Multiphoton filters, page 44*				FF700-SDi01-25x36	
	705 mm	*See Multiphoton filters, page 44*				FF705-Di01-25x36	
	720 nm	*Short-wave-pass; See Multiphoton filters, page 44*				FF720-SDi01-25x36	
	735 nm	*See Multiphoton filters, page 44*				FF735-Di02-25x36	
	740 nm	> 98% 480 – 720 nm	> 90% 750 – 825 nm	25.2 x 35.6 mm	1.05 mm	FF740-Di01-25x36	$380
	749 nm	> 96% 770 – 1100 nm	> 93% 400 – 730 nm	25.2 x 35.6 mm	3.0 mm	FF749-SDi01-25x36x3.0	$380
	750 nm	> 96% 770 – 920 nm	> 93% 450 – 730 nm	25.2 x 35.6 mm	1.05 mm	FF750-SDi02-25x36	$305
	757 nm	> 98% 450 – 746 nm	> 93% 768 – 1100 nm	25.2 x 35.6 mm	1.05 mm	FF757-Di01-25x36	$305
	765 nm	> 95% 450 – 750 nm	> 93% 780 – 950 nm	25.2 x 35.6 mm	2.0 mm	FF765-Di01-25x36x2.0	$380
	775 nm	*See Multiphoton filters, page 44*				FF775-Di01-25x36	
	776 nm	> 98% 450 – 764 nm	> 88% 789 – 1100 nm	25.2 x 35.6 mm	1.05 mm	FF776-Di01-25x36	$380
	791 nm	> 90% 795 – 940 nm	> 90% 687 – 787 nm	25.2 x 35.6 mm	1.05 mm	FF791-SDi01-25x36	$380
	801 mm	> 98% 450 – 790 nm	> 90% 813.5 – 1100 nm	25.2 x 35.6 mm	1.05 mm	FF801-Di02-25x36	$380
	825 nm	> 95% 850 – 1650 nm	> 90% 565 – 800 nm	25.2 x 35.6 mm	2.0 mm	FF825-SDi01-25x36x2.0	$630
	872 nm	> 92% 240 – 840 nm	> 90% 903 – 1100 nm	25.2 x 35.6 mm	2.0 mm	FF872-Di01-25x36x2.0	$525
	875 nm	*See Multiphoton filters, page 44*				FF875-Di01-25x36	
	925 nm	*See Multiphoton filters, page 44*				FF925-Di01-25x36	
	930 nm	> 98% 980 – 1140 nm	> 93% 750 – 880 nm	25.2 x 35.6 mm	2.0 mm	FF930-SDi01-25x36x2.0	$380

See spectra graphs and ASCII data for these filter sets at www.idex-hs.com/semrock

BrightLine® Image-splitting Dichroic Beamsplitters

These image-splitting dichroic beamsplitters are the industry standard enabling simultaneous multi-color imaging applications such as FRET and real-time live-cell imaging. The spectral edges of these filters are optimized for imaging of popular fluorophore-pairs providing maximum signal throughput, while maintaining minimal wavefront distortion in reflection and transmission thereby maximizing contrast and resolution of the overall imaging system. The 1 mm version enables reflected imaged beams up to 10 mm with a transmission range to 950 nm. The 3 mm version enables reflected imaged beams up to 37 mm *(when custom-sized)* with a transmission range to 1200 nm.

Image-splitting Dichroic Beamsplitters

Nominal Edge Wavelength	Common Fluorophore Pairs to Split	Average Reflection Band	Average Transmission Band	Size (L x W x H)	Filter Part Number	Price
389 nm		350 – 382 nm	396 – 850 nm	25.2x35.6 mm	FF389-Di01-25x36x1.5	$335
484 nm	DAPI/FITC (or BFP/GFP)	350 – 475 nm	492.3 – 950 nm	25.2 x 35.6 x 1.05 mm	FF484-FDi01-25x36	$390
509 nm	CFP/YFP	350 – 500 nm	518.3 – 950 nm	25.2 x 35.6 x 1.05 mm	FF509-FDi01-25x36	$390
538 nm	GFP/mOrange	350 – 528.4 nm	547.7 – 950 nm	25.2 x 35.6 x 1.05 mm	FF538-FDi01-25x36	$390
560 nm	YFP/dTomato	350 – 550 nm	570.1 – 950 nm	25.2 x 35.6 x 1.05 mm	FF560-FDi01-25x36	$390
580 nm	GFP/mCherry (or FITC/TxRed)	350 – 570 nm	590.8 – 950 nm	25.2 x 35.6 x 1.05 mm	FF580-FDi01-25x36	$390
640 nm	Cy3/Cy5	350 – 629.5 nm	652 – 950 nm	25.2 x 35.6 x 1.05 mm	FF640-FDi01-25x36	$390
662 nm	TxRed/Cy5	350 – 650 nm	673.7 – 950 nm	25.2 x 35.6 x 1.05 mm	FF662-FDi01-25x36	$390

Image-splitting Dichroic Beamsplitters for Super-resolution Microscopy

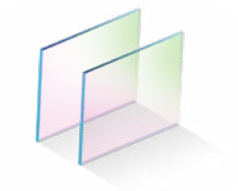
Nominal Edge Wavelength	Common Fluorophore Pairs to Split	Average Reflection Band	Average Transmission Band	Size (L x W x H)	Filter Part Number	Price
484 nm	DAPI/FITC (or BFP/GFP)	350 - 475 nm	492.3 - 1200 nm	25.2x35.6x3.0mm	FF484-FDi02-t3-25x36	$630
509 nm	CFP/YFP	350 – 500 nm	518.3 – 1200 nm	25.2x35.6x3.0mm	FF509-FDi02-t3-25x36	$630
538 nm	GFP/mOrange	350 - 528.4 nm	547.7 - 1200 nm	25.2x35.6x3.0mm	FF538-FDi02-t3-25x36	$630
560 nm	YFP/dTomato	350 – 550 nm	570.1 – 1200 nm	25.2x35.6x3.0mm	FF560-FDi02-t3-25x36	$630
580 nm	GFP/mCherry (or FITC/TxRed)	350 – 570 nm	590.8 – 1200 nm	25.2x35.6x3.0mm	FF580-FDi02-t3-25x36	$630
640 nm	Cy3/Cy5	350 – 629 nm	652 – 1200 nm	25.2x35.6x3.0mm	FF640-FDi02-t3-25x36	$630
662 nm	TexasRed/Cy5	350 - 650 nm	673.7 - 1200 nm	25.2x35.6x3.0mm	FF662-FDi02-t3-25x36	$630

Image Splitting Dichroic Beamsplitters Common Specifications

Property	Value	Comment
Transmission	> 93%	Averaged over the specified band
Reflection	> 95%	Averaged over the specified band
Flatness (FFxxx-FDi01) Flatness (FFxxx-FDi02-t3)	< λ/4 P-V at λ = 633 nm < λ/5 P-V RWE at λ = 633 nm	Spherical error measured over a 10 mm aperture[1] Over Clear Aperture

[1] A 10 mm spot size is typical assuming common microscope values. www.idex-hs.com/semrock. All other mechanical specifications are the same as BrightLine dichroic specifications on page 36.

BrightLine® Multiedge Dichroic Beamsplitters



Our BrightLine multiedge dichroic beamsplitters are available in dual, triple, quad, and the world's only penta band designs. Optimized for general broadband excitation sources or laser lines, high performance, multi-color fluorescence imaging is easily attainable with Semrock's BrightLine dichroic beamsplitters.

Dual-edge General Purpose Dichroic Beamsplitters *(polarization-insensitive; for use at 45°)*

For multiedge laser-optimized fluorescence dichroic beamsplitters, see page 70.

Nominal Edge Wavelength	Avg. Reflection Bands	Avg. Transmission Bands	Size (L x W x H)	Filter Part Number	Price
403 nm 502 nm	> 97.5% 370 – 393 nm > 97.5% 466 – 495 nm	> 90% 414 – 452 nm > 90% 510 – 550 nm	25.2 x 35.6 x 1.05 mm	FF403/502-Di01-25x36	$435
471 nm 539 nm	> 95% 439 – 459 nm > 95% 510 – 530 nm	> 93% 473 – 495 nm > 93% 546 – 576 nm	25.2 x 35.6 x 1.05 mm	FF471/539-Di01-25x36	$455
493 nm 574 nm	> 95% 456 – 480 nm > 95% 541 – 565 nm	> 90% 500 – 529 nm > 90% 584 – 679 nm	25.2 x 35.6 x 1.05 mm	FF493/574-Di01-25x36	$435
505 nm 606 nm	> 95% 458 – 499 nm > 95% 570 – 600 nm	> 90% 509 – 541 nm > 90% 612 – 647 nm	25.2 x 35.6 x 1.05 mm	FF505/606-Di01-25x36	$435
545 nm 650 nm	> 95% 532.0 nm > 95% 632.8 nm	> 90% 554 – 613 nm > 90% 658 – 742 nm	25.2 x 35.6 x 1.05 mm	FF545/650-Di01-25x36	$435
560 nm 659 nm	> 95% 514 – 553 nm > 95% 617 – 652 nm	> 90% 564 – 591 nm > 90% 665 – 718 nm	25.2 x 35.6 x 1.05 mm	FF560/659-Di01-25x36	$435

ACTUAL MEASURED DATA

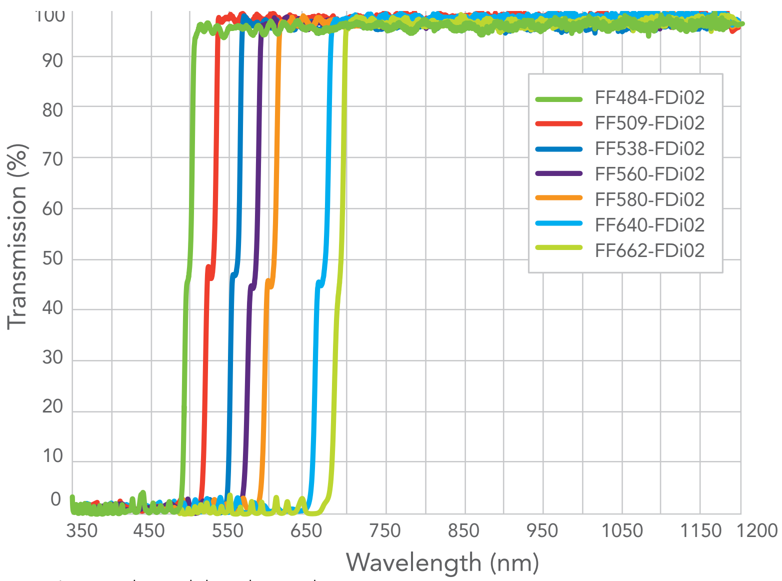


Image-splitting dichroic beamsplitters spectra

BrightLine® Multiedge Dichroic Beamsplitters

Triple-edge General Purpose Dichroic Beamsplitters *(polarization-insensitive; for use at 45°)*

For multiedge laser-optimized fluorescence dichroic beamsplitters, see page 72.

Nominal Edge Wavelength	Avg. Reflection Bands	Avg. Transmission Bands	Size (L x W x H)	Filter Part Number	Price
395 nm 495 nm 610 nm	> 97% 354 – 385 nm > 97% 465 – 483 nm > 97% 570 – 596 nm	> 95% 403 – 446 nm > 95% 502 – 552 nm > 95% 620 – 750 nm	25.2 x 35.6 x 1.05 mm	FF395/495/610-Di01-25x36	$530
403 nm 497 nm 574 nm	> 97% 386 – 393 nm > 97% 466 – 490 nm > 97% 546 – 565 nm	> 90% 414 – 450 nm > 90% 505 – 528 nm > 90% 584 – 645 nm	25.2 x 35.6 x 1.05 mm	FF403/497/574-Di01-25x36	$530
409 nm 493 nm 596 nm	> 95% 350 – 404 nm > 95% 461 – 487.5 nm > 95% 559.5 – 589.5 nm	> 93% 414 – 450 nm > 93% 499.5 – 546 nm > 93% 604 – 850 nm	25.2 x 35.6 x 1.05 mm	FF409/493/596-Di02-25x36	$530
436 nm 514 nm 604 nm	> 97.5% 394 – 414 nm > 97.5% 484 – 504 nm > 97.5% 566 – 586 nm	> 90% 446 – 468 nm > 90% 520 – 540 nm > 90% 614 – 642 nm	25.2 x 35.6 x 1.05 mm	FF436/514/604-Di01-25x36	$530
444 nm 520 nm 590 nm	> 98% 327 – 437 nm > 98% 494 – 512 nm > 98% 562 – 578 nm	> 90% 450 – 480 nm > 90% 527 – 547 nm > 90% 598 – 648 nm	25.2 x 35.6 x 1.05 mm	FF444/520/590-Di01-25x36	$530
444 nm 521 nm 608 nm	> 95% 420 – 430 nm > 95% 496 – 510 nm > 95% 579 – 596 nm	> 90% 451 – 480 nm > 90% 530 – 561 nm > 90% 618 – 664 nm	25.2 x 35.6 x 1.05 mm	FF444/521/608-Di01-25x36	$530
459 nm 526 nm 596 nm	> 95% 350 – 450 nm > 95% 497.6 – 519.5 nm > 95% 567.4 – 588.6 nm	> 93% 464 – 486 nm > 93% 532 – 554 nm > 93% 603 – 800 nm	25.2 x 35.6 x 1.05 mm	FF459/526/596-Di01-25x36	$530
468 nm 526 nm 596 nm	> 95% 350 – 462.5 nm > 95% 506.5 – 519.5 nm > 95% 567.5 – 588.6 nm	> 93% 474 – 494.5 nm > 93% 532 – 554 nm > 93% 603 – 800 nm	25.2 x 35.6 x 1.05 mm	FF468/526/596-Di01-25x36	$530

Quadruple-edge Dichroic Beamsplitters *(polarization-insensitive; for use at 45°)*

For multiedge laser-optimized fluorescence dichroic beamsplitters, see page 72.

Nominal Edge Wavelength	Avg. Reflection Bands	Avg. Transmission Bands	Size (L x W x H)	Filter Part Number	Price
409 nm 493 nm 596 nm 652 nm	> 95% 350 – 404 nm > 95% 461 – 487.5 nm > 95% 543 – 566 nm > 95% 626 – 644 nm	> 93% 414 – 450 nm > 93% 499.5 – 530 nm > 93% 580 – 611 nm > 93% 659.5 – 850 nm	25.2 x 35.6 x 1.05 mm	FF409/493/573/652-Di02-25x36	$640
410 nm 504 nm 582 nm 669 nm	> 95% 381 – 392 nm > 95% 475 – 495 nm > 95% 547 – 572 nm > 95% 643 – 656 nm	> 90% 420 – 460 nm > 90% 510 – 531 nm > 90% 589 – 623 nm > 90% 677 – 722 nm	25.2 x 35.6 x 1.05 mm	FF410/504/582/669-Di01-25x36	$640

Penta-edge Dichroic Beamsplitter *(polarization-insensitive; for use at 45°)*

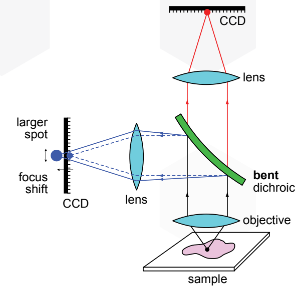
Nominal Edge Wavelength	Avg. Reflection Bands	Avg. Transmission Bands	Size (L x W x H)	Filter Part Number	Price
408 nm 504 nm 581 nm 667 nm 762 nm	> 95% 381 – 392 nm > 95% 475 – 495 nm > 95% 547 – 572 nm > 95% 643 – 656 nm > 95% 733 – 746 nm	> 90% 420 – 460 nm > 90% 510 – 531 nm > 90% 589 – 623 nm > 90% 677 – 711 nm > 90% 768 – 849 nm	25.2 x 35.6 x 1.05 mm	FF408/504/581/667/762-Di01-25x36	$745
409 nm 493 nm 596 nm 652 nm 759 nm	> 95% 350 – 404 nm > 95% 461 – 487.5 nm > 95% 543 – 566 nm > 95% 626 – 644 nm > 95% 721 – 479 nm	> 93% 414 – 450 nm > 93% 499.5 – 530 nm > 93% 580 – 611 nm > 93% 661 – 701 nm > 93% 768.5 – 849.5 nm	25.2 x 35.6 x 1.05 mm	FF409/493/573/652/759-Di01-25x36	$745
421 nm 491 nm 567 nm 659 nm 776 nm	> 95% 369 – 413 nm > 95% 471 – 483 nm > 95% 541 – 557 nm > 95% 630 – 647 nm > 95% 725 – 757 nm	> 93% 426 – 456 nm > 93% 498 – 524 nm > 93% 574 – 611 nm > 93% 667 – 701 nm > 93% 784 – 850 nm	25.2 x 35.6 x 1.05 mm	FF421/491/567/659/776-Di01-25x36	$855

BrightLine® Dichroic Beamsplitters

TECHNICAL NOTE

Flatness of Dichroic Beamsplitters Affects Focus and Image Quality

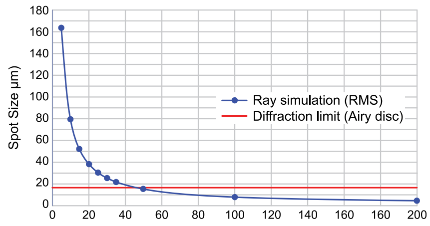
Optical filters are generally comprised of multi-layered thin-film coatings on plane, parallel glass substrates. All Semrock filters use a single substrate with coatings on one or both sides to maximize transmission and reliability and minimize artifacts associated with multiple interfaces. The glass substrate is not always perfectly flat, especially after it is coated, sometimes resulting in a slight bending of the substrate. Fortunately, this bending has no noticeable effect on light transmitted through an optical filter at or near normal incidence. For light incident at high angles of incidence, as is the case for a 45° dichroic beamsplitter, the only effect of a bent substrate on transmitted light is a slight divergence of the beam axis.



A bent dichroic can introduce aberrations.

However, a bent filter substrate can have noticeable impact on reflected light. Examples include an excitation beam reflected off a dichroic before impinging on a sample object, or an imaging beam that is split into two colors using a dichroic. Two main effects may occur: the position of the focal plane shifts and the size of the focused spot or the quality of the image is compromised.

Often a small shift of the focal plane is not a problem, because a lens or camera adjustment can be made to compensate. But in some cases the focal shift may be too large to compensate – focusing a laser beam onto the back focal plane of the objective in a Total Internal Reflection Fluorescence (TIRF) microscope, or imaging the grid onto the sample plane in a structured illumination microscope represent cases where care should be taken to use a flat dichroic, such as those designed for laser applications (for example, see page 68).



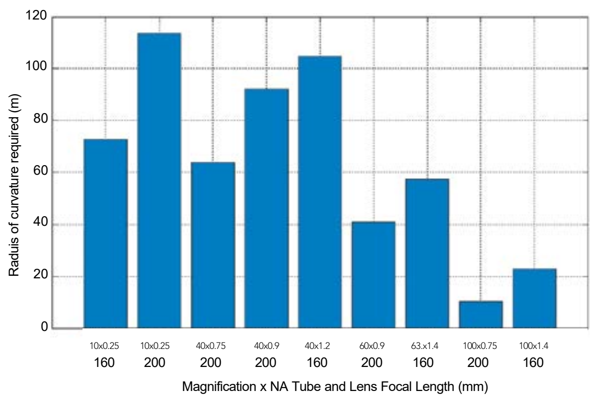
Dichroic radius of curvature affects spot size.

When light incident at 45° is reflected off a dichroic with a slight bend, the resulting optical aberrations (such as astigmatism) can degrade the quality of an image after an imaging lens. As an example, the graph on the right shows the spot size at an image plane that results from a perfect point source after reflecting off a dichroic with various radii of curvature.

This plot is based on a typical epifluorescence microscope configuration, assuming a perfect point source at the sample location, imaged onto the image plane (e.g., CCD surface) by an ideal 40X, 0.75 NA objective and a tube lens with a 200 mm typical focal length (industry standard tube length focal lengths range between 160 and 200 mm). The resulting beam diameter is 6.75 mm. The reflection off the dichroic is assumed to occur mid way between the objective and the tube lens. The field of view of the system is assumed to be limited by a 20 mm diameter field size at the camera plane. The light is assumed to have a wavelength of 510 nm (peak of GFP emission). For comparison, the diffraction-limited spot size that would result from a perfect objective and tube lens and a perfectly flat dichroic is 16.6 µm (red line on plot).

A sufficient criterion for an imaging beam (i.e., focused onto a detector array such as a CCD) reflected off a dichroic is that the diffraction-limited spot size should not change appreciably due to reflection off the beamsplitter. The required minimum radius of curvature for a number of objective-tube lens combinations (with standard tube lenses) that are common in fluorescence microscopes are summarized in the following figure. The required minimum radii vary from a few tens of meters for the higher magnification objectives (with smaller beam diameter) to as high as about 50 to 100 meters for the lower magnification objectives (with larger beam diameter).

While reflected image quality can be worse than the ideal diffraction-limited response for dichroics that are not perfectly flat, it should be noted that the true spot size at the image plane can be appreciably larger than the diffraction-limited spot size in an actual system. Nevertheless, care should be taken to select properly optimized, flatter dichroic beamsplitters when working with reflected light. Dichroics designed to reflect laser light ("laser dichroics," see pages 71 and 72) are generally flat enough to ensure negligible focal shift for laser beams up to several mm in diameter. Dichroics designed to reflect imaging beams ("imaging dichroics", see page 63) have the most extreme flatness requirements, since they must effectively eliminate the effects of astigmatism for beams as large as 1 cm or more.



Desired radii of curvature of dichroics suitable for image splitting applications for a number of common microscope objectives. Each objective is labeled with its magnification, numerical aperture (NA), and associated tube lens focal length (in mm).

BrightLine® Super-resolution / TIRF Laser Dichroic Beamsplitters

TECHNICAL NOTE

Choosing Dichroic Beamsplitters with Flatness/ RWE Appropriate to the Microscopy Method

Wavefront distortion can degrade image quality by reducing contrast or compromising resolution. In several microscopy applications, reducing wavefront distortion is critical to achieving the microscopy method. Specifying and selecting optical filters that minimize wavefront aberration is important to maximize or enable optical system performance. This article elucidates how to select optical filters for high performance microscopy, and provides guidance on choosing Semrock catalog filters for wavefront distortion performance required for applications.

Both standard and advanced microscopy methods require certain minimum standards of flatness on dichroic beamsplitters. For example, super-resolution and TIRF microscopy cannot be achieved if the flatness of the critical dichroic beamsplitters is worse than required. This Tech Note introduces the topic of how to choose Semrock dichroic beamsplitters appropriate to the microscopy method.

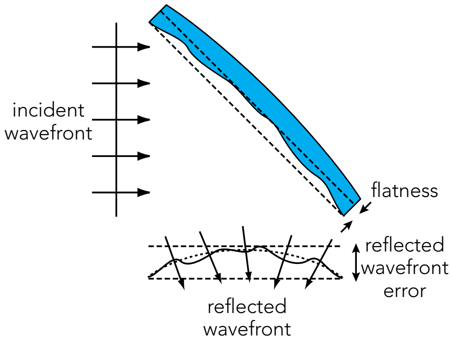
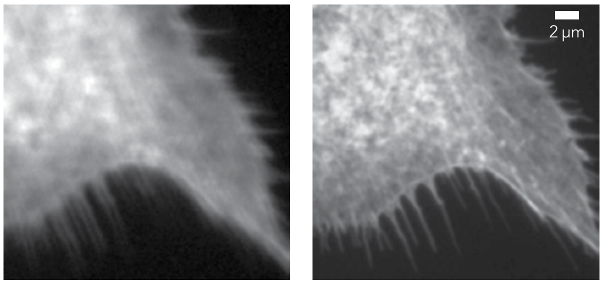


Figure [1]: For light incident at an angle upon a dichroic beamsplitter, deviations from flatness cause distortions in the reflected wavefront.

Optical filters are generally composed of multi-layered, thin-film coatings on plane, parallel glass substrates. There is variability in substrate flatness, and, additionally, the substrate may slightly bend after coating. For transmitted light, such bending has little effect on transmitted wavefront error (TWE) other than a slight displacement of the beam axis. However, for reflected light, especially light incident at non-perpendicular angles, deviations from flatness (see Figure 1) have two effects on reflected wavefront error (RWE): (1) the focal plane may shift position, or (2) the beam may acquire optical aberrations (e.g., astigmatism).



Radius of Curvature (m) ~6 ~1275

Figure [2]: Image sequence demonstrating the effect of substrate bending on image quality. A lower radius of curvature means greater substrate bending. As the radius of curvature decreases (and bending increases), image quality degrades. [Images of F-actin in bovine pulmonary artery endothelial cells (FluoCells® Prepared Slide #1, Thermo Fisher Scientific, Waltham, MA, USA) as imaged on a BX41 microscope (Olympus Corporation of the Americas, Center Valley, PA, USA) with a 40×, 0.75NA objective and Retiga camera (Teledyne Photometrics)]

A focal plane shift can be corrected by lens or camera adjustment in some microscopy methods, but in others this shift cannot be adjusted for and can therefore impede proper function. Also of significant concern, optical aberrations can degrade image quality, as illustrated in Figure [2], and can compromise the microscopy method. In determining suitable flatness need for a given application, the most important parameter is often the diameter of the beam striking the dichroic beamsplitter surface. Table 2 shows the Semrock product best suited to the application, for maximum diameter values. For more specific information, and for other beam diameter value and microscopy examples, the Semrock White Paper on this topic [1] provides additional information on RWE, TWE, and microscopy methods, as well as guidance from a system designer's perspective.

Because of potential degradation of imaging quality, it is important to determine when the flatness of dichroic beamsplitter is critical to a microscopy method. Table 1 lists examples of popular microscopy techniques in which it is critical to have dichroics of high flatness. As noted in this table, high flatness requirements can apply to both the illumination (excitation) and the detection (emission) light paths.

Microscopy Technique	Flatness Need in a Reflected Excitation Beam	Flatness Need in a Reflected Emission Beam
Widefield Fluorescence Microscopy	Non-critical	Critical
Total Internal Reflection Fluorescence (TIRF) Microscopy	Critical	Critical
Stochastic Switching (PALM, STORM, etc.)	Critical	Critical
Stimulated Emission Depletion (STED) – Pulsed Microscopy	Critical	Non-critical
Confocal Single-point Scanning Microscopy	Critical	Non-critical
Combining multiple laser beams	Critical	Not applicable

Table 1: A list of popular standard and advanced microscopy methods, categorized as to criticality of dependence on reflected wavefront flatness.

(continued)

(continued from previous page)

Semrock offers an extensive and industry-leading range of catalog filters for a variety of applications with specific Flatness/RWE needs. The Semrock Flatness Classifications listed in Table 2 provide an intuitive approach to selecting products of appropriate flatness for a given application.

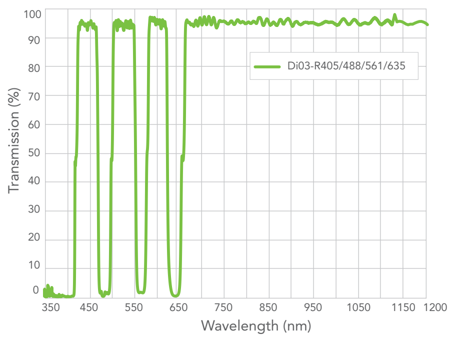
In determining suitable flatness need for a given application, the most important parameter is often the diameter of the beam striking the dichroic beamsplitter surface. Table 2 shows the Semrock product best suited to the application, for maximum diameter values. For more specific information, and for other beam diameter value and microscopy examples, the Semrock White Paper on this topic [1] provides additional information on RWE, TWE, and microscopy methods, as well as guidance from a system designer's perspective.

Flatness / Reflected Wavefront Error Classification	Example Applications	Nominal Radius of Curvature, m	Maximum Reflected Beam Diameter, mm	RWE PV @ 45°at 632.8 nm	Flatness PV @ 0° at 632.8 nm	Dichroic Family, and Example Part Numbers
Super-resolution / TIRF	TIRF, PALM, STORM, STED	~ 1275	22.5	<0.2λ	<~0.1λ	BrightLine super-resolution / TIRF (Di03-R405-t3-)
		~ 900	16.7	<0.33λ	<~0.2λ	BrightLine multiedge multiphoton (Di01-R405/488/561/635/800-t3-)
		~ 255	10	<1λ	<~0.5λ	BrightLine super-resolution / TIRF (Di03-R405-t1-)
		~ 110	6.3	<2.5λ	<~1.4λ	BrightLine multiedge multiphoton (Di01-R405/488/561/635/800-t1-)
Image-splitting	Splitting of emission signal on a pixel based detector	~ 1275	37	<0.2λ	<~0.1λ	BrightLine Image-splitting for super-resolution microscopy (FF509-FDi02-t3-)
		~ 100	10	<2λ	<~1.4λ	BrightLine Image-splitting for standard microscopy (FF509-FDi01-)
Laser	Confocal, combining/ splitting laser beams	~ 30	2.5	<6λ	<~4.25λ	BrightLine Laser (Di02-R405-) RazorEdge® (LPD02-488RU-) LaserMUX™ (LM01-503-)
Standard Epi-fluorescence	Widefield fluorescence	~ 6	Not Applicable	>>6λ	>15λ	BrightLine® (FF495-Di03-)

Table 2: Semrock Flatness / RWE Classifications and recommended catalog dichroic family information along with maximum allowable beam diameter values. More detailed information is found in the Semrock White Paper [1].

[1] Maximizing the Performance of Advanced Microscopes by Controlling Wavefront Error Using Optical Filters www.idex-hs.com/white-papers

ACTUAL MEASURED DATA



BrightLine® Super-resolution / TIRF Laser Dichroic Beamsplitters

TECHNICAL NOTE

Finding the Right Dichroic Beamsplitter

Semrock makes a wide variety of 45° dichroic beamsplitters optimized for different purposes. Every dichroic utilizes our advanced hard, ion-beam-sputtered coating technology for exceptional environmental and handling durability and no degradation even under the most intense illumination conditions. The dichroics are broadly categorized by the light source with which they are intended be used and the spectral edge steepness and physical flatness values required for various applications. The table below lists six broad families of Semrock dichroic beamsplitters according to these requirements.

Light Source	Edge Steepness	Flatness / RWE Classification	Family	Page
Broadband	Standard	Standard Epi-fluorescence	General Purpose Dichroics	61
Broadband	Standard	Image-splitting	Image-splitting Dichroics	63
Laser lines	Steep	Laser	Laser Dichroics	71
Laser lines	Steep	Super-resolution / TIRF	Super-resolution / TIRF Dichroics	70
Laser lines	Standard	Laser	Laser Notch Dichroics	73
Laser lines	Standard	Laser	Laser Beam Combining	74
Laser lines	Standard	Super-resolution / TIRF	Multiphoton Laser Beam Combining	45
Laser lines; Multiphoton	Steep	Super-resolution / TIRF	Multiedge Multiphoton Super-res / TIRF Dichroic	45
Precise laser lines	Ultrasteep	Laser	Ultrasteep Laser Dichroics	97

Dichroic beamsplitters designed to be used with broadband light sources generally ensure the highest average value of reflection over a band of source wavelengths often chosen for best overlap with a particular fluorophore absorption spectrum. Dichroics for laser light sources ensure high absolute reflection performance at specified laser lines, with precise spectral edges that are keyed to these lines and anti-reflection (AR) coatings on the filter backsides to minimize any coherent interference artifacts.

While all Semrock dichroics are among the steepest available 45° edge filters on the market, those optimized for laser-based epifluorescence and Raman applications are exceptionally steep to enable signal collection as close as possible to the laser line.

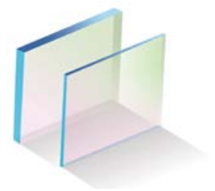
Flatter dichroic beamsplitters minimize wavefront errors that can result in defocus and imaging aberrations of the light reflected off these filters. Semrock classifies dichroic beamsplitters into four categories of flatness, as listed in the table below.

NOTE: Mounting can impact flatness performance. Values below apply to unmounted parts.

Flatness / RWE Classification & Application Specification of Semrock Dichroic Beamsplitters

Flatness / RWE Classification	Nominal Radius of Curvature	Application Specification
All Classifications	All curvatures	Transmission: does not cause significant aberrations to a transmitted beam over the full Clear Aperture
Super-resolution / TIRF	~ 1275 meters	Reflection: contributes less than one Rayleigh Range of shift in focus (relative to a perfectly flat mirror) at the focal plane of a lens after reflecting a laser beam with a diameter up to **22.5 mm**
	~ 255 meters	Reflection: contributes less than one Rayleigh Range of shift in focus (relative to a perfectly flat mirror) at the focal plane of a lens after reflecting a laser beam with a diameter up to **10 mm**
Image-splitting	~ 1275 meters	Reflection: contributes less than 1.5 x Airy Disk diameter to the RMS spot size of a focused, reflected emission beam with a diameter up to **37 mm**
	~ 100 meters	Reflection: contributes less than 1.5 x Airy Disk diameter to the RMS spot size of a focused, reflected emission beam with a diameter up to **10 mm**
Laser	~ 30 meters	Reflection: contributes less than one Rayleigh Range of shift in focus (relative to a perfectly flat mirror) at the focal plane of a lens after reflecting a laser beam with a diameter up to **2.5 mm**
Standard Epi-fluorescence	~ 6 meters	Reflection: designed to reflect broadband excitation light that is not focused or imaged

BrightLine® Super-resolution / TIRF Laser Dichroic Beamsplitters



Semrock is setting the industry standard for Super-resolution / TIRF microscopy dichroic beamsplitters compatible with popular microscopy filter cubes to improve the performance of laser based confocal and TIRF illumination systems. They are also ideal for reflection of imaging beams in conventional structured-illumination techniques as well as patterned illumination systems for localized photo-activation. These dichroic beamsplitters allow the use of much larger diameter illumination beams, offering researchers and instrument developers more flexibility in system design with no compromise to overall performance.

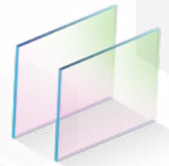
Nominal Edge Wavelength	Laser Wavelengths	Extended Avg. Reflection Band	Absolute Reflection Band	Avg. Transmission Band	1λ RWE 1 mm Thickness Filter Part Number	Price	λ/5 RWE 3 mm Thickness Filter Part Number	Price
414 nm	375.0 ± 3 nm 405.0 ± 5 nm	350.0–372.0 nm	372.0 – 410.0 nm	417.4 – 1200.0 nm	Di03-R405-t1-25x36	$555	Di03-R405-t3-25x36	$655
465 nm	440.0 +3/-1 nm 442.0 nm 457.9 nm	350.0–439.0 nm	439.0 – 457.9 nm	466.1 – 1200.0 nm	Di03-R442-t1-25x36	$555	Di03-R442-t3-25x36	$655
484 nm	457.9 nm 473.0 ± 5 nm	350.0-457.9 nm	457.9 – 478.0 nm	486.6 – 1200.0 nm	Di03-R473-t1-25x36	$555	Di03-R473-t3-25x36	$655
496 nm	473.0 ± 2 nm 488.0 +3/–2 nm	350.0–471.0 nm	471.0 – 491.0 nm	499.8 – 1200.0 nm	Di03-R488-t1-25x36	$555	Di03-R488-t3-25x36	$655
520 nm	505.0 nm 514.5 nm 515.0 nm	350.0–505.0 nm	505.0 – 515.0 nm	524.3 – 1200.0 nm	Di03-R514-t1-25x36	$555	Di03-R514-t3-25x36	$655
538 nm	514.5 nm 532.0 nm	350.0–514.0 nm	514.0 – 532.0 nm	541.6 – 1200.0 nm	Di03-R532-t1-25x36	$555	Di03-R532-t3-25x36	$655
576 nm	561.4 nm 568.2 nm	350.0–554.0 nm	554.0 – 568.2 nm	578.4 – 1200.0 nm	Di03-R561-t1-25x36	$555	Di03-R561-t3-25x36	$655
599 nm	593.5 nm 594.1 nm 594.0 ± 0.3 nm	350.0–593.5 nm	593.5 – 594.3 nm	605.0 – 1200.0 nm	Di03-R594-t1-25x36	$555	Di03-R594-t3-25x36	$655
656 nm	632.8 nm 635.0 +7/–3 nm 647.1 nm	350.0–632.8 nm	632.8 – 647.1 nm	658.8 – 1200.0 nm	Di03-R635-t1-25x36	$555	Di03-R635-t3-25x36	$655
672.9 nm	647.1 nm 658.0 nm 660.0 ± 5 nm	350.0-647.1 nm	647.1 – 665.0 nm	677.0 – 1200.0 nm	Di03-R660-t1-25x36	$660	Di03-R660-t3-25x36	$760
698.9 nm	671.0 nm 676.0 nm 685.0 ± 5 nm	350.0-671.0 nm	671.0 – 690.0 nm	702.5 – 1200.0 nm	Di03-R685-t1-25x36	$660	Di03-R685-t3-25x36	$760
800 nm	785.0 ± 5 nm	350.0–780.0 nm	780.0 – 790.0 nm	804.3 – 1600.0 nm	Di03-R785-t1-25x36	$660	Di03-R785-t3-25x36	$760
499 nm 575 nm	473 ± 2 , 488 +3 /-2 559 +5/-0, 561.4, 568.2	350.0–471.0 nm	471.0 – 491.0 nm 559.0 – 568.2 nm	503.3 – 543.0 nm 582.4 – 1200.0 nm	Di03-R488/561-t1-25x36	$610	Di03-R488/561-t3-25x36	$710
419 nm 498 nm 542 nm 659 nm	375 ± 3, 405 ± 5 473 +2/-0 , 488 +3 /-2 532 632.8, 635 +7/-0, 647.1	350.0–370.0 nm	370.0 – 410.0 nm 473.0 – 491.0 nm 530.5 – 533.5 nm 632.8 – 647.1 nm	426.0 – 462.0 nm 502.5 – 518.5 nm 550.0 – 613.0 nm 663.0 – 1200.0 nm	Di03-R405/488/532/635-t1-25x36	$715	Di03-R405/488/532/635-t3-25x36	$815
419 nm 498 nm 575 nm 655 nm	375 ± 3, 405 ± 5 473 +2/-0 , 488 +3 /-2 559 +5/-0, 561.4, 568.2 632.8, 635 +7/-0, 647.1	350.0–370.0 nm	370.0 – 410.0 nm 473.0 – 491.0 nm 559.0 – 568.2 nm 632.8 – 647.1 nm	426.0 – 462.0 nm 502.5 – 544.5 nm 582.0 – 617.5 nm 663.0 – 1200.0 nm	Di03-R405/488/561/635-t1-25x36	$715	Di03-R405/488/561/635-t3-25x36	$815

Super-resolution / TIRF Laser Dichroic Beamsplitters Common Specifications

Property	Value	Comment
RWE (Di03)	< 1λ P-V RWE (1 mm thickness) < λ/5 P-V RWE (3 mm thickness)	Measured at λ = 633 nm

All other optical & mechanical specifications are the same as BrightLine Laser Dichroic specifications on page 71.

BrightLine® Single-edge Laser Dichroic Beamsplitters



BrightLine laser dichroic beamsplitters have extended reflection down to 350 nm to enable photoactivation. These dichroic beamsplitters are optimized for the most popular lasers used for fluorescence imaging, including all-solid-state lasers. Reflection is guaranteed to be > 98% (s-polarization) and > 94% (average polarization) at the laser wavelengths, plus > 93% average transmission and very low ripple over extremely wide passbands out to 900 nm, 1200 nm or even 1600 nm.

UV & IR Laser Dichroic Beamsplitters *(polarization-insensitive; for use at 45°)*

Nominal Edge Wavelength	Laser Wavelengths	Extended Avg. Reflection Band	Absolute Reflection Band	Avg. Transmission Band	Size (mm) (L x W x H)	Filter Part Number	Price
273 nm	266.0 nm	230.0 – 245.0 nm	245.0 – 266.0 nm	277.0 – 1200.0 nm	25.2 x 35.6 x 1.05	Di01-R266-25x36	$610
331 nm	325.0 nm	230.0 – 300.0 nm	300.0 – 325.0 nm	336.0 – 1200.0 nm	25.2 x 35.6 x 1.05	Di01-R325-25x36	$610
363 nm	355.0 nm	230.0 – 325.0 nm	325.0 – 355.0 nm	367.0 – 1200.0 nm	25.2 x 35.6 x 1.05	Di01-R355-25x36	$610
414 nm	375.0 ± 3 nm 405.0 ± 5 nm	350.0 – 372.0 nm	372.0 – 410.0 nm	417.4 – 900.0 nm	25.2 x 35.6 x 1.05	Di02-R405-25x36	$505
462 nm	440.0 +3/-1 nm 442.0 nm 457.9 nm	350.0 – 439.0 nm	439.0 – 457.9 nm	466.1 – 900.0 nm	25.2 x 35.6 x 1.05	Di02-R442-25x36	$505
496 nm	473.0 ± 2 nm 488.0 +3/–2 nm	350.0 – 471.0 nm	471.0 – 491.0 nm	499.8 – 900.0 nm	25.2 x 35.6 x 1.05	Di02-R488-25x36	$505
520 nm	505.0 nm 514.5 nm 515.0 nm	350.0 – 505.0 nm	505.0 – 515.0 nm	524.3 – 1200.0 nm	25.2 x 35.6 x 1.05	Di02-R514-25x36	$505
536.8 nm	514.5 nm 532.0 nm	350.0 – 514.0nm	514.0 – 532.0 nm	541.6 – 1200.0 nm	25.2 x 35.6 x 1.05	Di02-R532-25x36	$505
573 nm	561.4 nm 568.2 nm	350.0 – 554.0 nm	554.0 – 568.2 nm	578.4 – 1200.0 nm	25.2 x 35.6 x 1.05	Di02-R561-25x36	$505
599.5 nm	593.5 nm 594.1 nm 594.0 ± 0.3 nm	350.0 – 593.5 nm	593.5 – 594.3 nm	605.0 – 1200.0 nm	25.2 x 35.6 x 1.05	Di02-R594-25x36	$505
653 nm	632.8 nm 635.0 +7/–3 nm 647.1 nm	350.0 – 632.8 nm	632.8 – 647.1 nm	658.8 – 1200.0 nm	25.2 x 35.6 x 1.05	Di02-R635-25x36	$505
800 nm	785 ± 5 nm	350.0 – 780.0 nm	780.0 – 790.0 nm	804.3 – 1200.0 nm	25.2 x 35.6 x 1.05	Di02-R785-25x36	$610
840 nm	785.0 ± 5 nm 808.0 + 2 nm 830.0 nm	350.0 – 780.0 nm	780.0 – 830.0 nm	845.0 – 1600.0 nm	25.2 x 35.6 x 1.05	Di02-R830-25x36	$610
993 nm	975.0 ± 5 nm 976.0 nm 980.0 nm	350.0 – 970.0 nm	970.0 – 980.0 nm	998.0 – 1600.0 nm	25.2 x 35.6 x 1.05	Di02-R980-25x36	$610
1078 nm	1030.0 nm 1047.1 nm 1064.0 nm	350.0 – 1030.0 nm	1030.0 – 1064.0 nm	1083.2 – 1600.0 nm	25.2 x 35.6 x 1.05	Di02-R1064-25x36	$610

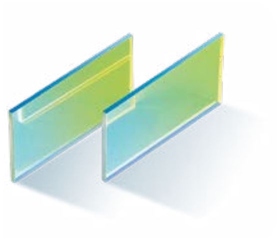
For multiedge laser-optimized dichroic beamsplitters, see page 70 and 72

Laser Dichroic Beamsplitters Common Specifications

Property	Value	Comment
Absolute Reflection	> 98% (s-polarization) > 90% (p-polarization) > 94% (average polarization)	Absolute reflectivity over the specified laser wavelengths/bands
Average Reflection	> 90% (average polarization)	Averaged over extended reflection range
Transmission	> 93%	Averaged over the transmission band above
Angle of Incidence	45.0°	Range for above optical specifications Based on a collimated beam of light
Dependence of Wavelength on Angle of Incidence (Edge Shift)	0.2% / degree	Linear relationship valid between about 40°- 50° (See MyLight for actual performance)
Cone Half Angle (for non-collimated light)	< 0.5°	Rays uniformly distributed and centered at 45°
Transmitted Wavefront Error	< λ / 4 RMS at λ = 633 nm	Peak-to-valley error < 5 x RMS value measured within clear aperture
Beam Deviation	≤ 10 arcseconds	
Second Surface	Anti-reflection (AR) coated	
Flatness (Di01 & Di02)	Reflection of a collimated, Gaussian laser beam with waist diameter up to 2.5 mm causes less than one Rayleigh Range of focal shift after the objective or a focusing lens.	
Filter Orientation	Reflective coating side should face toward light source and sample (see page 29)	
Microscope Compatibility	BrightLine filters are available to fit Leica, Nikon, Olympus, and Zeiss microscopes.	

All other mechanical and reliability specifications are the same as BrightLine dichroic specifications on page 36.

BrightLine® Laser Multiedge Dichroic Beamsplitters



Optimized for the most popular lasers used for fluorescence imaging, including all-solid-state lasers that are replacing older gas-laser technology. Laser Multiedge Dichroic Beamsplitters offer exceptionally high reflection at the laser wavelengths combined with very steep transitions from high reflection to high transmission (< 2.5% of the longest laser wavelength). They also offer sufficient flatness for laser applications *(see Technical Note on page 66).*

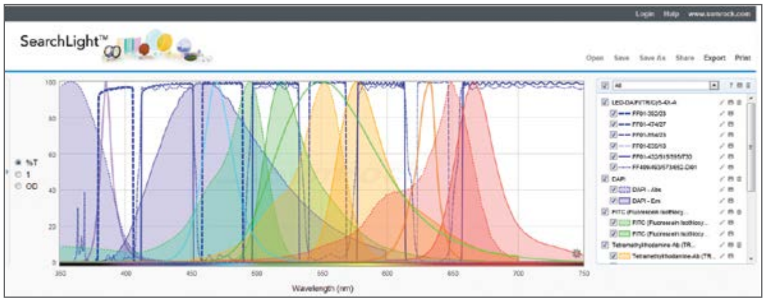
Laser Multiedge Dichroic Beamsplitters

Nominal Edge Wavelength	Laser Wavelengths (nm)	Absolute Reflection Band (nm)	Average Transmission Band (nm)	Size (mm) (L x W x H)	Filter Part Number	Price
499 nm	473 ± 2 , 488 +3 /-2	> 94% 471.0 – 491.0	> 93% 503.3 – 543	25.2 x 35.6 x 1.05	Di01-R488/561-25x36	$555
575 nm	559 +5/-0, 561.4, 568.2	> 94% 559.0 – 568.2	> 93% 582.4 – 800			
420 nm	375 ± 3, 405 ± 5	> 94% 370.0 – 410.0	> 93% 429.5 – 462.0	25.2 x 35.6 x 1.05	Di01-R405/488/594-25x36	$630
497 nm	473 +2/-0, 488 +3/-2	> 94% 473.0 – 491.0	> 93% 502.5 – 574.5			
602 nm	593.5 , 594.1, 594 ± 0.3	> 94% 588.3 – 594.3	> 93% 612.0 – 800.0			
422 nm	375 ± 3, 405 ±5	> 94% 370.0 – 410.0	> 93% 429.5 – 462	25.2 x 35.6 x 1.05	Di01-R405/488/532/635-25x36	$660
498 nm	473+ 2/-0, 488 +3-2	> 94% 473.0 – 491.0	> 93% 502.5 – 518.5			
542 nm	532	> 94% 530.5 – 533.5	> 93% 550 – 613			
656 nm	632.8, 635 +7/-0, 647.1	> 94% 632.8 – 647.1	> 93% 663 – 800			
497 nm	473 +2 /-2, 488 +3 /-2	> 94% 471.0 – 491.0	> 93% 503.5 – 526.5	25.2 x 35.6 x 1.05	Di01-R488/543/635-25x36	$630
552 nm	543 ± 1	> 94% 541.5 – 544.5	> 93% 560.0 – 615.5			
656 nm	632.8, 635 +7/-0, 647.1	> 94% 632.8 – 647.1	> 93% 665.5 – 800.0			

Super-resolution dual-edge and quad-edge dichroic beamsplitters, see page 70

SEARCHLIGHT

SearchLight allows fluorescence microscope users and optical instrument designers to predetermine the optimal fluorophore, light source, detector, and optical filter combinations for their microscope or system. By removing the guesswork and hours of searching multiple sources for spectral data, SearchLight users will be able to eliminate trial-and-error headaches and work more efficiently. Users may select from an extensive collection of preloaded spectra or upload their own spectral data in this free and openly accessible tool. Users can also save and share their data securely.



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StopLine® Notch Dichroic Beamsplitters

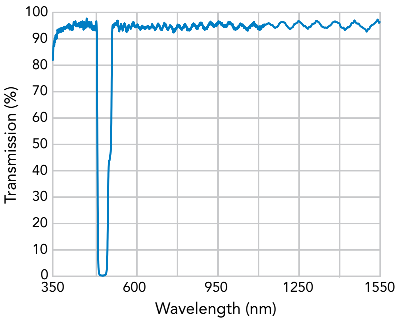
Our single-edge StopLine notch dichroics are designed for a 45° angle of incidence and will reflect just the incident laser source, while allowing wavelengths above and below the notch to transmit. These notch dichroics were designed specifically for Coherent Anti-Stokes Raman Spectroscopy (CARS) applications. The 1064 nm StopLine notch is also suitable for laser tweezing/trapping applications, reflecting just the trapping laser and allowing the fluorescence/bright-field wavelengths to transmit.

Notch Dichroic Beamsplitters

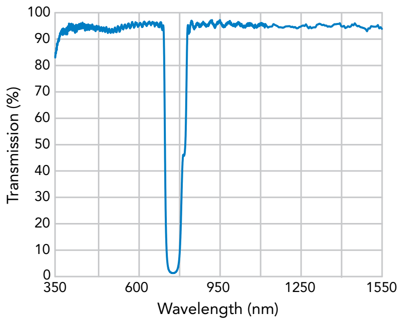
Laser Wavelength	Reflection Value & Wavelength	Avg. Transmission Bands	Size (mm) (L x W x H)	Filter Part Number	Price
405 nm	> 98% 405 nm	> 90% 350 – 386 nm & 434 – 1600 nm	25.2 x 35.6 x 1.05	NFD01-405-25x36	$765
473 nm	> 98% 473 nm	> 90% 350 – 451 nm & 507 – 1600 nm	25.2 x 35.6 x 1.05	NFD01-473-25x36	$765
488 nm	> 98% 488 nm	> 90% 350 – 465 nm & 523 – 1600 nm	25.2 x 35.6 x 1.05	NFD01-488-25x36	$765
532 nm	> 98% 532 nm	> 90% 350 – 507 nm & 570 – 1600 nm	25.2 x 35.6 x 1.05	NFD01-532-25x36	$765
632.8 nm	> 98% 632.8 nm	> 90% 350 – 603 nm & 678 – 1600 nm	25.2 x 35.6 x 1.05	NFD01-633-25x36	$765
785 nm	> 98% 785 nm	> 90% 350 – 749 nm & 841 – 1600 nm	25.2 x 35.6 x 1.05	NFD01-785-25x36	$765
1040 nm 1041 nm	> 98% 1040 nm	> 90% 350 – 992 nm & 1114 – 1600 nm	25.2 x 35.6 x 1.05	NFD01-1040-25x36	$765
1064 nm	> 98% 1064 nm	> 90% 350 – 1015 nm & 1140 – 1600 nm	25.2 x 35.6 x 1.05	NFD01-1064-25x36	$765

Actual Measured Data

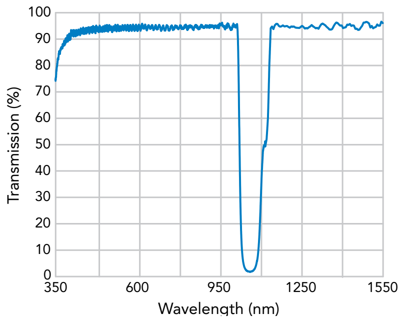
NFD01-532-25x36



NFD01-785-25x36



NFD01-1064-25x36



Notch Dichroic Beamsplitters Common Specifications

Property	Value	Comment
Reflection	> 98% (average polarization)	Absolute reflectivity over the specified laser wavelengths/bands
Transmission	> 90%	Averaged over the transmission band above
Angle of Incidence	45.0°	Range for above optical specifications Based on a collimated beam of light
Transmitted Wavefront Error	< λ / 4 RMS at λ = 633 nm	Peak-to-valley error < 5 x RMS
Second Surface	Anti-reflection (AR) coated	
Flatness	Reflection of a collimated, Gaussian laser beam with waist diameter up to 2.5 mm causes less than one Rayleigh Range of focal shift after the objective or a focusing lens.	
Reliability and Durability	Ion-beam-sputtered, hard-coated technology with epoxy-free, single-substrate construction for unrivaled filter life and no "burn-out" even when subjected to high optical intensities for a prolonged period of time. BrightLine filters are rigorously tested and proven to MIL-STD-810F and MIL-C-48497A environmental standards.	
Filter Orientation	Reflective coating side should face toward light source and sample (see page 29)	
Microscope Compatibility	BrightLine filters are available to fit Leica, Nikon, Olympus, and Zeiss microscopes.	

All other mechanical specifications are the same as BrightLine dichroic specifications on page 36.

LaserMUX™ Beam Combining Filters

LaserMUX filters are designed to efficiently combine or separate multiple laser beams at a 45° angle of incidence. These dichroic laser beam combiners are optimized to multiplex (MUX) popular laser lines, and can also be used in reverse to demultiplex (DEMUX). The ultra-low autofluorescence filters are ideally suited for OEM multi-laser fluorescence imaging and measurement applications including laser microscopy and flow cytometry, as well as for myriad end-user applications in a laboratory environment.

With high reflection and transmission performance at popular laser lines, these filters allow combining multiple different laser beams with exceptionally low loss. LaserMUX filters are hard-coated and come in an industry-standard 25 mm diameter x 3.5 mm thick black-anodized aluminum ring with a generous 22 mm Clear Aperture. Semrock also stocks a wide variety of other single-edge dichroic beamsplitters and multiedge dichroic beamsplitters.

Reflected Laser Wavelengths	Reflection Band	Transmission Laser Wavelengths	Passband	Size (Diameter x Thickness)	Filter Part Number	Price
375 ± 3 nm 405 +10/-5 nm	372.0 nm – 415.0 nm	440 +3/-1, 457.9, 473 +5/-0, 488 +3/-2, 514.5, 515, 532, 543.5, 561.4, 568.2, 594.1, 632.8, 635 +7/-0, 647.1 nm	439.0 nm – 647.1 nm	25 mm x 3.5 mm	LM01-427-25	$285
440 +3/-1 nm 457.9 nm	439.0 nm – 457.9 nm	473 +5/-0, 488 +3/-2, 514.5, 515, 532, 543.5, 561.4, 568.2, 594.1, 632.8, 635 +7/-0, 647.1 nm	473.0 nm – 647.1 nm	25 mm x 3.5 mm	LM01-466-25	$285
457.9 nm 473 nm	457.9 nm – 473.0 nm	488 +3/-0, 514.5, 515, 532, 543.5, 561.4, 568.2, 594.1, 632.8, 635 +7/-0, 647.1 nm	488.0 nm – 647.1 nm	25 mm x 3.5 mm	LM01-480-25	$285
473 +5/-0 nm 488 +3/-2 nm 1064.2 nm	473.0 nm – 491.0 nm	514.5, 515, 532, 543.5, 561.4, 568.2, 594.1, 632.8, 635 +7/-0, 647.1 nm	514.5 nm – 647.1 nm	25 mm x 3.5 mm	LM01-503-25	$285
514.5 nm 515 nm 532 nm 543.5 nm	514.5 nm – 543.5 nm	561.4, 568.2, 594.1, 632.8, 635 +7/-0, 647.1, 671, 676.4, 785 ± 5 nm	561.4 nm – 790.0 nm	25 mm x 3.5 mm	LM01-552-25	$285
561.4 nm 568.2 nm 594.1 nm	561.4 nm – 594.1 nm	632.8, 635 +7/-0, 647.1, 671, 676.4, 785 ± 5 nm	632.8 nm – 790.0 nm	25 mm x 3.5 mm	LM01-613-25	$285
632.8 nm 635 +7/-0 nm 647.1 nm	632.8 nm – 647.1 nm	671, 676.4, 785 ± 5 nm	671.0 nm – 790.0 nm	25 mm x 3.5 mm	LM01-659-25	$285

LaserMUX Common Specifications

Property	Value	Comment
Absolute Reflection	> 99% (s-polarization) > 96% (p-polarization) > 98% (average polarization)	For reflected laser wavelenghts
Average Reflection	> 98% (average polarization)	For reflection band
Absolute Transmission	> 94% (s-polarization) > 95% (p-polarization) > 95% (average polarization)	For transmitted laser wavelengths
Average Transmission	> 95% (average polarization)	For nominal passband
Angle of Incidence	45.0°	Based on a collimated beam of light
Performance for Non-collimated Light	The high-transmission portion of the long-wavelength edge and the low-transmission portion of the short-wavelength edge exhibit a small "blue shift" (shift toward shorter wavelengths). Even for cone half angles as large as 15° at normal incidence, the blue shift is only several nm.	
Clear Aperture	≥ 22 mm	For all optical specifications
Overall Mounted Diameter	25.0 mm + 0.0 / - 0.1 mm	Black anodized aluminum ring
Overall Mounted Thickness	3.5 mm + 0.0 +/- 0.1 mm	Black anodized aluminum ring
Unmounted Thickness	2.0 mm +/- 0.1mm	
Beam Deviation	< 30 arcseconds	Based on 20 arcsecond substrate wedge angle
Laser Damage Threshold	1 J/cm² @ 532 nm (10 ns pulse width)	Tested for LM01-552 nm filter only (see page 109)

Filters for Yokogawa CSU Confocal Scanners

Semrock offers fluorescence filters that enable you to achieve superior performance from your real-time confocal microscope system based on the Yokogawa CSU scanner. Like all BrightLine® filters, they are made exclusively with hard, ion-beam-sputtered coatings to provide unsurpassed brightness and durability. These filters are compatible with all scan head system configurations, regardless of the microscope, camera, and software platforms you have chosen.

Dichroic Beamsplitters for the Yokogawa CSU confocal scanners

These beamsplitters transmit the excitation laser light and reflect the fluorescence signal from the sample. Because the filters are precisely positioned between the spinning microlens disk and the pinhole array disk, they have been manufactured to exacting physical and spectral tolerances. Dichroic installation should be performed by Yokogawa-authorized personnel.

CSU-X1 filters support CSU22 and CSU-X1 scanheads

Transmitted Laser Wavelengths	Reflection Bands	Semrock Part Number	Price
405 nm, 488 nm, 561-568 nm, 638-647 nm	422-473 nm, 503-545 nm, 586-620 nm, 665-750 nm	Di01-T405/488/568/647-13x15x0.5	$855
400-410 nm, 488 nm, 561 nm	422-473 nm, 503-544 nm, 578-750 nm	Di01-T405/488/561-13x15x0.5	$820
405-488 nm	508-700 nm	Di01-T488-13x15x0.5	$725

Emission Filters for the Yokogawa CSU confocal scanners

These filters mount outside the CSU head in a filter wheel, and provide the utmost in transmission of the desired fluorescence signal while blocking the undesired scattered laser light and autofluorescence.

Blocked Laser Wavelengths	Transmission Bands	Size (Diameter x Thickness)	Semrock Part Number	Price
405 nm, 442 nm, 488 nm, 561 – 568 nm	503 – 546 nm, 583 – 700 nm	25.0 mm x 3.5 mm	Em01-R488/568-25	$530

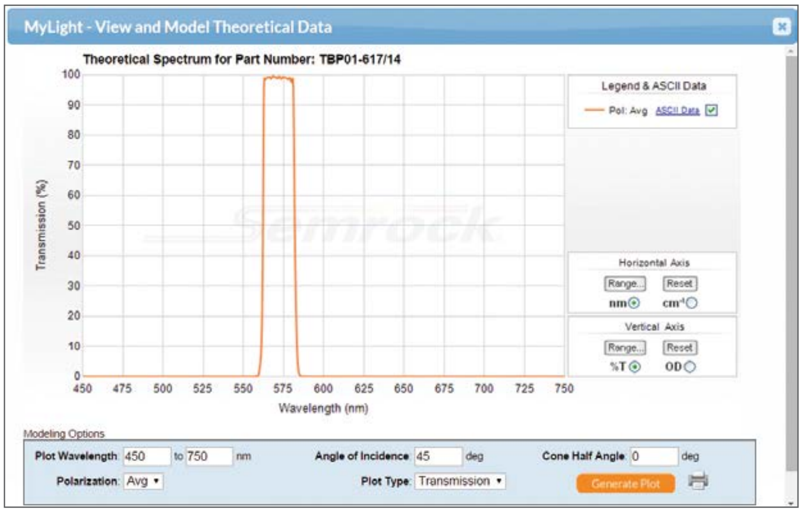
See spectra graphs and ASCII data for these filter sets at www.idex-hs.com/semrock

MyLight™

Interested in seeing how a Semrock standard filter behaves at a particular angle of incidence, state of polarization or cone half angle of illumination? Simply click the

Click for MyLight Tool

button located above the spectral graph and the MyLight window will access our theoretical design data and allow you to see spectral shifts in filter performance under varying illumination conditions. You can also expand (or contract) the displayed spectral range and assess filter performance in real time that previously required you to contact us and iterate towards an answer. MyLight data can be downloaded as an ASCII file and the graphs printed or saved as PDFs.



TECHNICAL NOTE

Measurement of Optical Filter Spectra

Due to limitations of standard metrology techniques, the measured spectral characteristics of thin-film interference filters are frequently not determined accurately, especially when there are steep and deep edges. The actual blocking provided by an optical filter is determined not only by its designed spectrum, but also by physical imperfections of the filter, such as pinholes generated during the thin-film coating process, dirt and other surface defects, or flaws in the filter mounting. Generally commercially available spectrophotometers are used to measure the transmission and OD spectral performance of optical filters. However, these instruments can have significant limitations when the optical filters have high edge steepness and/or very deep blocking.

As a result of these limitations, three main discrepancies appear between an actual filter spectrum and its measured representation (see Fig. 1). The first discrepancy is the "rounding" of sharp spectral features. This effect results from the non-zero bandwidth of the spectrophotometer probe beam. The second measurement discrepancy arises from limited sensitivity of the spectrophotometer. The third discrepancy is unique to measurements of very steep transitions from high blocking to high transmission, and is referred to as a "sideband measurement artifact." This artifact arises from the non-monochromatic probe beam that also has weak sidebands at wavelengths outside of its bandwidth.

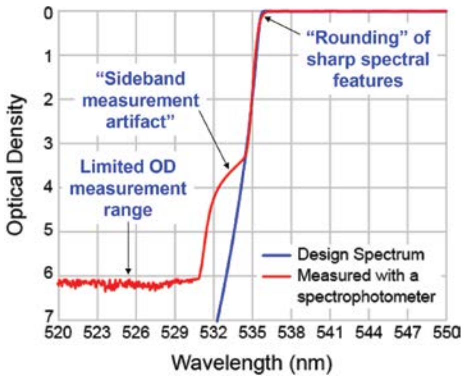


Figure 1: Measurement artifacts observed using a commercial spectrophotometer.

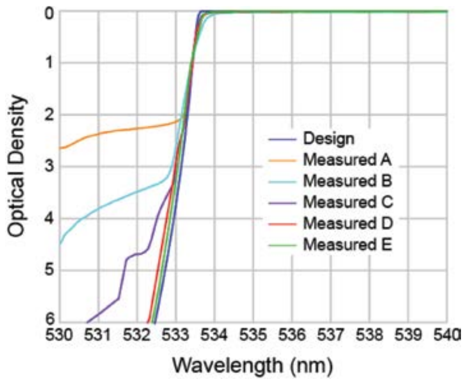


Figure 2: Design and measurement spectra of the same filter (specified in Fig. 1) using different measurement approaches as explained in the text.

Semrock utilizes different measurement approaches to evaluate filter spectra. As an example, Figure 2 shows five measured spectra of the steep edge of an E-grade RazorEdge® filter that is guaranteed to block a laser line at 532 nm with OD > 6 and transition to high transmission within 0.5% of the laser wavelength (by 534.7 nm). The measured spectra are overlaid on the design spectrum of the filter (blue line). As observed in this figure, choice of a particular measurement instrument and technique greatly influences the measured spectrum of a filter. Measurement method "A" in this graph is from a custom-built spectrophotometer. This measurement uses instrument settings – such as short detector integration time and low resolution – that are optimized for very rapid data collection from a large number of sample filters during thin-film filter manufacturing process. However this method has poor sensitivity and resolution. Measurement method "B" uses a standard commercial spectrophotometer (PerkinElmer LAMBDA 900 series). All of the discrepancies between the actual filter spectrum and the measured spectrum as noted above are apparent in this measurement. Measurement methods "C" and "D" utilize the same custom-built spectrophotometer from method "A." The basic principle of operation of this spectrophotometer is shown in Fig. 3. This instrument uses a low-noise CMOS camera (i.e., detector array) capable of measuring a wide range of wavelengths simultaneously. Measurement method "C" uses instrument settings (primarily integration time and resolution) designed to provide enhanced measurement of the steep and deep edge. However, the "sideband measurement artifact" is still apparent. Measurement method "D" is a modification of method "C" that applies additional filtering to remove this artifact. Method "E" shows the results of a very precise measurement made with a carefully filtered 532 nm laser and angle tuning of the filter itself. Experimentally acquired transmission vs. angle data is converted into transmission vs. wavelength results, using a theoretical model. Clearly, this measurement method comes closest to the actual design curve; however it is not as suitable for quality assurance of large volumes of filters.

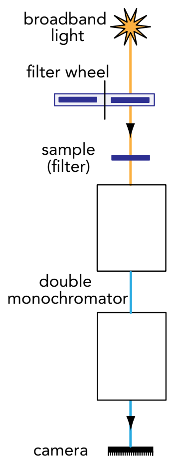


Figure 3: A custom-built spectrophotometer that enables faster and more accurate measurements

In summary, it is important to understand the measurement techniques used to generate optical filter spectra, as these techniques are not perfect. Use of the appropriate measurement approach for a given filter or application can reduce errors as well as over-design of experiments and systems that use filters, thus optimizing performance, results, and even filter cost.

For additional information on this topic visit our website: www.idex-hs.com/semrock

VersaChrome® Tunable Filters

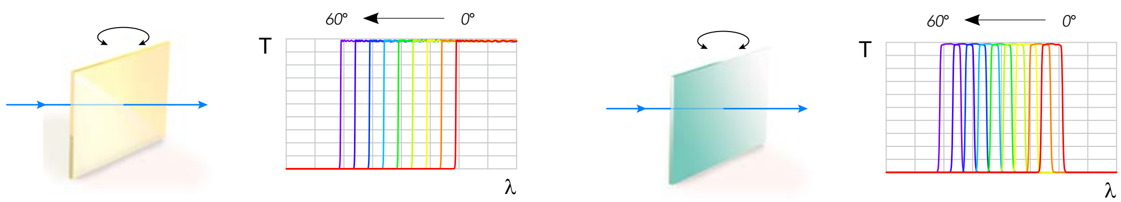
TECHNICAL NOTE

Tunable Bandpass Filters

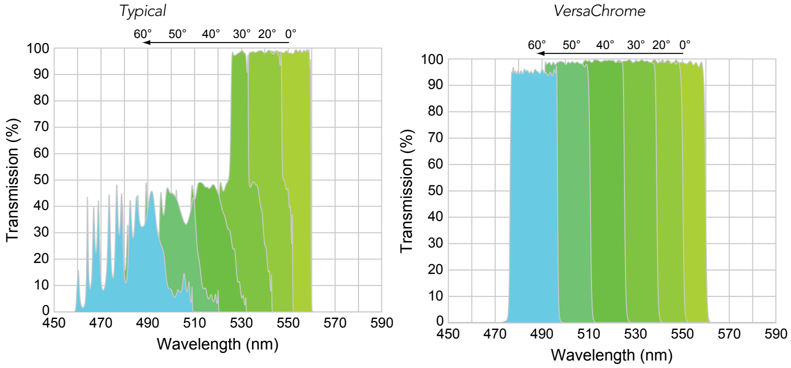
Thin-film filters are the ideal solution for wavelength selection in most optical systems due to exceptionally high transmission at passband wavelengths (close to 100%), very steep spectral edges, and blocking of optical density 6 or higher over wide spectral regions for maximum noise suppression. However, thin-film filters are considered to be "fixed" filters only, such that changing the spectral characteristics requires swapping filters, thus constraining system size, speed, and flexibility for systems that require dynamic filtering. Diffraction gratings are often used when wavelength tuning is required, but gratings exhibit inadequate spectral discrimination, have limited transmission, are polarization dependent, and are not capable of transmitting a beam carrying a two-dimensional image since one spatial dimension carries spectral information.

Fluorescence microscopy and other fluorescence imaging and quantitation applications, hyperspectral imaging, high-throughput spectroscopy, and fiber-optic telecommunications systems can all benefit from tunable optical filters with the spectral and two-dimensional imaging performance characteristics of thin-film filters and the center wavelength tuning flexibility of a diffraction grating. There exist several technologies that combine some of these characteristics, including liquid-crystal tunable filters, acousto-optic tunable filters, and linear-variable filters, but none are ideal and all have significant additional limitations.

Semrock has developed a revolutionary patented optical filter technology: thin-film optical filters that are tunable over a very wide range of wavelengths by adjusting the angle of incidence with essentially no change in spectral performance. As the diagrams (below) indicate, both edge filters and bandpass filters with wide tunability are possible.



It is well-known that the spectrum of any thin-film filter shifts toward shorter wavelengths when the angle of incidence of light upon the filter is increased from 0° (normal incidence) to larger angles. In general, however, the filter spectrum becomes highly distorted at larger angles, and the shift can be significantly different for s- and p-polarized light, also leading to a strong polarization dependence at higher angles. The graph on the left shows the spectrum of a typical fluorescence filter at six different angles of incidence ranging from 0° to 60°. Note that for angles greater than about 30° transmission for s-polarized light is approximately 0% and the ripple for p-polarized light is intolerably high.



In contrast, the spectrum of a Semrock VersaChrome bandpass filter (right) maintains high transmission, steep edges, and excellent out-of-band blocking over the full range of angles from 0 to 60°. At the heart of this invention is Semrock's discovery of a way to make very steep edge filters (both long-wave-pass, or "cut-on," and short-wave-pass, or "cut-off," type filters) at very high angles of incidence with essentially no polarization splitting and nearly equal edge steepnesses for both polarizations of light. An equally significant and related property is that the high edge steepness values for both polarizations and the lack of polarization splitting apply at all angles of incidence from normal incidence (0°) to very high angles. As a consequence, it is possible to angle tune the edge filter, or a combination of edge filters, over this full range of angles with little to no change in the properties of the edges regardless of the state of polarization of the light passing through the filter. And thus it is now possible to make tunable thin-film filters which operate over a very wide range of wavelengths – Semrock's VersaChrome series of filters are specified with a tuning range of at least 11% of the filter edge or center wavelength at normal incidence.

VersaChrome® Tunable Filters

TECHNICAL NOTE

Spectral Imaging with VersaChrome® Filters

Conventional spectral imaging systems are generally not able to offer the key advantages of thin-film interference filters, i.e., high transmission combined with steep spectral edges and high out-of-band blocking. Now with VersaChrome filters, these advantages can be realized in simple spectral imaging systems for applications ranging from fluorescence microscopy to hyperspectral imaging.

To demonstrate spectral imaging in a fluorescence microscope, a “lambda stack” of images (corresponding to a nearly continuous series of emission wavelengths) was acquired of a sample labeled with three spectrally overlapping fluorophores using a Semrock VersaChrome tunable filter (TBP01-617/14) placed in the emission channel of a standard upright microscope. Figure 1 shows six of the 61 images taken at 1 nm intervals, and Figure 2 shows measured intensity spectra taken from parts of the image where only a single fluorophore is present. The nucleus labeled with SYTOX® Orange can be easily discriminated from the other cellular structures (Fig. 1). However, since the F-actin and mitochondria are labeled with fluorophores that are highly overlapping (Alexa Fluor™ 568 and MitoTracker® Red, respectively), linear unmixing is necessary to discern the corresponding cellular constituents. Images deconvolved with linear unmixing are shown in Figure 3.

It is important to note that the spectral properties of these tunable filters are almost identical for both s- and p-polarizations of light – a feature that cannot be easily obtained using liquid-crystal and acousto-optic tunable filters. Polarization independence is highly desirable for spectral imaging systems, and yet polarization limitations of current tunable filters account for a loss of at least half of the signal in most instruments. Therefore VersaChrome filters not only enhance the throughput in spectral imaging but they also greatly simplify the complexity of instrumentation.

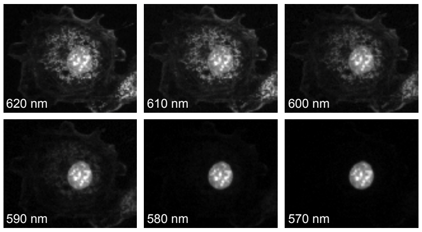


Figure 1

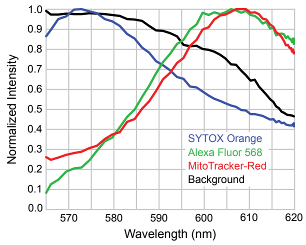


Figure 2

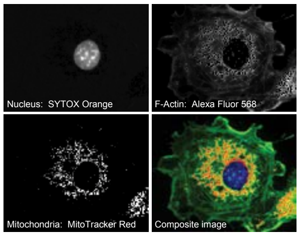


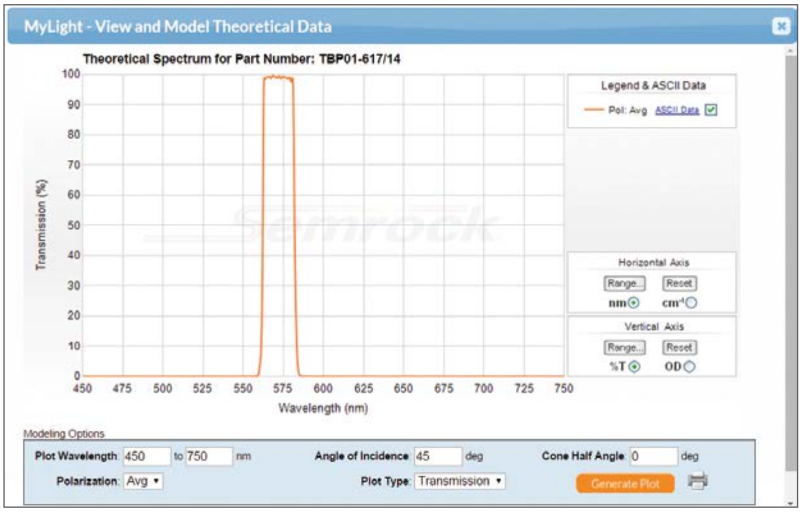
Figure 3

MyLight™

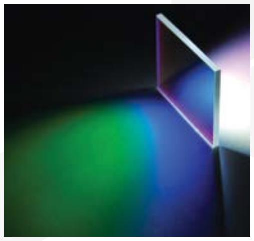
Interested in seeing how a Semrock standard filter behaves at a particular angle of incidence, state of polarization or cone half angle of illumination? Simply click the

Click for MyLight Tool

button located above the spectral graph and the MyLight window will access our theoretical design data and allow you to see spectral shifts in filter performance under varying illumination conditions. You can also expand (or contract) the displayed spectral range and assess filter performance in real time that previously required you to contact us and iterate towards an answer. MyLight data can be downloaded as an ASCII file and the graphs printed or saved as PDFs.



VersaChrome® Tunable Bandpass Filters



These game-changing optical filters do what no thin-film filter has ever done before: offer wavelength tunability over a very wide range of wavelengths by adjusting the angle of incidence with essentially no change in spectral performance. VersaChrome filters combine the highly desirable spectral characteristics and two-dimensional imaging capability of thin-film optical filters with the wavelength tuning flexibility of a diffraction grating. They are so innovative, they have been patented: U.S. Patents No. 8,441,710 and No. 9,304,237.

With a tuning range of greater than 11% of the normal-incidence wavelength (by varying the angle of incidence from 0 to 60°), only five filters are needed to cover the full visible spectrum. They are ideal for applications ranging from fluorescence imaging and measurements to hyperspectral imaging and high-throughput spectroscopy. With their excellent polarization insensitivity and high optical quality and damage threshold, they are well-suited for a wide range of laser applications as well.

Extended Overlap Tunable Bandpass Filters

Between 4–12 nm of additional overlap designed to allow for system variations such as AOI accuracy, cone-half angles, etc. OD 6 blocking over full tuning range for the most sensitive of measurements.

Tunable Color Range	At 60° CWL <	Average Transmission / Bandwidth	At 0° CWL >	Average Transmission / Bandwidth	Size (L x W x H)	Part Number	Price
	448.8	> 85% over 15 nm	501.5	> 90% over 15 nm	25.2 x 35.6 x 2.0 mm	TBP01-501/15-25x36	$2110
	501.5	> 85% over 14 nm	561.0	> 90% over 14 nm	25.2 x 35.6 x 2.0 mm	TBP01-561/14-25x36	$2110
	561.5	> 80% over 14 nm	627.7	> 90% over 14 nm	25.2 x 35.6 x 2.0 mm	TBP01-628/14-25x36	$2110
	627.7	> 85% over 13 nm	703.8	> 90% over 13 nm	25.2 x 35.6 x 2.0 mm	TBP01-704/13-25x36	$2110
	703.8	> 85% over 12 nm	790.0	> 90% over 12 nm	25.2 x 35.6 x 2.0 mm	TBP01-790/12-25x36	$2110
	790.0	> 85% over 11 nm	900.0	> 90% over 11 nm	25.2 x 35.6 x 2.0 mm	TBP01-900/11-25x36	$2110

Extended Overlap Filter Specifications

Property	Value	Comments
Guaranteed Transmission	See table above	Averaged over the passband centered on the CWL
Blocking	OD_{avg} > 6 UV - 1100 nm (0°) OD_{avg} > 6 UV - 925 nm (60°)	Excluding passband
Nominal Effective Index of Refraction (n_{eff})*	1.83	Nominal value, see website for specific n_{eff}

**See technical note on effective index on page 106*

All VersaChrome Filters Common Specifications

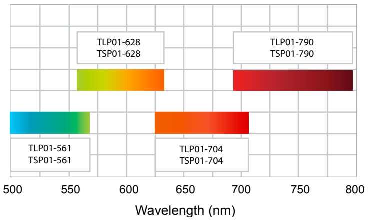
Property	Value	Comments
Substrate Material	Fused Silica	
Coating Type	Sputtered	
Transverse Dimensions and Tolerance	25.2 mm x 35.6 mm ± 0.1 mm	
Thickness and Tolerance	2.0 mm ± 0.1 mm	
Clear Aperture	> 80%	Elliptical, for all optical specifications
Transmitted Wavefront Error	< λ/4 RMS at λ = 633 mm	Peak-to-valley error < 5 x RMS
Beam Deviation	≤ 10 arcseconds	Measured per inch
Surface Quality	60-40 scratch-dig	Measured within clear aperture
Orientation	Coating (text) towards light	See page 29 for marking diagram

	Filter Holder	Part Number	Price
	Designed for single, 25.2 x 35.6 x 1.0 to 2.0 mm dichroic beamsplitters, fits on motor for rotating tunable filters.	FH1	$145

VersaChrome Edge™ Tunable Filters

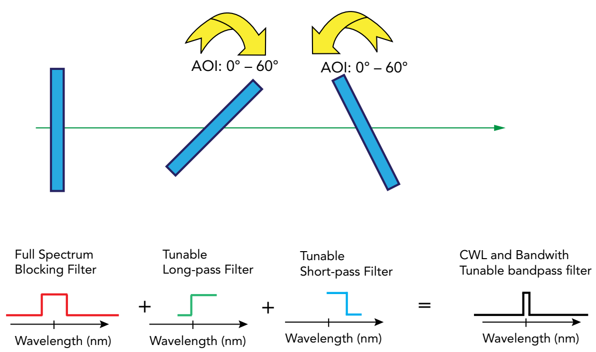
TECHNICAL NOTE

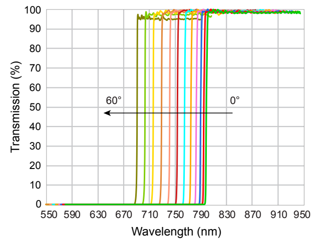
Tunable Edge Filters

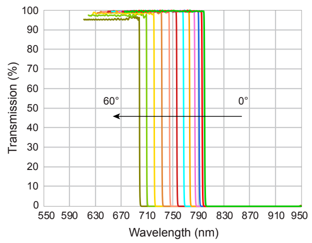


As fluorescence technology evolves, so too must the optical filters that are key to detection. Almost every new fluorophore requires its own bandpass filter to yield the best brightness or contrast. That optimal bandpass may need to change in order to maximize signal to noise when used in conjunction with other fluorophores. The typical approach to designing a new optical system or developing a new test (new fluorophore, chemistry, etc.) is to try an assortment of our catalog bandpass filters that span the right wavelength range, testing and selecting the one that performs best in practice. While Semrock's online plotting and analysis tool SearchLight (searchlight.idex-hs.com) makes analysis and selection of the best prospective bandpass filters quick and easy, sometimes there is no perfect match to be found off the shelf.

Until now, customers unable to find a catalog bandpass filter to meet their needs had to choose between using a suboptimal filter or purchasing a prototype run of a custom filter specification at significant cost. VersaChrome Edge tunable filters seek to fill that gap, allowing both researchers and instrument developers the ability to dynamically create and optimize their own bandpass filter shapes by combining three simple, versatile filters.



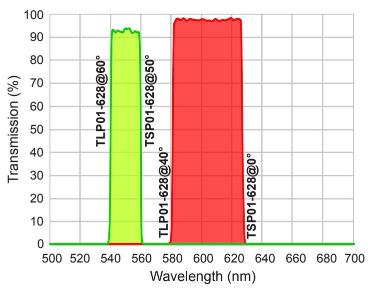




With the VersaChrome Edge Tunable Filters, Semrock is offering a new way to prototype. Our three new families of filters are designed to work together to create the equivalent of a single passband filter in the visible or near infrared. This allows researchers and instrument designers alike to not only create the bandpass they need, but also to fine-tune edge positions and passband width to maximize brightness and contrast/signal-to-noise in real time, within their measurement setup.

VersaChrome Edge tunable filters now allow you to design and optimize that perfect match for yourself – not on paper, but in the lab. The principle is simple: combine a long-wave pass filter with a short-wave pass filter to create the bandpass shape, and place in tandem with a full-spectrum blocking filter to provide extended out-of-band blocking. Together, the three filters perform like a traditional bandpass filter. The true elegance in the solution, however, lies in the edge filters themselves. By using our VersaChrome Edge tunable long wave pass and short wave pass filters, each edge can be angle-tuned to the precise cut-on or cut-off wavelength you need. Extended blocking down to UV wavelengths (250 nm) and up to the near infrared (NIR) can be provided by the addition of a full spectrum blocking filter.

The result is that, by combining angle-tuned TLP and TSP filters with a full-spectrum blocking filter, it is possible to create a passband filter with any center wavelength over a range of wavelengths in the visible and near infrared, and a passband width (FWHM) of any width from ≤ 5 nm to at least 12% of the CWL (~75 nm at 628 nm, or 120 nm at 1000 nm). Edge filters are available to independently control each edge to generate the exact passband required with edge wavelengths from 400 nm to beyond 1100 nm.



Edge Type	Passband edge at (nm)	Use these filters	Set at these AOIs
LWP	727.5	TLP01-790	45.58°
SWP	768.5	TLP01-790	29.57°

Input the desired Center-Wavelength (CWL) and Guaranteed-Minimum-Bandwidth (GMBW) or Full-Width-Half-Maximum (FWHM) to achieve a required passband using Semrock's VersaChrome Edge Tunable Filter Calculator (see page 82) to calculate which filters and rotational angles will achieve this result.

VersaChrome Edge™ Tunable Filters

VersaChrome Edge tunable filters unlock virtually unlimited spectral flexibility for fluorescence microscopy and hyperspectral imaging, as well as for spectroscopy applications. By utilizing a combination of VersaChrome Edge tunable long-wave-pass and short-wave-pass filters, a bandpass filter as narrow as sub 5 nm FWHM or as wide as 12% of the center wavelength throughout the visible and near-infrared wavelength ranges can be created. Semrock's patented tunable thin-film filters can't be found anywhere else in the market. U.S. Patents No. 8,441,710 and No. 9,304,237.

VersaChrome Edge Tunable Longpass Filters

Tunable Color Range	At 60° Edge ≤	Avg. Transmission / Bandwidth	At 0° Edge ≥	Avg. Transmission / Bandwidth	$OD_{avg} \geq 6$	Part Number	Price
	561.0	> 90% over 82 nm	628.0	> 93% over 82 nm	488 nm to edge	TLP01-628-25x36	$1765
	628.0	> 90% over 82 nm	704.0	> 93% over 92 nm	547 nm to edge	TLP01-704-25x36	$1765
	704.0	> 90% over 92 nm	790.0	> 93% over 103 nm	613 nm to edge	TLP01-790-25x36	$1765
	790.0	> 90% over 101 nm	887.0	> 93% over 114 nm	687 nm to edge	TLP01-887-25x36	$1765
	887.0	> 90% over 114 nm	995.0	> 93% over 127 nm	772 nm to edge	TLP01-995-25x36	$1765

VersaChrome Edge Tunable Shortpass Filters

Tunable Color Range	At 60° Edge ≤	Avg. Transmission / Bandwidth	At 0° Edge ≥	Avg. Transmission / Bandwidth	$OD_{avg} \geq 6$	Part Number	Price
	561.0	> 90% over 66 nm	628.0	> 93% over 74 nm	Edge to 720 nm	TSP01-628-25x36	$1765
	628.0	> 90% over 82 nm	704.0	> 93% over 83 nm	Edge to 808 nm	TSP01-704-25x36	$1765
	704.0	> 90% over 92 nm	790.0	> 93% over 93 nm	Edge to 907 nm	TSP01-790-25x36	$1765
	790.0	> 90% over 89 nm	887.0	> 93% over 100 nm	Edge to 1017 nm	TSP01-887-25x36	$1765
	887.0	> 90% over 100 nm	995.0	> 93% over 112 nm	Edge to 1140 nm	TSP01-995-25x36	$1765

VersaChrome Edge Common Specifications

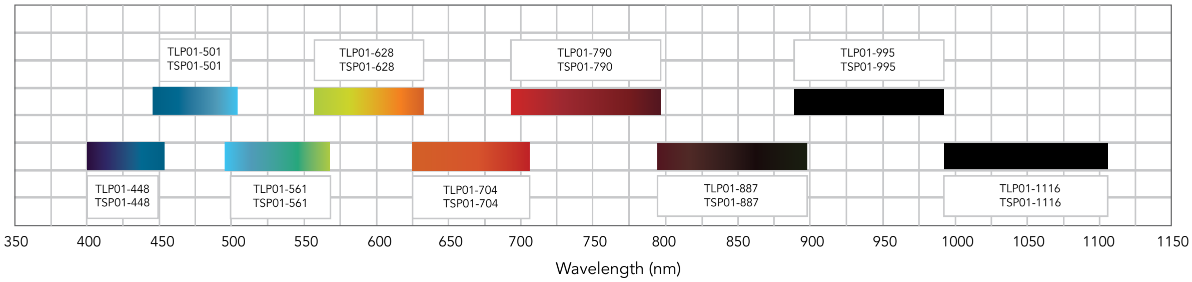
Property	Value	Comments
Guaranteed Transmission	See tables above	Averaged over the passband, beginning 0.5% away from 50% transmission edge
LWP Blocking	OD_{avg} > 6 from λ_{Short} to 98% of λ_{Edge} (0°) OD_{avg} > 6 from λ_{Short} to 97.5% of λ_{Edge} (60°)	OD = - $\log_{10}$ (transmission) λ_{Edge} & λ_{Short} listed in table
SWP Blocking	OD_{avg} > 6 from 102% of λ_{Edge} to λ_{Long} (0°) OD_{avg} > 6 from 102.5% of λ_{Edge} to λ_{Long} (60°)	OD = - $\log_{10}$ (transmission) λ_{Edge} & λ_{Long} listed in table
Nominal Effective Index of Refraction (n_{eff})*		See website for specific filter n_{eff}

*All other mechanical specifications are the same as the VersaChrome specifications on page 79.

VersaChrome Edge™ Tunable Filters

BrightLine® Full Spectrum Blocking Single-band Bandpass Filters

Center Wavelength	UV-VIS Blocking Band	Avg. Transmision / Bandwidth	VIS-IR Blocking Band	Housed Size (Diameter x Thickness)	Glass Thickness	Part Number	Price
403 nm	250 – 348 nm	> 90% 355 – 450 nm	459 – 1200 nm	25 mm x 3.5 mm	2.0 mm	FF01-403/95-25	$555
451 nm	250 – 390 nm	> 93% 398 – 504 nm	514 – 1200 nm	25 mm x 3.5 mm	2.0 mm	FF01-451/106-25	$525
505 nm	250 – 436 nm	> 93% 445 – 564 nm	575 – 1200 nm	25 mm x 3.5 mm	2.0 mm	FF01-505/119-25	$525
565 nm	250 – 488 nm	> 93% 498 – 631 nm	644 – 1200 nm	25 mm x 3.5 mm	2.0 mm	FF01-565/133-25	$525
632 nm	250 – 547 nm	> 93% 558 – 706 nm	720 – 1200 nm	25 mm x 3.5 mm	2.0 mm	FF01-632/148-25	$525
709 nm	250 – 613 nm	> 93% 625 – 792 nm	808 – 1200 nm	25 mm x 3.5 mm	2.0 mm	FF01-709/167-25	$525
795 nm	250 – 687 nm	> 93% 701 – 889 nm	907 – 1200 nm	25 mm x 3.5 mm	2.0 mm	FF01-795/188-25	$555
893 nm	250 – 772 nm	> 93% 788 – 997 nm	1017 – 1700 nm	25 mm x 3.5 mm	2.0 mm	FF01-893/209-25	$555
1001 nm	250 – 866 nm	> 93% 884 – 1118 nm	1140 – 1700 nm	25 mm x 3.5 mm	2.0 mm	FF01-1001/234-25	$555



PRODUCT NOTE

VersaChrome Edge Tunable Filter Calculator

Semrock's VersaChrome Edge filters unlock virtually unlimited spectral flexibility for fluorescence microscopy and hyperspectral imaging as well as spectroscopy applications. By utilizing a combination of VersaChrome Edge™ tunable long-wave-pass and short-wave-pass filters, a bandpass filter as narrow as ≤ 5 nm FWHM or as wide as 12% of the center wavelength throughout the visible and near-infrared wavelength ranges can be created.

Input the desired Center-Wavelength (CWL) and Guaranteed-Minimum-Bandwidth (GMBW) or Full-Width-Half-Maximum (FWHM) for a required passband to calculate which filters and rotational angles will achieve this result.

Required Inputs

CWL

FWHM

---OR---

GMBW

Calculate Reset

Optional Inputs - Edge positions available on package label.

	Edge at 60°	Edge at 0°
LWP		
SWP		

Compensation plate thickness (mm)

Accuracy within ±1nm

For more information visit: www.idex-hs.com/versachrome-edge-tunable-filters
www.idex-hs.com/versachrome-calculator

Semrock Optical Filter Advantage

With proven results, we give you access to high-level engineering know-how that will help make every photon count in your system. As the pioneering experts in optical filters for life science, analytical instrumentation, and medical diagnostics applications, we have continually set the standards for advanced performance and reliability. Our unwavering commitment to quality and customer service allows us to consistently deliver much more than just optical filters.

Overall, Semrock optical filters are brighter, more durable, and spectrally more sophisticated than those made by other coating technologies, driving significant improvements for our customers and their applications: faster measurement times, reduced downtime, repeatable manufacturing, and lower optical component count.

We make our unique products with lot-to-lot consistency in high volumes, providing our OEM customers with a dependable supply. We find solutions "within the box" of our standard catalog, and "out of the box" with the help of our expert design staff, and we apply each strategy in the right proportion.

Looking for a partner who prioritizes your OEM system needs? Learn more at www.idex-hs.com/semrock

IDEX HEALTH & SCIENCE | Semrock

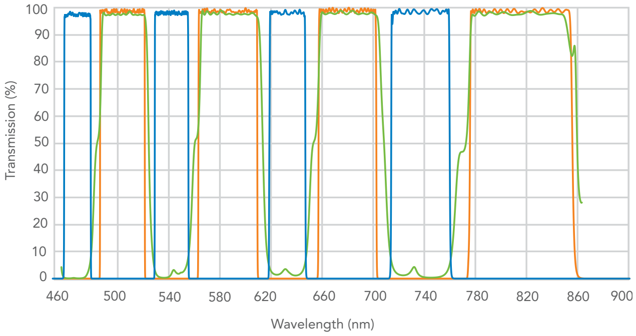
Intelligent Solutions for Life®
Fluidics | Optics | Consumables | Assemblies

Outstanding Sensitivity in Real-time Imaging

Fluorescence Guided Surgery enables surgeons to identify critical structures, tumor margins, and blood flow in tissues in real time. Due to high levels of ambient lighting in a surgical environment, filter design is critical in maximizing detection sensitivity and limiting background contamination. Several factors influence the efficiency of fluorescence detection, and all components in the imaging system therefore require careful design and optimization.

We can help you design filters that achieve the best fluorescence intraoperative visualization through our multidisciplinary expertise across optical filtering, lenses, and illumination systems.

- Superior brightness and contrast
- State-of-the-art simultaneous multiple fluorophore imaging
- Improved rejection of ambient light



A full multiband set optimized for high transmission and steep edges with deep blocking between bands.

Partner with our RD&E team for rapid prototypes to high-volume production with lot to lot consistency. Semrock optical filters are designed with high complexity, signal efficiency, and wavelength filtering with deepest out-of-band blocking even at high angles of incidence (AOI).

Learn more at www.idex-hs.com/semrock

Laser Wavelength Reference Table

Laser Line	Laser Type	Prominent Applications	Verona™ Pg 90	RazorEdge® (LWP) Pg 93	MaxLine® Pg 99	MaxDiode™ Pg 101	StopLine® Pg 103	EdgeBasic™ (LWP) Pg 91	EdgeBasic™ (SWP) Pg 91	BrightLine® Laser Dichroics Pg 70	LaserMUX™ Pg 74	Stopline® Dichroics Pg 73
224.3	HeAg gas	Raman		●								
244	Doubled Ar-ion gas	Raman		●								
248.6	NeCu gas	Raman		●	●							
257.3	Doubled Ar-ion gas	Raman		●								
266.0	Quadrupled DPSS	Raman		●	●					●		
325.0	HeCd gas	Raman		●	●					●		
355.0	Tripled DPSS	Raman		●	●			●		●		
363.8	Ar-ion gas	Raman		●	●			●				
~ 375	Diode	Fluorescence (DAPI)				●		●		●	●	
~ 405	Diode	Fluorescence (DAPI)				●	●	●		●	●	●
~ 440	Diode	Fluorescence (CFP)				●				●	●	
441.6	HeCd gas	Raman, Fluorescence (CFP)		●	●					●	●	
457.9	Ar-ion gas	Fluorescence (CFP)		●	●			●		●	●	
~ 470	Diode	Fluorescence (GFP)				●				●	●	
473.0	Doubled DPSS	Fluorescence (GFP), Raman		●	●	●	●	●		●		●
488.0	Ar-ion gas	Raman, Fluorescence (FITC, GFP)		●	●		●	●		●	●	●
~ 488	Doubled OPS	Fluorescence (FITC, GFP)					●	●		●	●	
491.0	Doubled DPSS	Fluorescence (FITC, GFP)			●			●		●	●	
514.5	Ar-ion gas	Raman, Fluorescence (YFP)		●	●		●	●		●	●	
515.0	Doubled DPSS	Fluorescence (YFP)					●	●		●	●	
532.0	Doubled DPSS	Raman, Fluorescence	●	●	●		●	●	●	●	●	●
543.5	HeNe gas	Fluorescence (TRITC, Cy3)			●						●	
561.4	Doubled DPSS	Fluorescence (RFP, Texas Red®)		●	●		●	●		●	●	
568.2	Kr-ion gas	Fluorescence (RFP, Texas Red)		●	●			●		●	●	
593.5	Doubled DPSS	Fluorescence (RFP, Texas Red)					●	●		●	●	
594.1	HeNe gas	Fluorescence (RFP, Texas Red)					●	●		●	●	
632.8	HeNe gas	Raman, Fluorescence (Cy5)	●	●	●		●	●	●	●	●	
~ 635	Diode	Fluorescence (Cy5)				●		●	●	●	●	
638	Diode	Raman		●	●			●	●	●		
647.1	Kr-ion gas	Fluorescence (Cy5)		●	●			●	●	●	●	
~ 660	Diode	Raman						●		●		
664.0	Doubled DPSS	Raman		●				●				
~ 685	Diode	Raman								●		
671.0	Doubled DPSS	Raman, Fluorescence (Cy5.5, Cy7)		●	●							
780.0	EC diode	Raman		●	●			●				
~ 785	Diode	Raman	●			●		●	●			
785.0	EC Diode	Raman		●	●	●	●	●	●	●		●
~ 808	Diode	DPSS pumping, Raman		●	●		●	●				
810.0	Diode	DPSS pumping, Raman			●							
830.0	EC diode	Raman		●	●			●		●		
976.0	EC diode	Raman		●	●			●				
980.0	EC diode	Raman		●	●			●		●		
1030.0	DPSS	Raman			●							
1040.0	DPSS	Multiphoton										●
1047.1	DPSS	Raman			●			●				
1064.0	DPSS	Raman		●	●			●		●		●
1319.0	DPSS	Raman		●				●				

Key: *Diode = semiconductor diode laser* *EC diode = wavelength-stabilized external-cavity diode laser*
DPSS = diode-pumped solid-state laser *OPS = optically pumped semiconductor laser*
Doubled, Tripled, Quadrupled = harmonic frequency upconversion using nonlinear optics

Semrock White Paper Abstract Library

Visit www.idex-hs.com/white-papers and filter by "Optical Filters Advanced and Fundamentals" and "White Papers" in the left-hand navigation for full downloadable versions.

Maximizing the Performance of Advanced Microscopes by Controlling Wavefront Error Using Optical Filters

Wavefront distortion can degrade image quality by reducing contrast or compromising resolution. In several microscopy applications, reducing wavefront distortion is critical to achieving the microscopy method. Specifying and selecting optical filters that minimize wavefront aberration is important to maximize or enable optical system performance. This article elucidates how to select optical filters for high performance microscopy, and provides guidance on choosing Semrock catalog filters for wavefront distortion performance required for applications.

Super-resolution Microscopy

The latest incarnation of the modern fluorescence microscope has led to a paradigm shift. This wave is about breaking the diffraction limit first proposed in 1873 by Ernst Abbe and the implications of this development are profound. This new technology, called super-resolution microscopy, allows for the visualization of cellular samples with a resolution similar to that of an electron microscope, yet it retains the advantages of an optical fluorescence microscope.

Optical Filters for Laser-based Fluorescence Microscopes

Lasers are increasingly and advantageously replacing broadband light sources for many fluorescence imaging applications. However, fluorescence applications based on lasers impose new constraints on imaging systems and their components. For example, optical filters used confocal and Total Internal Reflection Fluorescence (TIRF) microscopes have specific requirements that are unique compared to those filters used in broadband light source based instruments.

Filter Sets for Next Generation Microscopy

LED-based light engines are gaining in popularity for fluorescence imaging. However, the full potential of LED light engines remains to be realized in most imaging configurations because they are still being used with conventional filter sets designed for mercury or xenon arc lamps. Semrock's LED-based light engine filter sets are aligned to the unique spectral peaks of the most popular LED-based light engines on the market today.

Fluorescent Proteins: Theory, Applications and Best Practices

The latest incarnation of the modern fluorescence microscope has led to a paradigm shift. This wave is about breaking the diffraction limit first proposed in 1873 by Ernst Abbe and the implications of this development are profound. This new technology, called super-resolution microscopy, allows for the visualization of cellular samples with a resolution similar to that of an electron microscope, yet it retains the advantages of an optical fluorescence microscope.

Spectral Modeling in Fluorescence Microscopy

SearchLight is a free, online spectrum plotting and analysis tool that allows fluorescence microscope users and optical instrument designers to model and evaluate the spectral performance of fluorophores, filter sets, light sources, and detectors as components of an overall system. This white paper provides the theoretical basis for the SearchLight calculations, illustrating the individual aspects with academic precision, but also with very useful insights into practical problems related to noise in biological fluorescence microscopy systems.

Spectral Imaging with VersaChrome

Spectral imaging with linear unmixing is necessary in multicolor fluorescence imaging when fluorophore spectra are highly overlapping. Tunable fluorescence filters now enable spectral imaging with all the advantages of thin-film filters, including high transmission with steep spectral edges and high out-of-band blocking.

Creating Your Own Bandpass Filter

Semrock's VersaChrome Edge™ filters unlock virtually unlimited spectral flexibility for fluorescence microscopy and hyperspectral imaging as well as spectroscopy applications. By utilizing a combination of VersaChrome Edge™ tunable long-wave-pass and short-wave-pass filters, a bandpass filter as narrow as sub 5nm FWHM or as wide as 12% of the center wavelength throughout the visible and near-infrared wavelength ranges can be created.

Semrock VersaChrome Tunable Bandpass Filters

Many optical systems can benefit from tunable filters with the spectral and two-dimensional imaging performance characteristics of thinfilm filters and the center wavelength tuning speed and flexibility of a diffraction grating.

Flatness of Dichroic Beamsplitters Affects Focus & Image Quality

Dichroic beamsplitters are now used as "image-splitting" elements for many applications, such as live-cell imaging and FRET, in which both the transmitted and reflected signals are imaged onto a camera. The optical quality of such dichroics is critical to achieving high-quality images, especially for the reflected light. If the beamsplitter is not sufficiently flat, then significant optical aberrations may be introduced and the imaging may be severely compromised.

The Physics of Pixel Shift

Pixel shift refers to the shift of a microscope image that can occur when switching between fluorescence filter cubes. This is undesirable because the individual images obtained with these cubes do not overlap precisely with each other, causing issues in the analysis and understanding of the image data. This white paper explains the optical physics behind pixel shift, and outlines some key considerations in the design of optical filter sets with “zero pixel shift” (less than one pixel error) performance.

Pixel Shift in Fluorescence Microscopy

Multicolor imaging in fluorescence microscopy is typically performed by acquiring sequential images at different emission wavelengths, and overlaying these images to study the spatial distribution of cellular components. Imaging artifacts such as “pixel shift” can compromise the extent to which such a composite image correctly represents the biological phenomena. This white paper discusses pixel shift in the context of multicolor imaging, how these shifts can be mitigated, and which types of multicolor imaging can be used to improve microscopy performance.

Practical Aspects of Mirror Usage in Optical Systems for Biology

Why are so many different models of mirrors found in biological optics setups, and how does one know which mirror to purchase for a specific purpose? This paper seeks to answer those questions, by providing practical, useful information on the now ubiquitous flat dielectric mirror. It also outlines some of the key design considerations and specifications to consider when selecting the appropriate flat mirror for an optical system used in biology.

Multimodal NLO Imaging

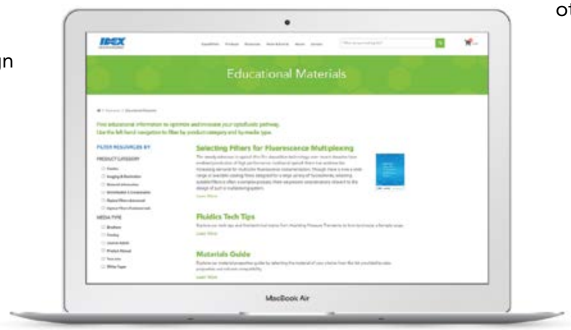
Nonlinear optical (NLO) imaging is a powerful microscopy technique in the field of biomedical optics, in which ultrafast laser excitation is used to exploit several nonlinear optical effects that can provide high-contrast imaging of biological samples. This white paper discusses the emergence of NLO imaging and how it has been facilitated by advances in three key technology areas: ultrafast lasers; high-performance, hard-coated optical filters; and high-sensitivity detectors. Fluorophores commonly used in combination with NLO fluorescence imaging are also discussed.

Understanding Polarization

Despite its importance for many optical systems and applications, polarization is often considered a more esoteric property of light that is not so well understood. In this article our aim is to answer some basic questions about the polarization of light, including: what polarization is and how it is described, how it is controlled by optical components, and when it matters in optical systems.

How to Calculate Luminosity, Dominant Wavelength, and Excitation Purity

This article provides a brief overview of a simple, clear, and unambiguous method for calculating the color an observer sees when looking through an optical filter at a well-defined light source using the CIE 1931 Color Specification System.



Measurements of Optical Filter Spectra

Due to limitations of standard metrology techniques, the measured spectral characteristics of thin-film interference filters are frequently not determined accurately, especially when there are steep edges and deep blocking. Use of the optimal measurement approach for a given filter or application can reduce errors in and overdesign of experiments and systems that use filters, thus optimizing performance, results, and cost.

Selecting Filters for Fluorescence Multiplexing

The steady advances in optical thin film deposition technology over recent decades have enabled production of high performance multiband optical filters that address the increasing demand for multicolor fluorescence instrumentation. Though there is now a wide range of available catalog filters designed for a large variety of fluorophores, selecting suitable filters is often a complex process. Here we present considerations relevant to the design of such a multiplexing system.

KolaDeep Spectral Measurement System

Many biomedical devices now require optical filters with very high blocking (OD) and steep spectral edges. The KolaDeep™ Spectral Measurement System (SMS), a proprietary new award-winning metrology platform, measures the steepest and deepest spectral features of IDEX Health & Science Semrock optical filters. This white paper presents examples and analyses of filters measured with KolaDeep and other Semrock SMS platforms.

TECHNICAL NOTE

You Can Clean Semrock Optical Filters!

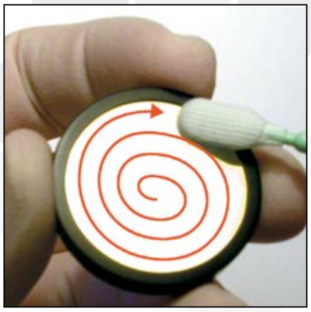
Semrock manufactures the most durable optical filters available. However, it is important to note that while all optical components should be handled with care, soft-coated filters are especially susceptible to damage by handling and cleaning. Fortunately, Semrock supplies only hard-coated filters, so all of Semrock's filters may be readily cleaned using the following recommended method.

The following are recommended to properly clean your filters:

- **Unpowdered laboratory gloves** – prevent finger oils from contaminating the glass and keep solvents from contacting skin;
- **Eye protection** – critical for avoiding getting any solvent in your eyes;
- **Compressed air** – clean, filtered laboratory compressed nitrogen or air is ideal, but "canned" compressed air or even a rubber "bulb blower" in a relatively clean environment is acceptable;
- **Lint-free swab** – cotton-based swabs work best;
- **Lens cleaning tissue** – lint-free tissue paper is also acceptable;
- **Cleaning solvent** – we recommend Isopropyl Alcohol (IPA) and/or Acetone. Care should be taken when handling these solvents, especially to avoid ingestion.

1. **Blow off contaminants**. Many contaminants are loosely attached to the surface and can be blown off. Using laboratory gloves, hold the filter in one hand and aim the air stream away from the filter. Start the air stream using a moderate air flow. Maintaining an oblique angle to the part – never blow straight on the filter surface – now bring the air stream to the filter, and slowly move it across the surface. Repeat until no more loose particles are disappearing.

2. **Clean filter.** If dust or debris remains, it is probably "stuck" to the surface and must be removed with mechanical force and/or chemical action. Create a firm but "pointy" tip with the lint-free wipe or lens tissue by folding it multiple times into a triangular shape or wrapping it around a swab. Lint-free swabs may also be used directly in place of a folded wipe. Moisten the wipe or swab with either IPA or Acetone, but avoid too much excess solvent.



The key to cleaning the optic is to maintain one continuous motion at as constant a speed as possible. Some people prefer to clean using a "figure 8" pattern while others choose to start in the center of the part and wipe outward in a spiral pattern. Do not stop the wipe on the surface – keep the wipe moving at a constant speed, lifting the moving wipe off the part when you reach the end of the pattern.

3. **Inspect filter.** Use a room light or any bright light source to inspect the optic to ensure that it is clean. Tip, tilt, and rotate the optic while viewing it as close to your eye as you can focus. If contamination remains, start with a brand new wipe or swab and repeat step 2 above.

4. **Repeat** steps 1 – 3 for the other side of the filter if contamination exists.

Precautions for Edge Blackened Filters

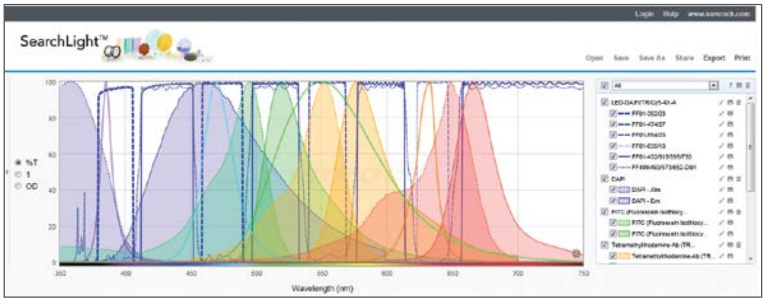
For Semrock edge blackened filters, the above procedures can be used with the following precautions.

- Only IPA or water based cleaning solutions can be used.
- Acetone, Methanol, and other chemical solutions should be avoided as they will damage the edge blackening material.
- Aggressive wiping of the blackened edge should be avoided.

Note: *IPA and Acetone each have pros and cons, so choose the solvent that works best for you after trying both.*

SEARCHLIGHT

SearchLight allows fluorescence microscope users and optical instrument designers to predetermine the optimal fluorophore, light source, detector, and optical filter combinations for their microscope or system. By removing the guesswork and hours of searching multiple sources for spectral data, SearchLight users will be able to eliminate trial-and-error headaches and work more efficiently. Users may select from an extensive collection of preloaded spectra or upload their own spectral data in this free and openly accessible tool. Users can also save and share their data securely.



Share: The share feature within SearchLight enables collaboration across researchers, engineers, companies and institutions by creating a unique URL link to the session which can be emailed to a colleague or collaborator.

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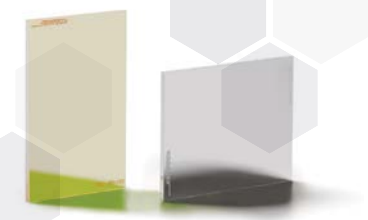
General Purpose Mirrors

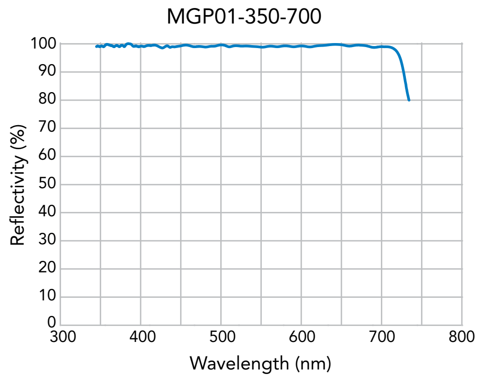


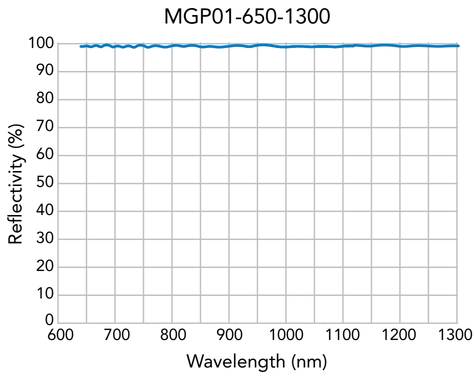
Semrock general purpose mirrors offer the ability to have hard-coated mirrors in a thinner-than-standard thickness. These mirrors can be used in microscopes or by researchers looking to do beam steering. With high reflectivity and convenient 25.2 x 35.6 x 1.05 mm size, these MGP mirrors allow the flexibility needed in a laboratory or research setting.

- High reflectivity over the visible or near-infrared region
- Ideal mirror for photo-bleaching samples
- Image-splitting Flatness / RWE classification (~100 m radius of curvature)
- Proven no burn-out durability – for lasting and reliable performance

Reflection Band	Flatness	Size	Glass Thickness	Part Number	Price
R_{avg} > 98% 350–700 nm	Image-splitting	25.2 x 35.6 mm	1.05 mm	MGP01-350-700-25x36	$495
R_{avg} > 98% 650–1300 nm	Image-splitting	25.2 x 35.6 mm	1.05 mm	MGP01-650-1300-25x36	$495

ACTUAL MEASURED DATA FROM TYPICAL FILTERS IS SHOWN





Common Specifications

Property	Value	Comment
Angle of Incidence	45°± 1.5°	
Surface Figure	Image-splitting	Contributes less than 1.5x Airy Disk diameter to the RMS spot size of a focused, reflected beam with a diameter up to 10 mm.
Substrate Material	Fused Silica	
Coating Type	"Hard" ion-beam-sputtered	
Clear Aperture	80% of glass dimension	Elliptical
Transverse Dimension	25.2 x 35.6 mm +/- 0.1mm	
Thickness & Tolerance	1.05 mm +/- 0.05 mm	
Surface Quality	60-40 Scratch-dig	
Pulse Dispersion	The General Purpose Mirrors will not introduce appreciable pulse broadening for most laser pulses that are > 1 picosecond; however, pulse distortion is likely for significantly shorter laser pulses, including femtosecond pulses.	
Reliability & Durability	Ion-beam-sputtered, hard-coating technology with unrivaled filter life. General Purpose Mirrors are rigorously tested and proven to MIL-STD-810F and MIL-C-48497A environmental standards.	
Orientation	Reflective coating side should face towards light source (see page 29).	

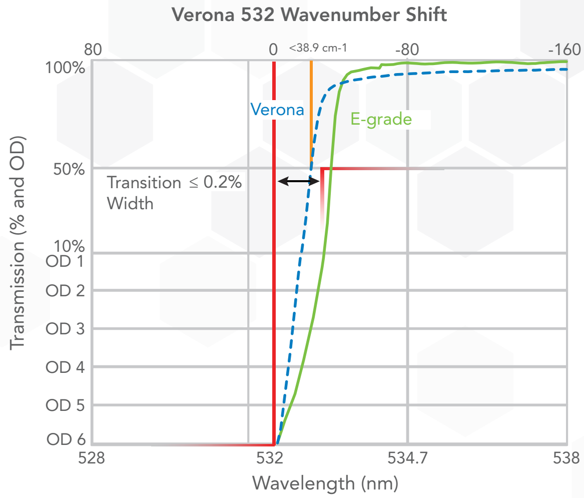
Able to mount in filter cubes (see page 37) or Semrock's Filter Holder (see page 79).

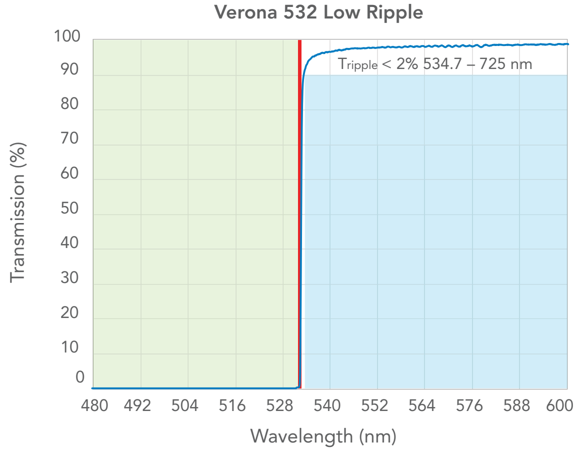
Verona™ Raman Filter Family

Semrock's long-pass Verona optical filters provide industry-best solutions for deep blocking close to the laser line for Raman applications. Verona is just the beginning of our evolving Raman product line to match the rapidly developing Raman market. Our understanding of how crucial flat transmission is for the maximal collection of weak Raman signals is why we offer a filter with both low ripple and improved steepness from our RazorEdge™ series, making the Verona family the new gold standard for Raman analysis.

Push the limits of what you can see with your Raman system with Verona Raman filters.

- Transition width* ≤ 0.2% relative to the edge wavelength while still achieving transmission > 90% and blocking > OD6
- Steepness improved from our RazorEdge series
- Low ripple to provide the best signal-to-noise ratio and allow for maximal collection of weak Raman spectral features
- 532 nm and 785 nm wavelengths now available (488 nm and 633 nm coming soon)
- Deep blocking of > OD6 at the laser line that eliminates bleed-through of excitation light
- Hard coated for high laser damage threshold to reduce degradation in performance under ambient conditions
- With our award-winning, proprietary KolaDeep™ spectral measurement system, we provide the spectral data to prove our superior deep blocking and edge-steepness performance
- Available in 12.5 mm housed standard sized parts to meet your application needs





12.5 mm Diameter

Laser Line	Transition Width	Passband	Part Number	Price
785 nm	< 25.9 cm^{-1}	788.9 – 1770.7 nm	VLP02-785-12.5	$815
532 nm	< 38.9 cm^{-1}	534.7 – 1300 nm	VLP01-532-12.5	$815
633 nm	COMING SOON EARLY 2023			
488 nm	COMING SOON EARLY 2023			

Verona Specifications

Property	Specifications	Comments
Edge Steepness (Typical)	0.2% of laser wavelength	Measured from OD = 6 to 50% transmission wavelength
Ripple on passband transmission	< 2%	
Angle of Incidence	0.0° ± 2.0°	Range for above optical specifications
Cone Half Angle	0°	Rays uniformly distributed about 0°
Clear Aperture	≥ 10 mm	
Outer Diameter	12.5 mm + 0.0 / – 0.1 mm	
Substrate Thickness	3.0 mm	
Mounted Thickness	5.0 mm	

EdgeBasic™ Long / Short Wave Pass Filters

EdgeBasic long wave pass and short wave pass filters offer a superb combination of performance and value for applications in Raman spectroscopy and fluorescence imaging and measurements. This group of filters is ideal for specific Raman applications that do not require measuring the smallest possible Raman shifts, yet demand exceptional laser-line blocking and high transmission over a range of Raman lines.

- Deep laser-line blocking – for maximum laser rejection (OD > 6)
- Extended short-wavelength blocking (LWP) – for high-fidelity fluorescence imaging
- High signal transmission – to detect the weakest signals (> 98% typical)
- Proven no burn-out durability – for lasting and reliable performance
- For the ultimate performance, upgrade to state-of-the-art RazorEdge® Raman filters

Long Wave Pass

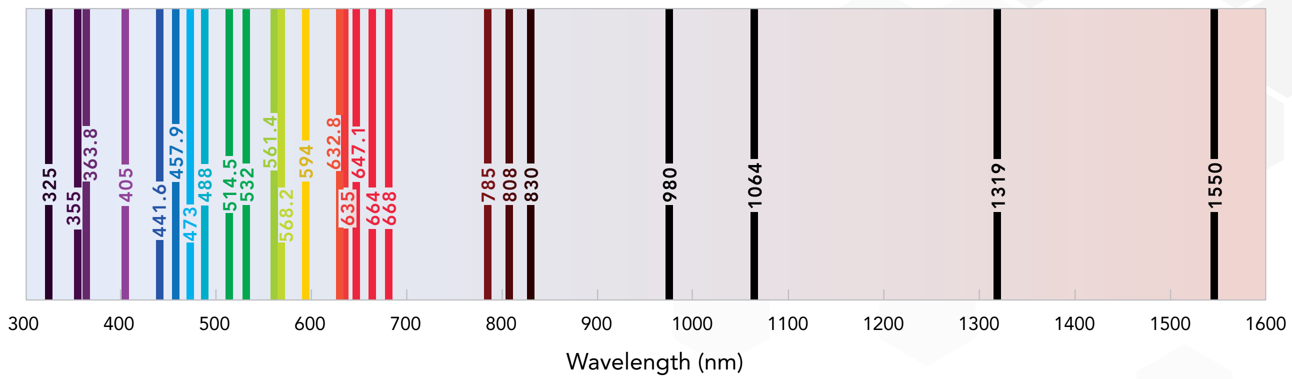
Nominal Laser Wavelength	Laser Wavelength Range λ_{short}	λ_{long}	Passband	Part Number	Price
325 nm	325.0 nm	325.0 nm	334.1 – 900.0 nm	BLP01-325R-25	$455
355 nm	355.0 nm	355.0 nm	364.9 – 900.0 nm	BLP01-355R-25	$455
363.8 nm	363.8 nm	363.8 nm	374.0 – 900.0 nm	BLP01-364R-25	$455
405 nm	400.0 nm	410.0 nm	421.5 – 900.0 nm	BLP01-405R-25	$405
441.6 nm	441.6 nm	441.6 nm	454.0 – 900.0 nm	BLP01-442R-25	$405
457.9 nm	439.0 nm	457.9 nm	470.7 – 900.0 nm	BLP01-458R-25	$405
473 nm	473.0 nm	473.0 nm	486.2 – 900.0 nm	BLP01-473R-25	$405
488 nm	486.0 nm	491.0 nm	504.7 – 900.0 nm	BLP01-488R-25	$405
514.5 nm	505.0 nm	515.0 nm	529.4 – 900.0 nm	BLP01-514R-25	$405
532 nm	532.0 nm	532.0 nm	546.9 – 900.0 nm	BLP01-532R-25	$405
561.4 nm	561.4 nm	561.4 nm	577.1 – 900.0 nm	BLP02-561R-25	$405
568.2 nm	561.4 nm	568.2 nm	584.1 – 900.0 nm	BLP01-568R-25	$405
594 nm	593.5 nm	594.3 nm	610.9 – 900.0 nm	BLP01-594R-25	$405
632.8 nm	632.8 nm	632.8 nm	650.5 – 1200.0 nm	BLP01-633R-25	$405
635 nm	632.8 nm	642.0 nm	660.0 – 1200.0 nm	BLP01-635R-25	$405
647.1 nm	647.1 nm	647.1 nm	665.2 – 1200.0 nm	BLP01-647R-25	$405
664 nm	664.0 nm	664.0 nm	682.6 – 1200.0 nm	BLP01-664R-25	$405
785 nm	780.0 nm	790.0 nm	812.1 – 1200.0 nm	BLP01-785R-25	$405
808 nm	808.0 nm	808.0 nm	830.6 – 1600.0 nm	BLP01-808R-25	$405
830 nm	830.0 nm	830.0 nm	853.2 – 1600.0 nm	BLP01-830R-25	$405
980 nm	980.0 nm	980.0 nm	1007.4 – 1600.0 nm	BLP01-980R-25	$455
1064 nm	1064.0 nm	1064.0 nm	1093.8 – 1600.0 nm	BLP01-1064R-25	$455
1319 nm	1319.0 nm	1319.0 nm	1355.9 – 2000.0 nm	BLP02-1319R-25	$455
1550 mm	1550.0 nm	1550.0 nm	1593.4 – 2000.0 nm	BLP01-1550R-25	$455

Short Wave Pass

Nominal Laser Wavelength	Laser Wavelength Range λ_{short}	λ_{long}	Passband	Part Number	Price
532 nm	532.0 nm	532.0 nm	350.0 – 517.1 nm	BSP01-532R-25	$455
632.8 nm	632.8 nm	647.1 nm	350.0 – 615.1 nm	BSP01-633R-25	$455
785 nm	780.0 nm	790.0 nm	350.0 – 758.2 nm	BSP01-785R-25	$455

See spectra graphs and ASCII data for these filter sets at www.idex-hs.com/semrock

EdgeBasic™ Long / Short Wave Pass Filters



Longpass Specifications

Property	Value	Comments
Edge Steepness (typical)	1.5% of λ_{long}	Measured from OD 6 to 50%
Transition Width	< 2.5% of λ_{long}	From λ_{long} to the 50% transmission wavelength
Blocking at Laser Wavelengths	OD_{abs} > 6 from 80% of λ_{short} to λ_{long} OD_{avg} > 5 from 270 nm to 80% of λ_{short} ($\lambda_s \leq$ 1064 nm) OD_{avg} > 5 from 800 nm to 80% of λ_{short} (λ_s > 1064 nm)	OD = - $\log_{10}$ (transmission)
Guaranteed Transmission	> 93%	Averaged over the passband
Minimum Transmission	> 90%	Over the passband

Shortpass Specifications

Property	Value	Comments
Edge Steepness (typical)	1.5% of λ_{short}	Measured from OD 6 to 50%
Transition Width	< 2.5% of λ_{short}	From 50% transmission wavelength to λ_{short}
Blocking at Laser Wavelengths	OD_{abs} > 6 from λ_{short} to 120% of λ_{long} OD_{avg} > 5 from 120% of λ_{long} to 750 nm OD_{avg} > 4 from 750 nm to 925 nm OD_{avg} > 3 from 925 nm to 1200 nm	OD = - $\log_{10}$ (transmission)
Guaranteed Transmission	> 93%	Averaged over the passband >400nm
Minimum Transmission	> 85%	> 70% 350 – 400 nm

Common Specifications

Property	Value	Comments
Guaranteed Transmission	> 93%	Averaged over the passband For Shortpass > 80% 350 – 400nm
Typical Transmission	> 98%	Averaged over the passband
Angle of Incidence	0.0° ± 2.0°	Range for above optical specifications
Cone Half Angle	< 5°	Rays uniformly distributed about 0°
Angle Tuning Range	- 0.3% of Laser Wavelength	Wavelength "blue shift" increasing angle from 0° to 8°
Substrate Material	Low-autofluorescence optical quality glass	
Substrate Thickness	2.0 ± 0.1 mm	
Clear Aperture	> 22 mm	
Outer Diameter	25.0 + 0.0 / - 0.1 mm	Black-anodized aluminum ring
Overall Thickness	3.5 ± 0.1 mm	Black-anodized aluminum ring
Beam Deviation	< 10 arc seconds	
Surface Quality	60-40 scratch-dig	
Filter Orientation	Arrow on ring indicates preferred direction of propagation of light	

RazorEdge® Long Wave Pass Raman Edge Filters

Semrock stocks an unsurpassed selection of the highest performance edge filters available for Raman Spectroscopy, with edge wavelengths from 224 to 1319 nm. Now you can see the weakest signals closer to the laser line than you ever have before. With their deep laser-line blocking, ultra-wide and low-ripple passbands, proven hard-coating reliability, and high laser damage threshold, they offer performance that lasts. U.S. Patent No. 7,068,430.

- The steepest edge filters on the market – RazorEdge E-grade filters, see how steep on page 94
- For long-wave-pass edge filters and normal incidence, see below
- For short-wave-pass edge filters and normal incidence, see page 95
- For ultrasteep 45° beamsplitters, see page 97
- For a suitably matched laser-line filter, see page 99

25 mm and 50 mm Diameters

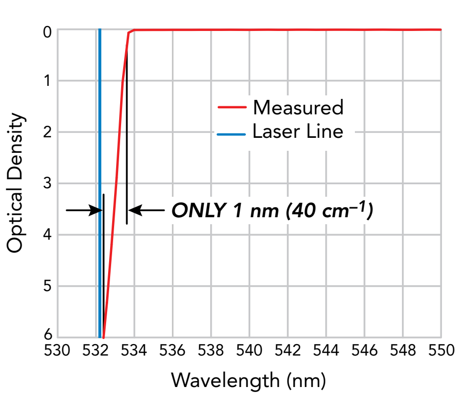
Laser Line	Transition Width[1]	Passband	Part Number	Price
224.3 nm	< 1920 cm^{-1}	235.0-505.9 nm	LP02-224R-25	$1230
244 nm	< 498 cm^{-1}	247.6 - 550.4 nm	LP02-244RS-25	$1230
248.6 nm	< 805 cm^{-1}	261.0-560.8 nm	LP02-248RS-25	$1230
257.3 nm	< 385 cm^{-1}	263.0-580.4 nm	LP02-257RU-25	$1230
266.0 nm	< 372 cm^{-1}	272.4-600.0 nm	LP02-266RU-25	$1095
325.0 nm	< 153 cm^{-1} < 305 cm^{-1}	327.1-733.1 nm 329.2-733.1 nm	LP03-325RE-25 LP03-325RU-25	$1095 $745
355.0 nm	< 140 cm^{-1} < 279 cm^{-1}	357.3-800.8 nm 359.6-800.8 nm	LP02-355RE-25 LP02-355RU-25	$1230 $745
363.8 nm	< 272 cm^{-1}	368.5-820.6 nm	LP02-364RU-25	$850
407.0 nm	< 243 cm^{-1}	412.3-918.0 nm	LP02-407RU-25	$745
441.6 nm	< 113 cm^{-1} < 224 cm^{-1}	444.5-996.1 nm 447.3-996.1 nm	LP02-442RE-25 LP02-442RU-25	$1230 $850
457.9 nm	< 109 cm^{-1} < 216 cm^{-1}	460.9-1032.9 nm 463.9-1032.9 nm	LP03-458RE-25 LP03-458RU-25	$1230 $745
473.0 nm	< 105 cm^{-1} < 209 cm^{-1}	476.1-1066.9 nm 479.1-1066.9 nm	LP02-473RE-25 LP02-473RU-25	$1095 $745
488.0 nm	< 102 cm^{-1} < 203 cm^{-1}	491.2-1100.8 nm 494.3-1100.8 nm	LP02-488RE-25 LP02-488RU-25	$1095 $745
514.5 nm	< 97 cm^{-1} < 192 cm^{-1}	517.8-1160.5 nm 521.2-1160.5 nm	LP02-514RE-25 LP02-514RU-25	$1230 $850
532.0 nm	< 90 cm^{-1} < 186 cm^{-1}	535.4-1200.0 nm 538.9-1200.0 nm	LP03-532RE-25 LP03-532RU-25	$1095 $745

Laser Line	Transition Width[1]	Passband	Part Number	Price
561.4 nm	< 89 cm^{-1} < 176 cm^{-1}	565.0-1266.3 nm 568.7-1266.3 nm	LP02-561RE-25 LP02-561RU-25	$1230 $850
632.8 nm	< 79 cm^{-1} < 156 cm^{-1}	636.9-1427.4 nm 641.0-1427.4 nm	LP02-633RE-25 LP02-633RU-25	$1095 $745
638 nm	< 78 cm^{-1} < 155 cm^{-1}	642.1-1439.1 nm 646.3-1439.1 nm	LP02-638RE-25 LP02-638RU-25	$1230 $850
647.1 nm	< 153 cm^{-1}	655.5-1459.6 nm	LP02-647RU-25	$850
664.0 nm	< 149 cm^{-1}	672.6-1497.7 nm	LP02-664RU-25	$850
671.0 nm	< 147.6 cm^{-1}	679.7-1513.5 nm	LP02-671RU-25	$745
780.0 nm	< 127 cm^{-1}	790.1-1759.4 nm	LP02-780RU-25	$850
785.0 nm	< 63 cm^{-1} < 126 cm^{-1}	790.1-1770.7 nm 795.2-1770.7 nm	LP02-785RE-25 LP02-785RU-25	$1095 $745
808.0 nm	< 62 cm^{-1} < 123 cm^{-1}	813.3-1822.6 nm 818.5-1822.6 nm	LP02-808RE-25 LP02-808RU-25	$1230 $850
830.0 nm	< 60 cm^{-1} < 119 cm^{-1}	835.4-1872.2 nm 840.8-1872.2 nm	LP02-830RE-25 LP02-830RU-25	$1230 $745
980.0 nm	< 51 cm^{-1} < 101 cm^{-1}	986.4-2000.0 nm 992.7-2000.0 nm	LP02-980RE-25 LP02-980RU-25	$1230 $745
1064.0 nm	< 47 cm^{-1} < 93 cm^{-1}	1070.9-2000.0 nm 1077.8-2000.0 nm	LP02-1064RE-25 LP02-1064RU-25	$1230 $745
50 mm LWP Edge Filters 50 mm LWP Edge Filters			idex-hs.com/semrock	

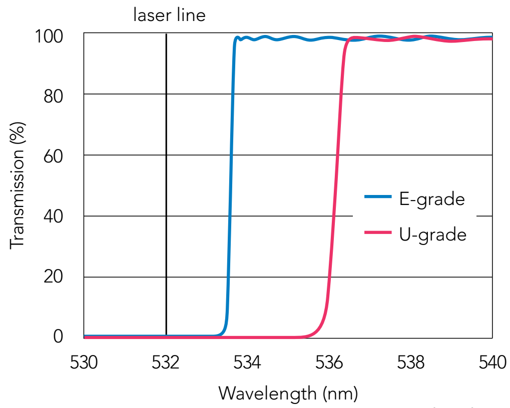
[1] See pages 94 and 102 for more information on transition width and wavenumbers

ACTUAL MEASURED DATA RAZOREDGE RAMAN FILTER SPECTRA

Actual measured OD 532 nm E-grade filter



The spectral response of a U-grade filter is located anywhere between the red and blue lines below.



PRODUCT NOTE

Edge Steepness and Transition Width

Semrock edge filters – including our steepest RazorEdge® Raman filters as well as our EdgeBasic™ filters for application-specific Raman systems and fluorescence imaging – are specified with a guaranteed "Transition Width."

> Transition Width = maximum allowed spectral width between the laser line (where OD > 6) and the 50% transmission point

Any given filter can also be described by its "Edge Steepness," which is the actual steepness of the filter, regardless of the precise wavelength placement of the edge.

> Edge Steepness = actual steepness of a filter measured from the OD 6 point to the 50% transmission point

Figure 1 illustrates Transition Width and Edge Steepness for an edge filter designed to block the 785 nm laser line (example shows a U-grade RazorEdge filter). Table 1 below lists the guaranteed Transition Width and typical Edge Steepness (for 25 mm diameter parts) for Semrock edge filters.

All Verona and RazorEdge filters provide exceptional steepness to allow measurement of signals very close to the blocked laser line with high signal-to-noise ratio. However, the state-of-the-art E-grade RazorEdge filters take closeness to an extreme level.

The graph at the right illustrates that U-grade RazorEdge filters have a transition width that is 1% of the laser wavelength. E-grade filters have a Transition width that is twice as narrow, or 0.5% of the laser line!

Table 1

Edge Filter Type	Guaranteed Transition Width (% of laser wavelength)	Typical Edge Steepness (% of laser wavelength)
Verona	Refer to page 90	
RazorEdge E-grade	< 0.5% (< 90 cm^{-1} for 532)	0.2% (1.1 nm for 532)
RazorEdge U-grade	< 1.0% (< 186 cm^{-1} for 532)	0.5% (2.7 nm for 532)
EdgeBasic	< 2.5% (< 458 cm^{-1} for 532)	1.5% (8.0 nm for 532)

* except UV filters

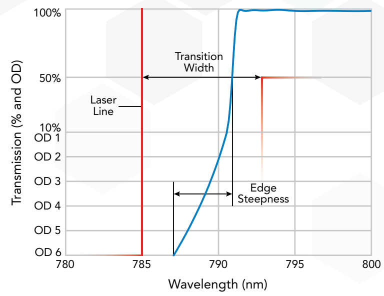


Figure 1: Transition width and edge steepness illustrated.

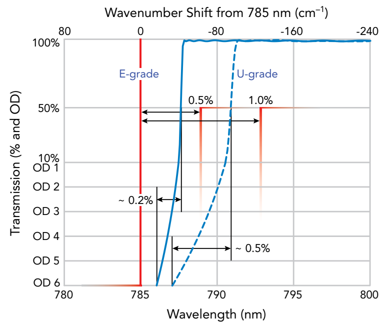


Figure 2: Transition widths and edge steepnesses for LP02-785RE and LP02-785RU filters (see page 95).

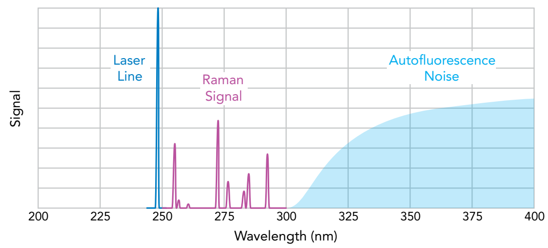
TECHNICAL NOTE

Ultraviolet (UV) Raman Spectroscopy

Raman spectroscopy measurements generally face two limitations: (1) Raman scattering cross sections are tiny, requiring intense lasers and sensitive detection systems just to achieve enough signal; and (2) the signal-to-noise ratio is further limited by fundamental, intrinsic noise sources like sample autofluorescence. Raman measurements are most commonly performed with green, red, or near-infrared (IR) lasers, largely because of the availability of established lasers and detectors at these wavelengths. However, by measuring Raman spectra in the ultraviolet (UV) wavelength range, both of the above limitations can be substantially alleviated.

Visible and near-IR lasers have photon energies below the first electronic transitions of most molecules. However, when the photon energy of the laser lies within the electronic spectrum of a molecule, as is the case for UV lasers and most molecules, the intensity of Raman-active vibrations can increase by many orders of magnitude – this effect is called "resonance-enhanced Raman scattering."

Although UV lasers tend to excite strong autofluorescence, it typically occurs only at wavelengths above about 300 nm,



independent of the UV laser wavelength. Since even a 4000 cm^{-1} (very large) Stokes shift leads to Raman emission below 300 nm when excited by a common 266 nm laser, autofluorescence simply does not interfere with the Raman signal making high signal-to-noise ratio measurements possible.

An increasing number of compact, affordable, and high-power UV lasers have become widely available, such as quadrupled, diode-pumped Nd:YAG lasers at 266 nm and NeCu hollow-cathode metal-ion lasers at 248.6 nm, making ultra-sensitive UV Raman spectroscopy a now widely accessible technique.

RazorEdge® Short Wave Pass Raman Edge Filters

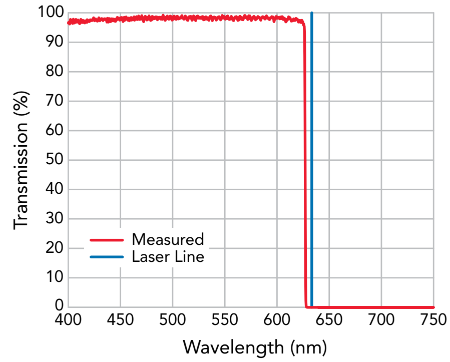
These unique filters are ideal for Anti-Stokes Raman applications. An addition to the popular high-performance RazorEdge family of steep edge filters, these short-wave-pass filters are designed to attenuate a designated laser-line by six orders of magnitude, and yet maintain a typical edge steepness of only 0.5% of the laser wavelength. Both short and long-wave-pass RazorEdge filters are perfectly matched to Semrock's popular MaxLine® laser-line cleanup filters. U.S. Patent No. 7,068,430

25 mm and 50 mm Diameters

Laser Line	Transition Width	Passband	Part Number	Price
532.0 nm	< 186 cm^{-1}	350.0 – 525.2 nm	SP01-532RU-25	$855
561.4 nm	< 176 cm^{-1}	400.0 – 554.1 nm	SP01-561RU-25	$745
632.8 nm	< 160 cm^{-1}	372.0 – 624.6 nm	SP01-633RU-25	$855
785.0 nm	< 129 cm^{-1}	400.0 – 774.8 nm	SP01-785RU-25	$745
50 mm SWP Edge Filters 50 mm SWP Edge Filters			idex-hs.com/semrock	

See spectra graphs and ASCII data for all of our filters at www.idex-hs.com/semrock

ACTUAL MEASURED DATA FROM A 632.8 nm RAZOREDGE FILTER



PRODUCT NOTE

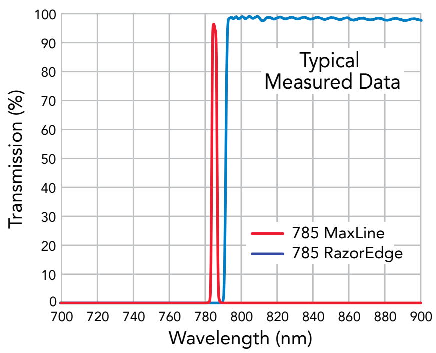
RazorEdge and MaxLine® are a Perfect Match

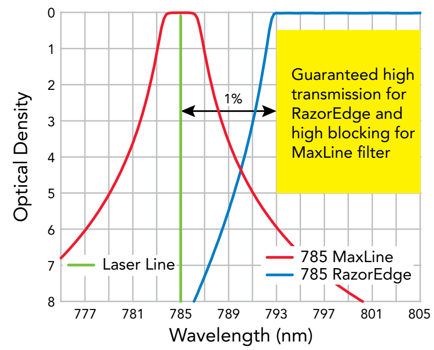
The MaxLine *(see page 98)* and RazorEdge U-grade *(see page 92)* filters make an ideal filter pair for applications like Raman spectroscopy – they fit together like hand-in-glove. The MaxLine filter spectrally "cleans up" the excitation laser light before it reaches the sample under test – allowing only the desired laser line to reach the sample – and then the RazorEdge filter removes the laser line from the light scattered off the sample, while efficiently transmitting desired light at wavelengths very close to the laser line.

Typical measured spectral curves of 785 nm filters on a linear transmission plot demonstrate how the incredibly steep edges and high transmission exhibited by both of these filters allow them to be spectrally positioned very close together, while still maintaining complementary transmission and blocking characteristics.

The optical density plot *(for explanation of OD, see page 107)* illustrates the complementary nature of these filters on a logarithmic scale using the theoretical design spectral curves. The MaxLine filter provides very high transmission (> 90%) of light immediately in the vicinity of the laser line, and then rapidly rolls off to achieve very high blocking (> OD 5) at wavelengths within 1% of the laser line. The RazorEdge filter provides extremely high blocking (> OD 6) of the laser line itself, and then rapidly climbs to achieve very high transmission (> 90%) of the desired signal light at wavelengths only 1% away from the laser line.

If you are currently using an E-grade RazorEdge filter and need a laser clean-up filter, please contact Semrock.





RazorEdge® Common Specifications

RazorEdge Specifications

Properties apply to all long-wave-pass and short-wave-pass edge filters unless otherwise noted

Property		Specification	Comment
Edge Steepness (typical)	E-grade	0.2% of laser wavelength	Measured from OD 6 to 50%; Up to 0.8% for 248-300 nm filters and 3.3% for 224 nm filter
	U-grade	0.5% of laser wavelength	
Blocking at Laser Wavelength		> 6 OD	OD = - $\log_{10}$ (transmission)
Transition Width	E-grade	< 0.5% of laser wavelength	Measured from laser wavelength to 50% transmission wavelength; < 4.5% for 224 nm filter
	U-grade	< 1% of laser wavelength	
Guaranteed Passband Transmission		> 93%	Except > 90% for 224 – 325 nm filters; Averaged over the Passband
Typical Passband Transmission		> 98%	
Angle of Incidence		0.0° ± 2.0°	Range for above optical specifications
Cone Half Angle		< 5°	Rays uniformly distributed about 0°
Angle Tuning Range [1]		-0.3% of Laser Wavelength (-1.6 nm or + 60 cm^{-1} for 532 nm)	Wavelength "blue shift" attained by increasing angle from 0° to 8°
Laser Damage Threshold		0.5 J/cm^2 @ 266 nm 1 J/cm^2 @ 532 nm	10 ns pulse width Tested for 266 and 532 nm filters only (see page 109)
Clear Aperture		≥22 mm (or ≥ 45 mm)	
Outer Diameter		25.0 + 0.0 / -0.1 mm (or 50.0 + 0.0 / -0.1 nm)	Black-anodized aluminum ring
Substrate Thickness		2.0 mm	
Overall Thickness		3.5 ± 0.1 mm	Black-anodized aluminum ring (thickness measured unmounted)
Beam Deviation		≤ 10 arcseconds	

[1] For small angles (in degrees), the wavelength shift near the laser wavelength is $\Delta\lambda$ (nm) = -5.0 x 10^{-5} x λ_L x θ^2 and the wavenumber shift is Δ(wavenumbers) (cm^{-1}) = 500 x θ^2 / λ_L, where λ_L (in nm) is the laser wavelength. See Wavenumbers Technical Note on page 102.

General Specifications (all RazorEdge filters)

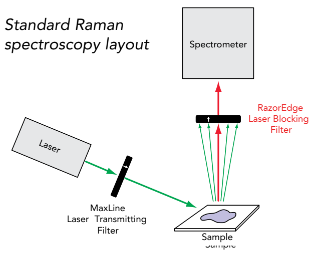
Property	Specification	Comment
Coating Type	"Hard" ion-beam-sputtered	
Reliability and Durability	Ion-beam-sputtered, hard-coated technology with epoxy-free, single-substrate construction for unrivaled filter life. RazorEdge filters are rigorously tested and proven to MIL-STD-810F and MIL-C-48497A environmental standards.	
Transmitted Wavefront Error	< λ / 4 RMS at λ = 633 nm	Peak-to-valley error < 5 x RMS value measured within clear aperture
Surface Quality	60-40 scratch-dig	
Temperature Dependence	< 5 ppm / °C	
Substrate Material	Ultra-low autofluorescence fused silica	
Filter Orientation	For mounted filters, arrow on ring indicates preferred direction of propagation of transmitted light. For rectangular dichroics, reflective coating side should face toward light source and sample.	

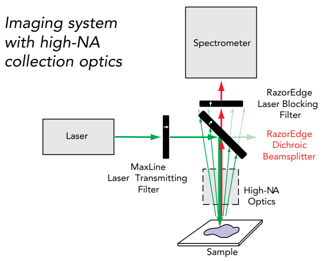
TECHNICAL NOTE

RazorEdge Filter Layouts

Only the unique RazorEdge Dichroic beamsplitter reflects a standard laser line incident at 45° while transmitting longer Raman-shifted wavelengths with an ultrasteep transition far superior to anything else available on the open market. The guaranteed transition width of < 1% of the laser wavelength for U-grade (regardless of polarization) makes these filters a perfect match to our popular normal-incidence RazorEdge ultrasteep long-wave-pass filters.

In order for the two-filter configuration to work, the 45° beamsplitter must be as steep as the laser-blocking filter. Traditionally thin-film filters could not achieve very steep edges at 45° because of the "polarization splitting" problem – the edge position tends to be different for different polarizations of light. However, through continued innovation in thin-film filter technology, Semrock has been able to achieve ultrasteep 45° beamsplitters with the same steepness of our renowned RazorEdge laser-blocking filters: the transition from the laser line to the passband of the filter is guaranteed to be less than 1% of the laser wavelength (for U-grade filters).





RazorEdge Dichroic™ Beamsplitters

The unique RazorEdge Dichroic beamsplitters exhibit unparalleled performance. Each filter reflects a standard laser line incident at 45° while efficiently passing the longer Raman-shifted wavelengths. They exhibit ultrasteep transition from reflection to transmission, far superior to anything else available on the open market. The guaranteed transition width of < 1% of the laser wavelength for U-grade (regardless of polarization) makes these filters a perfect match to our popular normal-incidence RazorEdge ultrasteep long-wave-pass filters. These beamsplitters are so innovative that they are patent pending.

Available as either mounted in 25 mm diameter x 3.5 mm thick black-anodized aluminum ring or unmounted as 25.2 x 35.6 x 1.1 mm or 25.2 x 35.6 x 2.0 mm

Laser Line	Transition Width	Passband	25 mm Mounted Part Number	25.2 x 35.6 x 1.1 mm Part Number	25.2 x 35.6 x 2.0 mm Part Number
488.0 nm	< 203 cm^{-1}	494.3 – 756.4 nm	LPD02-488RU-25	LPD02-488RU-25x36x1.1	LPD02-488RU-25x36x2.0
532.0 nm	< 186 cm^{-1}	538.9 – 824.8 nm	LPD02-532RU-25	LPD02-532RU-25x36x1.1	LPD02-532RU-25x36x2.0
632.8 nm	< 156 cm^{-1}	641.0 – 980.8 nm	LPD02-633RU-25	LPD02-633RU-25x36x1.1	LPD02-633RU-25x36x2.0
785.0 nm	< 126 cm^{-1}	795.2 – 1213.8 nm	LPD02-785RU-25	LPD02-785RU-25x36x1.1	LPD02-785RU-25x36x2.0
830.0 nm	< 119 cm^{-1}	840.8 – 1286.5 nm	LPD02-830RU-25	LPD02-830RU-25x36x1.1	LPD02-830RU-25x36x2.0
1064.0 nm	< 93 cm^{-1}	1077.8 – 1650.8 nm	LPD02-1064RU-25		LPD02-1064RU-25x36x2.0
		Price	$660	$871	$871

Available in 1.1 mm thicknesses for microscopes

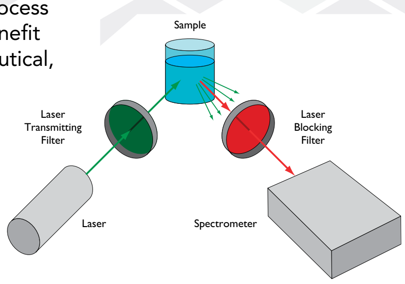
See spectra graphs and ASCII data for all of our filters at www.idex-hs.com/semrock

Dichroic Beamsplitter Specifications

Property		Specification	Comment
Edge Steepness (typical)		0.5% of laser wavelength (2.5 nm or 90 cm^{-1} for 532 nm filter)	Measured from 5% to 50% transmission for light with average polarization
Transition Width	U-grade	< 1% of laser wavelength	Measured from laser wavelength to 50% transmission wavelength for light with average polarization
Reflection at Laser Wavelength		> 98% (s-polarization) > 90% (p-polarization)	
Average Passband Transmission		> 93%	Averaged over the Passband (Passband wavelengths detailed above)
Dependence of Wavelength on Angle of Incidence (Edge Shift)		≤ 0.2% / degree	Linear relationship valid between 35° & 55° (see MyLight for actual performance)
Cone Half Angle (for non-collimated light)		< 0.5°	Rays uniformly distributed and centered at 45°
Size of Round Dichroics	Clear Aperture	≥ 22 mm	
	Outer Diameter	25.0 + 0.0 / – 0.1 mm	Black-anodized aluminum ring
	Overall Thickness	3.5 ± 0.1 mm	Black-anodized aluminum ring
Size of Rectangular Dichroics	Clear Aperture	> 80%	Elliptical
	Size	25.2 mm x 35.6 mm ± 0.1 mm	
	Unmounted Thickness	1.05 mm ± 0.05 mm	
Wedge Angle		≤ 20 arcseconds	
Flatness		Reflection of a collimated, Gaussian laser beam with waist diameter up to 3 mm causes less than one Rayleigh Range of focal shift after a focusing lens.	

TECHNICAL NOTE

Filter Types for Raman Spectroscopy Applications



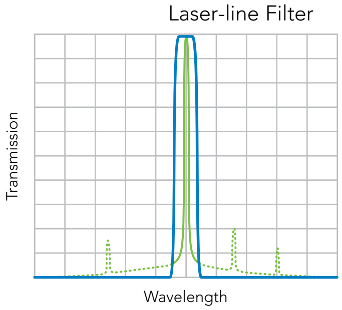
Raman spectroscopy is widely used today for applications ranging from industrial process control to laboratory research to bio/chemical defense measures. Industries that benefit from this highly specific analysis technique include the chemical, polymer, pharmaceutical, semiconductor, gemology, computer hard disk, and medical fields. In Raman spectroscopy, an intense laser beam is used to create Raman (inelastic) scattered light from a sample under test. The Raman "finger print" is measured by a dispersive or Fourier Transform spectrometer.

There are three basic types of Raman instrumentation. Raman microscopes, also called micro-Raman spectrophotometers, are larger-scale laboratory analytical instruments for making fast, high-accuracy Raman measurements on very small, specific sample areas. Traditional laboratory Raman spectrometers are primarily used for R&D applications, and range from "home-built" to flexible commercial systems that offer a variety of laser sources, means for holding solid and liquid samples, and different filter and spectrometer types. Finally, a rapidly emerging class of Raman instrumentation is the Raman micro-probe analyzer. These complete, compact and often portable systems are ideal for use in the field or in tight manufacturing and process environments. They utilize a remote probe tip that contains optical filters and lenses, connected to the main unit via optical fiber.

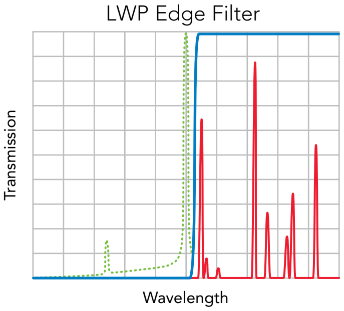
Optical filters are critical components in Raman spectroscopy systems to prevent all undesired light from reaching the spectrometer and swamping the relatively weak Raman signal. Laser Transmitting Filters inserted between the laser and the sample block all undesired light from the laser (such as broadband spontaneous emission or plasma lines) as well as any Raman scattering or fluorescence generated between the laser and the sample (as in a fiber micro-probe system). Laser Blocking Filters inserted between the sample and the spectrometer block the Rayleigh (elastic) scattered light at the laser wavelength.

The illustration above shows a common system layout in which the Raman emission is collected along a separate optical path from the laser excitation path. Systems designed for imaging (e.g., Raman microscopy systems) or with remote fiber probes are often laid out with the excitation and emission paths coincident, so that both may take advantage of the same fiber and lenses *(see Technical Note on page 96)*.

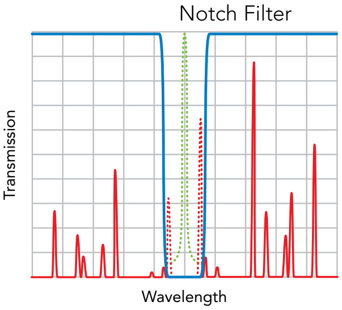
There are three basic types of filters used in systems with separate excitation and emission paths: Laser-line filters, Edge Filters, and Notch Filters. The examples below show how the various filters are used. In these graphs the blue lines represent the filter transmission spectra, the green lines represent the laser spectrum, and the red lines represent the Raman signal (not to scale).



Laser-transmitting filter for both Stokes and Anti-Stokes measurements



Laser-blocking steep edge filter for superior Stokes measurements



Versatile laser-blocking notch filter for both Stokes and Anti-Stokes measurements

Laser-line Filters are ideal for use as Laser Transmitting Filters, and Notch Filters are an obvious choice for Laser Blocking Filters. In systems using these two filter types, both Stokes and Anti-Stokes Raman scattering can be measured simultaneously. However, in many cases Edge Filters provide a superior alternative to notch filters. For example, a long-wave-pass (LWP) Edge Filter used as a Laser Blocking Filter for measuring Stokes scattering offers better transmission, higher laser-line blocking, and the steepest edge performance to see Raman signals extremely close to the laser line. For more details on choosing between edge filters and notch filters, *see the Technical Note "Edge Filters vs. Notch Filters for Raman Instrumentation" on page 108.*

In systems with a common excitation and emission path, the laser must be introduced into the path with an optic that also allows the Raman emission to be transmitted to the detection system. A 45° dichroic beamsplitter is needed in this case. If this beamsplitter is not as steep as the edge filter or laser-line filter, the ability to get as close to the laser line as those filters allow is lost.

Semrock manufactures high-performance MaxLine® Laser-line filters *(page 99)*, RazorEdge® long-wave-pass and short-wave-pass filters *(page 93)*, EdgeBasic™ value long-wave-pass filters *(page 91)*, ultrasteep RazorEdge Dichroic™ beamsplitter filters *(page 97)*, and StopLine® notch filters *(page 103* as standard catalog products. Non-standard wavelengths and specifications for these filters are routinely manufactured for volume OEM applications.

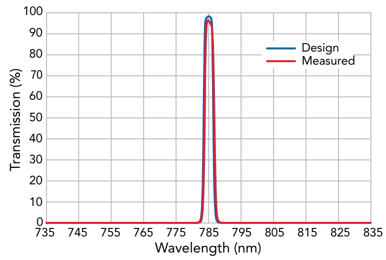
MaxLine® Laser-line Filters

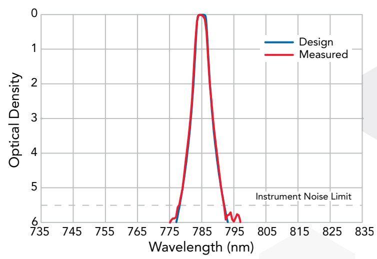
Semrock MaxLine Laser-line Filters have an unprecedented high transmission exceeding 90% at the laser line, while rapidly rolling off to an optical density (OD) > 5 at wavelengths differing by only 1% from the laser wavelength, and OD > 6 at wavelengths differing by only 1.5% from the laser wavelength. U.S. Patent No. 7,119,960.

- Highest laser-line transmission – stop wasting expensive laser light
- Steepest edges – perfect match to RazorEdge® U-grade filters (see page 93)
- Ideal complement to StopLine® deep notch filters for fluorescence and other applications (see page 103)
- Hard dielectric coatings for proven reliability and durability
- For diode lasers, use our MaxDiode™ Laser Clean-up filters (see page 101)

	Wavelength	Guaranteed Transmission	Typical Bandwidth	OD 5 Blue Range (nm)	OD 6 Blue Range (nm)	OD 6 Red Range (nm)	OD 5 Red Range (nm)	12.5 mm Diameter Part Number	25 mm Diameter Part Number
Ultraviolet	248.6 nm	> 40%	1.7 nm	228.2-246.1	228.7-244.9	252.3-273.5	251.1-279.9	LL01-248-12.5	LL01-248-25
	266.0 nm	> 55%	1.9 nm	242.8-263.3	244.7-262.0	270.0-292.6	268.7-302.2	LL01-266-12.5	LL01-266-25
	280.0 nm	> 60%	1.5 nm	254.4-277.2	257.6-275.8	282.8-320.4	284.2-308	LL01-280-12.5	LL01-280-25
	320.0 nm	> 70%	1.3 nm	286.9-316.8	294.4-315.2	323.2-373.8	324.8-352	LL01-320-12.5	LL01-320-25
	325.0 nm	> 80%	1.2 nm	291.0-321.8	299.0-320.1	329.9-357.5	328.3-380.7	LL01-325-12.5	LL01-325-25
	355.0 nm	> 80%	1.3 nm	314.8-351.5	326.6-349.7	360.3-390.5	358.6-422.5	LL01-355-12.5	LL01-355-25
	360.0 nm	> 85%	1.1 nm	318.7-356.4	331.2-354.6	363.6-429.6	365.4-396	LL01-360-12.5	LL01-360-25
Visible	405.0 nm	> 90%	1.5 nm	353.5-401.0	372.6-398.9	411.1-445.5	409.1-495.3	LL01-405-12.5	LL01-405-25
	407.0 nm	> 90%	1.5 nm	355.0-402.9	374.4-400.9	413.1-447.7	411.1-498.3	LL01-407-12.5	LL01-407-25
	441.6 nm	> 90%	1.7 nm	381.0-437.2	406.3-435.0	448.2-485.8	446.0-551.1	LL01-442-12.5	LL01-442-25
	457.9 nm	> 90%	1.7 nm	393.1-453.3	421.3-451.0	464.8-503.7	462.5-576.7	LL01-458-12.5	LL01-458-25
	473.0 nm	> 90%	1.8 nm	404.2-468.3	435.2-465.9	480.1-520.3	477.7-600.9	LL01-473-12.5	LL01-473-25
	488.0 nm	> 90%	1.9 nm	415.1-483.1	449.0-480.7	495.3-536.8	492.9-625.3	LL01-488-12.5	LL01-488-25
	514.5 nm	> 90%	2.0 nm	434.1-509.4	473.3-506.8	522.2-566.0	519.6-669.5	LL01-514-12.5	LL01-514-25
	532.0 nm	> 90%	2.0 nm	446.5-526.7	489.4-524.0	540.0-585.2	537.3-699.4	LL01-532-12.5	LL01-532-25
	543.5 nm	> 90%	2.1 nm	454.6-538.1	500.0-535.3	551.7-597.9	548.9-719.5	LL01-543-12.5	LL01-543-25
	561.4 nm	> 90%	2.1 nm	467.0-555.8	516.5-553.0	569.8-617.5	567.0-751.2	LL02-561-12.5	LL02-561-25
	568.2 nm	> 90%	2.2 nm	471.7-562.5	522.7-559.7	576.7-625.0	573.9-763.4	LL01-568-12.5	LL01-568-25
	632.8 nm	> 90%	2.4 nm	515.4-626.5	582.2-623.3	642.3-696.1	639.1-884.7	LL01-633-12.5	LL01-633-25
	638.0 nm	> 90%	2.4 nm	518.8-631.6	587-628.4	647.6-701.8	644.4-894.9	LL01-638-12.5	LL01-638-25
	647.1 nm	> 90%	2.5 nm	524.8-640.6	595.3-637.4	656.8-711.8	653.6-912.9	LL01-647-12.5	LL01-647-25
	671.0 nm	> 90%	2.6 nm	540.4-664.3	617.3-660.9	681.1-738.1	677.7-961.2	LL01-671-12.5	LL01-671-25
Near-Infrared	780.0 nm	> 90%	3.0 nm	609.0-772.2	717.6-768.3	791.7-858.0	787.8-1201.8	LL01-780-12.5	LL01-780-25
	785.0 nm	> 90%	3.0 nm	612.0-777.2	722.2-773.2	796.8-863.5	792.9-1213.8	LL01-785-12.5	LL01-785-25
	808.0 nm	> 90%	3.1 nm	625.9-799.9	743.4-795.9	820.1-888.8	816.1-1033.5	LL01-808-12.5	LL01-808-25
	810.0 nm	> 90%	3.1 nm	627.1-801.9	745.2-797.9	822.2-891.0	818.1-1143.4	LL01-810-12.5	LL01-810-25
	830.0 nm	> 90%	3.2 nm	639.1-821.7	763.6-817.6	842.5-913.0	838.3-1067.9	LL01-830-12.5	LL01-830-25
	852.0 nm	> 90%	3.2 nm	652-843.5	783.8-839.2	864.8-937.2	860.5-1106.6	LL01-852-12.5	LL01-852-25
	976.0 nm	> 90%	3.7 nm	722.2-966.2	897.9-961.4	990.6-1073.6	985.8-1325.2	LL01-976-12.5	LL01-976-25
	980.0 nm	> 90%	3.7 nm	724.4-970.2	901.6-965.3	994.7-1078.0	989.8-1332.6	LL01-980-12.5	LL01-980-25
	1030.0 nm	> 90%	3.9 nm	1014.6-1019.7	947.6-1014.6	1045.5-1133	1040.3-1368.2	LL01-1030-12.5	LL01-1030-25
	1047.1 nm	> 90%	4.0 nm	963.3-1036.6	963.3-1031.4	1062.8-1151.8	1057.6-1398.6	LL01-1047-12.5	LL01-1047-25
	1064.0 nm	> 90%	4.0 nm	978.9-1053.4	978.9-1048.0	1080.0-1170.4	1074.6-1428.9	LL01-1064-12.5	LL01-1064-25
							Price	Visit idex-hs.com/semrock Search the MaxLine Filter Family	

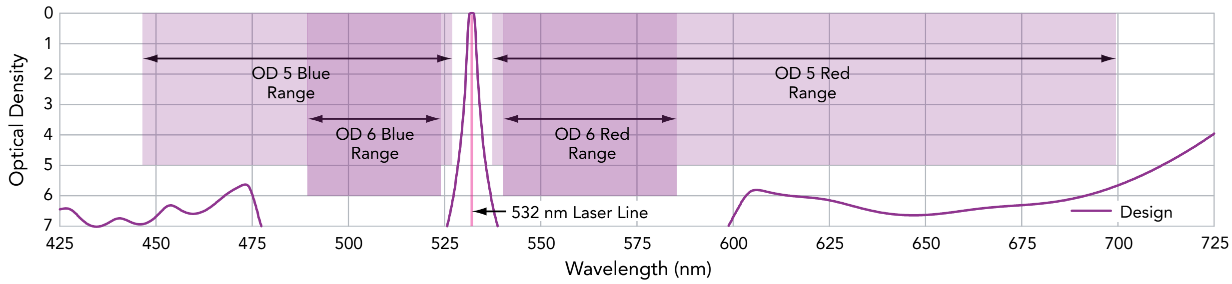
MaxLine® Laser-line Spectra and Specifications





These graphs demonstrate the outstanding performance of the 785 nm MaxLine laser-line filter, which has transmission guaranteed to exceed 90% at the laser line and OD > 5 blocking less than 1% away from the laser line. Note the excellent agreement with the design curves.

MaxLine Filter Blocking Performance *(532 nm filter shown)*



Common Specifications

Property		Value	Comment
Laser Wavelength λ_L		Standard laser wavelengths available	*See page 99*
Transmission at Laser Line		> 90%	Except λ_L < 400 nm; will typically be even higher
Bandwidth	Typical	0.38% of λ_L	Full Width at Half Maximum (FWHM) Typical 0.7% and Maximum 0.9% for 248.6 & 266 nm
	Maximum	0.7% of λ_L	
Blocking[1]		OD > 5 from λ_L ± 1% to 4500 cm^{-1} (red shift) and 3600 cm^{-1} (blue shift); OD > 6 from λ_L ± 1.5% to 0.92 and 1.10 × λ_L	OD = – $\log_{10}$(Transmission)
Angle of Incidence		0.0° ± 2.0°	*See technical note on page 106*
Temperature Dependence		< 5 ppm / °C	< 0.003 nm / °C for 532 nm filter
Laser Damage Threshold		0.1 J/cm^2 @ 532 nm (10 ns pulse width)	Tested for 532 nm filter only *(see page 109)*
Substrate Material		Low autofluorescence NBK7 or better	Fused silica for 248.6, 266, and 325 nm filters
Substrate Thickness		2.0 ± 0.1 mm	
Overall Thickness		3.5 ± 0.1 mm	Black-anodized aluminum ring
Coating Type		"Hard" ion-beam-sputtered	
Outer Diameter		12.5 + 0.0 / – 0.1 mm (or 25.0 + 0.0 / – 0.1 mm)	Black-anodized aluminum ring
Clear Aperture		≥ 10 mm (or ≥ 22 mm)	For all optical specifications
Transmitted Wavefront Error		< λ / 4 RMS at λ = 633 nm	Peak-to-valley error < 5 x RMS measured within clear aperture
Beam Deviation		≤ 10 arcseconds	
Surface Quality		60-40 scratch-dig	Measured within clear aperture
Reliability and Durability		Ion-beam-sputtered, hard-coating technology with epoxy-free, single-substrate construction for unrivaled filter life. MaxLine filters are rigorously tested and proven to MIL-STD-810F and MIL-C-48497A environmental standards.	

[1] The wavelengths associated with these red and blue shifts are given by $\lambda = 1/(1/\lambda_L - \text{red shift} \times 10^{-7})$ and $\lambda = 1/(1/\lambda_L + \text{blue shift} \times 10^{-7})$, respectively, where λ and λ_L are in nm, and the shifts are in cm^{-1}. Note that the red shifts are 3600 cm^{-1} for the 808 and 830 nm filters and 2700 cm^{-1} for the 980 nm filter, and the red and blue shifts are 2400 and 800 cm^{-1}, respectively, for the 1047 and 1064 nm filters. *See Technical Note on wavenumbers on page 102.*

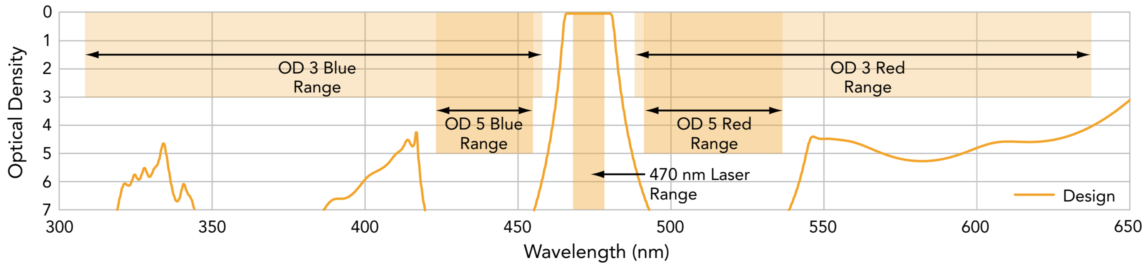
MaxDiode™ Laser Diode Clean-up Filters

Our MaxDiode filters are ideal for both volume OEM manufacturers of laser-based fluorescence instrumentation and laboratory researchers who use diode lasers for fluorescence excitation and other types of spectroscopic applications. Keep the desirable laser light while eliminating the noise with MaxDiode filters.

- Square low-ripple passband for total consistency as your laser ages, over temperatures, or when installing a replacement laser
- Highest transmission, exceeding 90% over each diode's possible laser wavelengths
- Extremely steep edges transitioning to very high blocking to successfully filter undesired out-of-band noise
- For narrow-line lasers, use our MaxLine® laser-line filters (see page 99.

Laser Diode Wavelength	Transmission & Bandwidth	Center Wave-length	OD 3 Blocking Range	OD 5 Blocking Range	12.5 mm Part Number	25 mm Part Number
375 nm	> 90% over 6 nm	375 nm	212-365 & 385-554 nm	337-359 & 393-415 nm	LD01-375/6-12.5	LD01-375/6-25
405 nm	> 90% over 10 nm	405 nm	358-389 & 420-466 nm	361-384 & 428-457 nm	LD01-405/10-12.5	LD01-405/10-25
440 nm	> 90% over 8 nm	439 nm	281-425 & 453-609 nm	392-422 & 456-499 nm	LD01-439/8-12.5	LD01-439/8-25
470 nm	> 90% over 10 nm	473 nm	308-458 & 488-638 nm	423-455 & 491-537 nm	LD01-473/10-12.5	LD01-473/10-25
640 nm	> 90% over 8 nm	640 nm	400-625 & 655-720 nm	580-622 & 658-717 nm	LD01-640/8-12.5	LD01-640/8-25
785 nm	> 90% over 10 nm	785 nm	475-768 & 800-888 nm	705-765 & 803-885 nm	LD01-785/10-12.5	LD01-785/10-25
975 nm	> 90% over 10 nm	975 nm	725-950 & 997-1100 nm	860-945 & 1000-1090 nm	LD01-975/10-12.5	LD01-975/10-25
				Price	$315	$570

MaxDiode Filter Blocking Performance *(470 nm filter shown)*



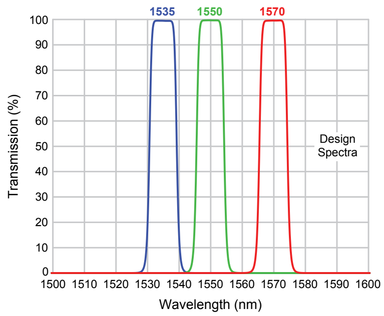
Laser Diode Wavelength	Transmission & Bandwidth	Center Wave-length	OD 3.5 Blocking Range	OD 5 Blocking Range	12.5 mm Part Number	25 mm Part Number
445 nm	> 90% over 11 nm	445 nm	456.5 nm	350-430 nm & 461-900 nm	LD02-445/11-12.5	LD02-445/11-25
488 nm	> 90% over 10 nm	488 nm	500 nm	350-473 nm & 503-900 nm	LD02-488/10-12.5	LD02-488/10-25
514 nm	> 90% over 9 nm	514 nm	525.5 nm	350-498 nm & 530-900 nm	LD02-514/9-12.5	LD02-514/9-25
592 nm	> 90% over 6 nm	592 nm	606 nm	350-576 nm & 608-900 nm	LD02-592/6-12.5	LD02-592/6-25
637 nm	> 90% over 9 nm	637 nm	652.5 nm	350-619 nm & 655-900 nm	LD02-637/9-12.5	LD02-637/9-25
730 nm	> 90% over 9 nm	730 nm	749 nm	350-710 nm & 750-900 nm	LD02-730/9-12.5	LD02-730/9-25
785 nm	> 90% over 9 nm	785 nm	799.5 nm	350-764 nm & 806-900 nm	LD02-785/9-12.5	LD02-785/9-25
				Price	$315	$675

Common Specifications

Property	Value	Comment
Transmission over Full Bandwidth	> 90%	Will typically be even higher
Transmission Ripple	< ± 1.5%	Measured peak-to-peak across bandwidth
Blocking Wavelength Ranges	Optimized to eliminate spontaneous emission	*See table above*
Angle of Incidence	0.0° ± 5.0°	Range for above optical specifications
Performance for Non-collimated Light	The high-transmission portion of the long-wavelength edge and the low-transmission portion of the short-wavelength edge exhibit a small "blue shift" (shift toward shorter wavelengths). Even for cone half angles as large as 15° at normal incidence, the blue shift is only several nm.	

All other mechanical specifications are the same as MaxLine® specifications on page 100.

Near Infrared Bandpass Filters



Semrock's industry-leading ion-beam-sputtering manufacturing is now available for making optical filters with precise spectral features (sharp edges, passbands, etc.) at near-IR wavelengths, with features out to ~ 1700 nm, and high transmission to wavelengths > 2000 nm. The bandpass filters on this page are ideal as laser source clean-up filters and as detection filters which pass particular laser wavelengths and virtually eliminate background over the full InGaAs detector range (850 – 1750 nm). They are optimized for the most popular "retina-safe" lasers in the 1.5 μm wavelength range, where maximum permissible eye exposures are much higher than in the visible or at the 1.06 μm neodymium line. Applications include laser radar, remote sensing, rangefinding, and laser-induced breakdown spectroscopy (LIBS).

Near-IR bandpass filters are a good match for Er-doped fiber and Er-doped glass lasers at 1535 nm, r-doped fiber and InGaAsP semiconductor lasers at 1550 nm, and Nd:YAG-pumped optical parametric oscillators (OPO's) at 1570 nm.

Center Wavelength	Transmission & Bandwidth	Nominal Full-width, Half-Maximum	OD 5 Blocking Range	OD 6 Blocking Range	Part Number	Price
1535 nm	> 90% over 3 nm	6.8 nm	850 – 1519 nm 1550 – 1750 nm	1412 – 1512 nm 1558 – 1688 nm	NIR01-1535/3-25	$735
1550 nm	> 90% over 3 nm	8.8 nm	850 – 1534 nm 1565 – 1750 nm	1426 – 1526 nm 1573 – 1705 nm	NIR01-1550/3-25	$735
1570 nm	> 90% over 3 nm	8.9 nm	850 – 1554 nm 1585 – 1750 nm	1444 – 1546 nm 1593 – 1727 nm	NIR01-1570/3-25	$735

LDT specification = 1 J/cm² @1570 nm (10 ns pulse width)

Except for the transmission, bandwidth, and blocking specifications listed above, all other specifications are identical to MaxLine® specifications on page 100.

TECHNICAL NOTE

Measuring Light with Wavelengths and Wavenumbers

The "color" of light is generally identified by the distribution of power or intensity as a function of wavelength λ.
For example, visible light has a wavelength that ranges from about 400 nm to just over 700 nm. However, sometimes it is convenient to describe light in terms of units called "wavenumbers," where the wavenumber w is typically measured in units of cm^{-1} ("inverse centimeters") and is simply equal to the inverse of the wavelength:

$$w\left(\text{cm}^{-1}\right) = \frac{10^7}{\lambda\ (\text{nm})}$$

In applications like Raman spectroscopy, often both wavelength and wavenumber units are used together, leading to potential confusion. For example, laser lines are generally identified by wavelength, but the separation of a particular Raman line from the laser line is generally given by a "wavenumber shift" Δw, since this quantity is fixed by the molecular properties of the material and independent of which laser wavelength is used to excite the line.

When speaking of a "shift" from a first known wavelength λ_1 to a second known wavelength λ_2, the resulting wavelength shift Δλ is given by

$$\Delta\lambda = \lambda_2 - \lambda_1$$

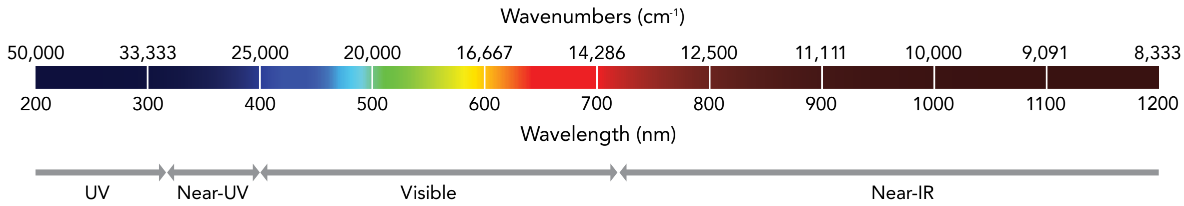
whereas the resulting wavenumber shift Δw is given by

$$\Delta w = \left(\frac{1}{\lambda_2} - \frac{1}{\lambda_1}\right) \times 10^7 = -\frac{\Delta\lambda}{\lambda_1\lambda_2} \times 10^7$$

When speaking of a known wavenumber shift Δw from a first known wavelength λ_1, the resulting second wavelength λ_2 is given by

$$\lambda_2 = \frac{1}{1/\lambda_1 + \Delta w \times 10^{-7}}$$

Note that when the final wavelength λ_2 is longer than the initial wavelength λ_1, which corresponds to a "red shift," in the above equations $\Delta w < 0$, consistent with a shift toward smaller values of w. However, when the final wavelength λ_2 is shorter than the initial wavelength λ_1, which corresponds to a "blue shift," $\Delta w > 0$, consistent with a shift toward larger values of w.



StopLine® Single-notch Filters

StopLine deep notch filters rival the performance of holographic notch filters but in a less expensive, more convenient, and more reliable thin-film filter format (U.S. Patents No. 7,123,416 and No. 9,354,370). These filters are ideal for applications including Raman spectroscopy, laser-based fluorescence instruments, and biomedical laser systems.

- The stunning StopLine E-grade notch filters offer high transmission over ultra-wide passbands (UV to 1600 nm)
- Deep laser-line blocking for maximum laser rejection (OD > 6)
- High laser damage threshold and proven reliability
- Rejected light is reflected, for convenient alignment and best stray-light control
- Multi-notch filters are available for blocking multiple laser lines (see page 105)

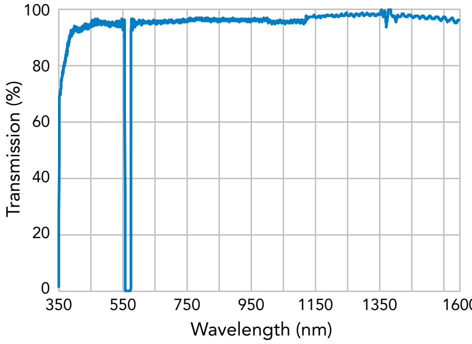
Semrock introduced a breakthrough invention in thin-film optical filters: our StopLine E-grade thin-film notch filters have ultrawide passbands with deep and narrow laser-line blocking. Unheard of previously in a thin-film notch filter made with multiple, discrete layers, these patent-pending notch filters attenuate the laser wavelength with OD > 6 while passing light from the UV well into the near-infrared (1600 nm). They are especially suited for optical systems addressing multiple regions of the optical spectrum (e.g., UV, Visible, and Near-IR), and for systems based on multiple detection modes (e.g., fluorescence, Raman spectroscopy, laser-induced breakdown spectroscopy, etc.).

Wavelength	Passband Range	Typical 50% Notch Bandwidth	Laser-line Blocking	Part Number	Price
405.0 nm	330.0 – 1600.0 nm	9 nm	OD > 6	NF03-405E-25	$945
473.0 nm	350.0 - 1600.0 nm	13 nm	OD > 6	NF03-473E-25	$945
488.0 nm	350.0 – 1600.0 nm	14 nm	OD > 6	NF03-488E-25	$945
514.5 nm	350.0 – 1600.0 nm	16 nm	OD > 6	NF03-514E-25	$990
532.0 nm	350.0 – 1600.0 nm 399.0 – 709.3 nm	17 nm 17 nm	OD > 6 OD > 6	NF03-532E-25 NF01-532U-25	$945 $765
561.4 nm	350.0 – 1600.0 nm	19 nm	OD > 6	NF03-561E-25	$990
594.1 nm	350.0 – 1600.0 nm	22 nm	OD > 6	NF03-594E-25	$945
632.8 nm	350.0 – 1600.0 nm	25 nm	OD > 6	NF03-633E-25	$945
642.0 nm	350.0 - 1600.0 nm	26 nm	OD > 6	NF03-642E-25	$990
658.0 nm	350.0 – 1600.0 nm	27 nm	OD > 6	NF03-658E-25	$990
785.0 nm	350.0 – 1600.0 nm	39 nm	OD > 6	NF03-785E-25	$945
808.0 nm	350.0 – 1600.0 nm	41 nm	OD > 6	NF03-808E-25	$945

Looking for a 1064 nm notch filter? Try the NF03-532/1064E on page 105.

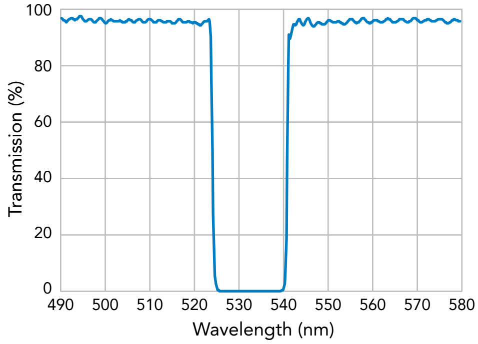
NF03-561E

Typical Measured Data



NF03-532E

Typical Measured Data



StopLine® Single-notch Filter Common Specifications

Property		Value	Comment
Laser Line Blocking:	E- & U-grade	> 6 OD	At the design laser wavelength; OD = - $\log_{10}$ (transmission)
Typical 50% Notch Bandwidth	E- & U-grade	NBW = $55 \times 10^{-6} \times \lambda_L^2 + 14 \times 10^{-3} \times \lambda_L - 5.9$ e.g. 17 nm (600 cm^{-1}) for 532.0 nm filter	Full width at 50% transmission; λ_L is design laser wavelength (NBW and λ_L in nm)
Maximum 50% Notch Bandwidth		< 1.1 × NBW	
90% Notch Bandwidth		< 1.3 × NBW	Full width at 90% transmission
Passband	E-grade	350 –1600 nm	Excluding notch λ_L is design laser wavelength (nm)
	U-grade	from 0.75 × λ_L to λ_L / 0.75	
Average Passband Transmission	E-grade	> 80% 350 – 400 nm, > 93% 400 – 1600 nm	Excluding notch Lowest wavelength is 330 nm for NF03-405E
	U-grade	> 90%	
Passband Transmission Ripple		< 2.5%	Calculated as standard deviation
Angle of Incidence		0.0° ± 5.0°	*See technical note on page 106*
Angle Tuning Range[1]		- 1% of laser wavelength (- 5.3 nm or + 190 cm^{-1} for 532 nm filter)	Wavelength "blue-shift" attained by increasing angle from 0° to 14°
Laser Damage Threshold		1 J/cm^2 @ 532 nm (10 ns pulse width)	Tested for 532 nm filter only (*see page 109*)
Coating Type		"Hard" ion-beam-sputtered	
Clear Aperture		≥ 22 mm	For all optical specifications
Outer Diameter		25.0 + 0.0 / - 0.1 mm	Black-anodized aluminum ring
Overall Thickness		3.5 ± 0.1 mm	Black-anodized aluminum ring

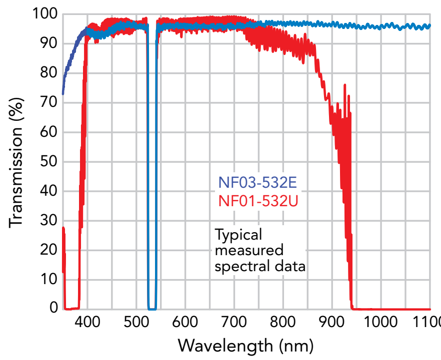
All other General Specifications are the same as the RazorEdge® specifications on page 96.

[1] For small angles θ (in degrees), the wavelength shift near the laser wavelength is $\Delta\lambda$ (nm) = $-5.0 \times 10^{-5} \times \lambda_L \times \theta^2$ and the wavenumber shift is Δ(wavenumbers) (cm^{-1}) = $500 \times \theta^2 / \lambda_L$, where λ_L (in nm) is the laser wavelength. See Technical Note on wavenumbers on page 102.

PRODUCT NOTE

Notch Filters

Notch filters are ideal for applications that require nearly complete rejection of a laser line while passing as much non-laser light as possible. Hard-coated thin-film notch filters offer a superior solution due to their excellent transmission (> 90%), deep laser-line blocking (OD > 6) with a narrow notch bandwidth (~ 3% of the laser wavelength), environmental reliability, high laser damage threshold (> 1 J/cm^2), and compact format with convenient back-reflection of the rejected laser light. However, until now, the main drawback of standard thin-film notch filters has been a limited passband range due to the fundamental and higher-harmonic spectral stop bands (see red curve on graph at right).



To achieve a wider passband than standard thin-film notch filters could provide, optical engineers had to turn to "holographic" or "Rugate" notch filters. Unfortunately, holographic filters suffer from lower reliability and transmission (due to the gelatin-based, laminated structure), higher cost (resulting from the sequential production process), and poorer system noise performance and/or higher system complexity. Rugate notch filters, based on a sinusoidally varying index of refraction, generally suffer from lower transmission, especially at shorter wavelengths, and less deep notches.

Semrock E-grade StopLine notch filters offer a breakthrough in optical notch filter technology, bringing together all the advantages of hard-coated standard thin-film notch filters with the ultrawide passbands that were previously possible only with holographic and Rugate notch filters. The spectral performance of the E-grade StopLine filters is virtually identical to that of Semrock's renowned U-grade StopLine filters, but with passbands that extend from the UV (< 350 nm) to the near-IR (> 1600 nm).

StopLine® Multi-notch Filters

Semrock's unique multi-notch filters meet or exceed even the most demanding requirements of our OEM customers. These include dual-, triple-, and even quadruple-notch filters for a variety of multi-laser instruments. Applications include:

- Laser-based fluorescence instruments
- Confocal and multi-photon fluorescence microscopes
- Analytical and medical laser systems

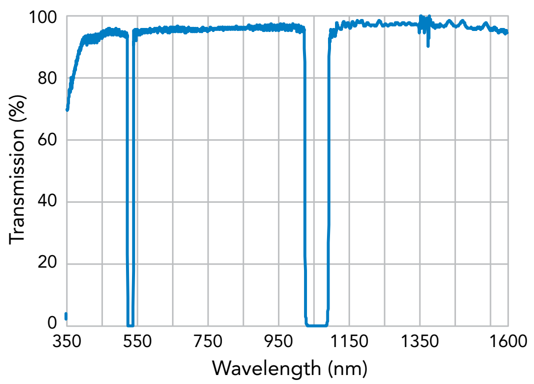
Our advanced manufacturing process allows for notch wavelengths that are not integer multiples of the other.

Laser Wavelengths	Laser-line Blocking	Glass Thickness	Housed Size (Diameter x Thickness)	Part Number	Price
Dual-notch Filters					
488 & 647 nm	OD > 6	3.5 mm	25 mm x 5.0 mm	NF01-488/647-25x5.0	$1125
532 & 1064 nm	OD > 6	2.0 mm	25 mm x 3.5 mm	NF03-532/1064E-25	$1125
Quadruple-notch Filters					
400 – 410, 488, 532, & 631 – 640 nm	OD > 6	2.0 mm	25 mm x 3.5 mm	NF03-405/488/532/635E-25	$1175
400 – 410, 488, 561, & 631 – 640 nm	OD > 6	2.0 mm	25 mm x 3.5 mm	NF03-405/488/561/635E-25	$1175

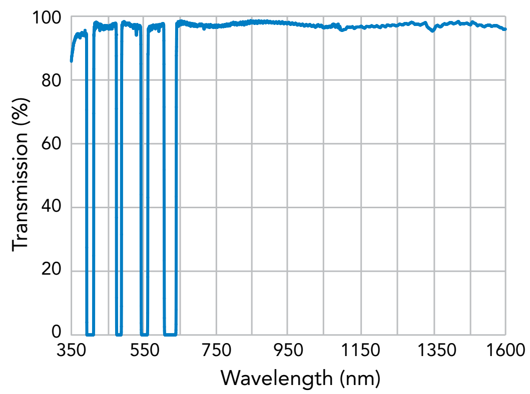
For multi-notch common specifications, please see www.idex-hs.com/semrock for full details.

ACTUAL MEASURED DATA FROM TYPICAL FILTERS IS SHOWN

NF03-532/1064E-25 Dual-notch Filter



NF03-405/488/561/635E-25 Quad-notch Filter



For complete graphs, ASCII data, and the latest offerings, go to www.idex-hs.com/semrock.

TECHNICAL NOTE

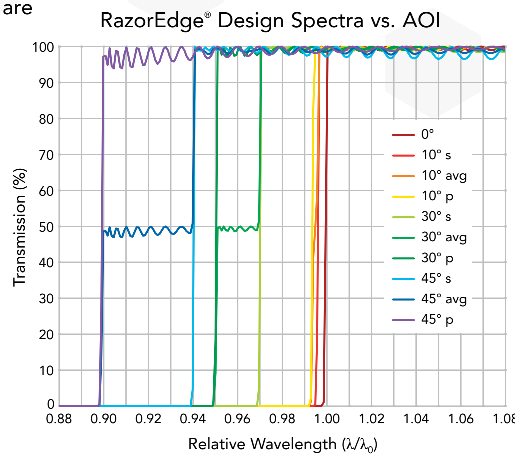
Filter Spectra at Non-normal Angles of Incidence

Many of the filters in this catalog (with the exception of dichroic beamsplitters, polarization, and the MaxMirror®) are optimized for use with light at or near normal incidence. However, for some applications it is desirable to understand how the spectral properties change for a non-zero angle of incidence (AOI).

There are two main effects exhibited by the filter spectrum as the angle is increased from normal:

1. the features of the spectrum shift to shorter wavelengths;
2. two distinct spectra emerge – one for s-polarized light and one for p-polarized light.

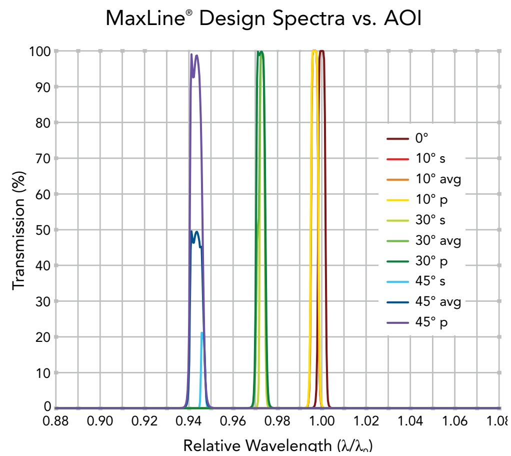
As an example, the graph at the right shows a series of spectra derived from a typical RazorEdge long-wave-pass (LWP) filter design. Because the designs are so similar for all of the RazorEdge filters designed for normal incidence, the set of curves in the graph can be applied approximately to any of the filters. Here the wavelength λ is compared to the wavelength λ_0 of a particular spectral feature (in this case the edge location) at normal incidence. As can be seen from the spectral curves, as the angle is increased from normal incidence the filter edge shifts toward shorter wavelengths and the edges associated with s- and p-polarized light shift by different amounts. For LWP filters, the edge associated with p-polarized light shifts more than the edge associated with s-polarized light, whereas for short-wave-pass (SWP) filters the opposite is true. Because of this polarization splitting, the spectrum for unpolarized light demonstrates a "shelf" near the 50% transmission point when the splitting significantly exceeds the edge steepness. However, the edge steepness for polarized light remains very high.



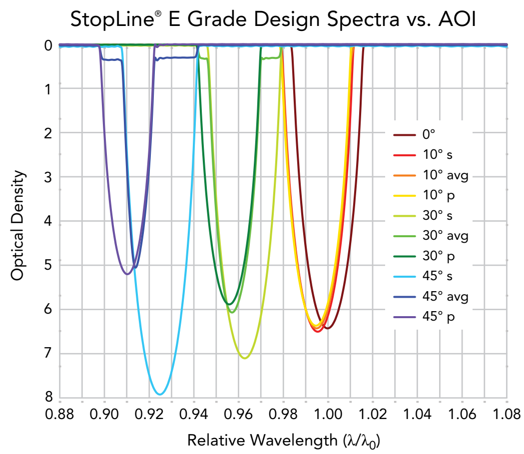
The shift of almost any spectral feature can be approximately quantified by a simple model of the wavelength λ of the feature vs. angle of incidence θ, given by the equation:

$$\lambda(\theta) = \lambda_0 \sqrt{1-(\sin\theta/n_{eff})^2}$$

where n_{eff} is called the effective index of refraction, and λ_0 is the wavelength of the spectral feature of interest at normal incidence. Different shifts that occur for different spectral features and different filters are described by a different effective index. For the RazorEdge example above, the shift of the 90% transmission point on the edge is described by this equation with n_{eff} = 2.08 and 1.62 for s- and p-polarized light, respectively.



Other types of filters don't necessarily exhibit such a marked difference in the shift of features for s- and p-polarized light. For example, the middle graph shows a series of spectra derived from a typical MaxLine laser-line filter design curve. As the angle is increased from normal incidence, the center wavelength shifts toward shorter wavelengths and the bandwidth broadens slightly for p-polarized light while narrowing for s-polarized light. The center wavelength shifts are described by the above equation with n_{eff} = 2.19 and 2.13 for s- and p-polarized light, respectively. The most striking feature is the decrease in transmission for s-polarized light, whereas the transmission remains quite high for p-polarized light.



As another example, the graph at the right shows a series of spectra derived from a typical E-grade StopLine notch filter design curve. As the angle is increased from normal incidence, the notch center wavelength shifts to shorter wavelengths; however, the shift is greater for p-polarized light than it is for s-polarized light. The shift is described by the above equation with n_{eff} = 1.71 and 1.86 for p- and s-polarized light, respectively. Further, whereas the notch depth and bandwidth both decrease as the angle of incidence is increased for p-polarized light, in contrast the notch depth and bandwidth increase for s-polarized light. Note that it is possible to optimize the design of a notch filter to have a very deep notch even at a 45° angle of incidence.

Interested in seeing how a Semrock standard filter behaves at a particular angle of incidence, state of polarization or cone half angle of illumination? Simply click the Click for MyLight Tool button on the Semrock website or model this filter in SearchLight.

White Paper Library
Mirrors
Edge Filters
Dichroic Beamsplitters
Laser-line Filters
Laser Diode Filters
NIR Filters
Notch Filters
Lamp Clean-up Filters
More

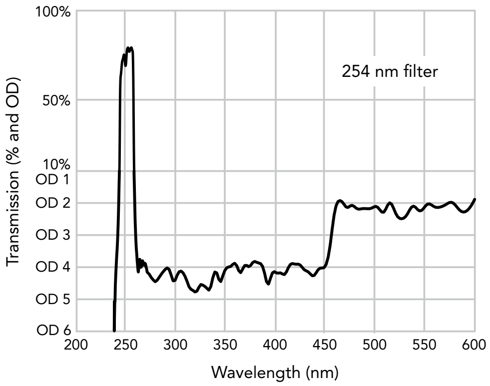
MaxLamp™ Mercury Line Filters

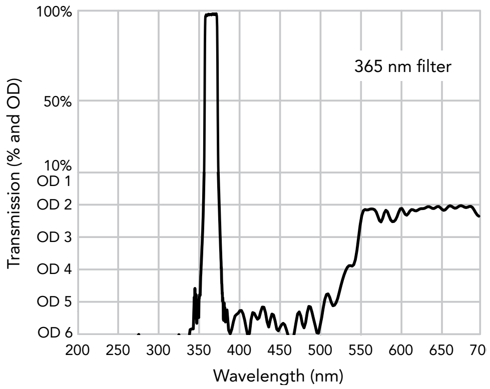
These ultra-high-performance MaxLamp mercury line filters are ideal for use with high-power mercury arc lamps for applications including spectroscopy, optical metrology, and photolithography mask-aligner and stepper systems. Maximum throughput is obtained by careful optimization of the filter design to allow for use in a variety of different applications. The non-absorbing blocking ensures that all other mercury lines, as well as intra-line intensity, are effectively eliminated.

- High transmission > 65% in the UV and > 93% in the Near-UV
- Steep edges for quick transitions
- Exceptional blocking over large portions of visible spectrum

Mercury Line	Transmission and Passband	UV Blocking	Blue Blocking	Red Blocking	Part Number	Price
253.7 nm	> 65% 244 - 256 nm	OD_{avg} > 6: 200 - 236 nm	OD_{avg} > 4: 263 - 450 nm	OD_{avg} > 2: 450 - 600 nm	Hg01-254-25	$525
365.0 nm	> 93% 360 - 372 nm	OD_{avg} > 6: 200 - 348 nm	OD_{avg} > 5: 382 - 500 nm	OD_{avg} > 2: 500 - 700 nm	Hg01-365-25	$420

ACTUAL MEASURED DATA SHOWN





Common Specifications

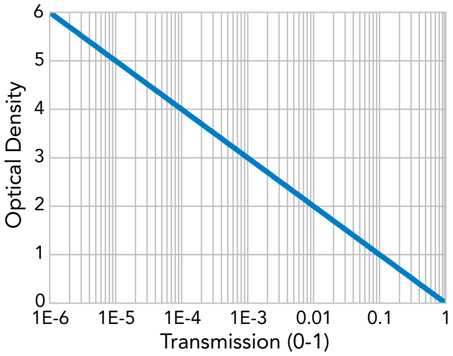
Property	Value		Comment
Guaranteed Transmission	253.7 nm	> 65%	Averaged over the passband, see table above
	365.0 nm	> 93%	
Angle of Incidence	0° ± 7°		Range of angles over which optical specifications are given for collimated light
Cone Half Angle	10°		For uniformly distributed non-collimated light
Autofluorescence	Ultra-low		Fused silica substrate
Outer Diameter	25.0 + 0.0 / - 0.1 mm		Black anodized aluminum ring
Overall Thickness	3.5 mm ± 0.1mm		Black anodized aluminum ring
Clear Aperture	≥22 mm		For all optical specifications
Surface Quality	80-50 scratch-dig		Measured within clear aperture

All other mechanical specifications are the same as MaxLine® specifications on page 100

TECHNICAL NOTE

Working with Optical Density

Optical Density – or OD, as it is commonly called – is a convenient tool to describe the transmission of light through a highly blocking optical filter (when the transmission is extremely small). OD is simply defined as the negative of the logarithm (base 10) of the transmission, where the transmission varies between 0 and 1 ($OD = -\log_{10}(T)$). Therefore, the transmission is simply 10 raised to the power of minus the OD ($T = 10^{-OD}$). The graph below left demonstrates the power of OD: a variation in transmission of six orders of magnitude (1,000,000 times) is described very simply by OD values ranging between 0 and 6. The table of examples below middle, and the list of "rules" below right, provide some handy tips for quickly converting between OD and transmission. Multiplying and dividing the transmission by two and ten is equivalent to subtracting and adding 0.3 and 1 in OD, respectively.



Transmission	OD
1	0
0.5	0.3
0.2	0.7
0.1	1.0
0.05	1.3
0.02	1.7
0.01	2.0
0.005	2.3
0.002	2.7
0.001	3.0

The "1" Rule
T = 1 → OD = 0

The "x 2" Rule
T x 2 → OD – 0.3

The "÷ 2" Rule
T ÷ 2 → OD + 0.3

The "x 10" Rule
T x 10 → OD – 1

The "÷ 10" Rule
T ÷ 10 → OD + 1

TECHNICAL NOTE

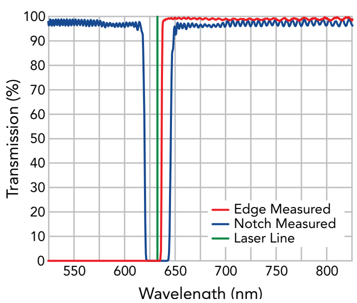
Edge Filters vs. Notch Filters for Raman Instrumentation

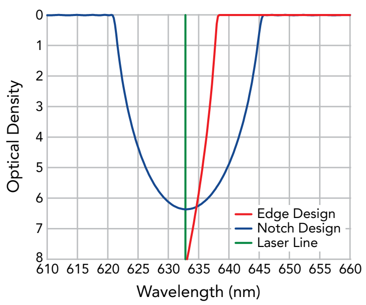
RazorEdge® Filter Advantages:
- Steepest possible edge for looking at the smallest Stokes shifts
- Largest blocking of the laser line for maximum laser rejection

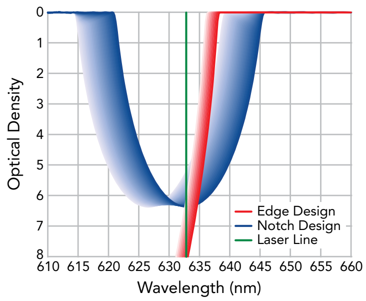
StopLine® Notch Filter Advantages:
- Measure Stokes and Anti-Stokes signals simultaneously
- Greater angle-tunability and bandwidth for use with variable laser lines

The graph below left illustrates the ability of a long-wave-pass (LWP) filter to get extremely close to the laser line. The graph in the center compares the steepness of an edge filter to that of a notch filter. A steeper edge means a narrower transition width from the laser line to the high-transmission region of the filter. With transition widths guaranteed to be below 1% of the laser wavelength (on Semrock U-grade edge filters), these filters don't need to be angle-tuned!

The graph on the right shows the relative tuning ranges that can be achieved for edge filters and notch filters. Semrock edge filters can be tuned up to 0.3% of the laser wavelength. The filters shift toward shorter wavelengths as the angle of incidence is increased from 0° to about 8°. Semrock notch filters can be tuned up to 1.0% of the laser wavelength. These filters also shift toward shorter wavelengths as the angle of incidence is increased from 0° up to about 14°.

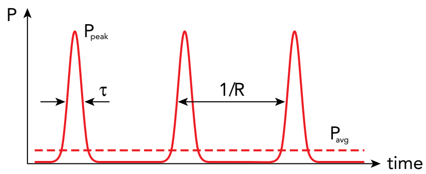






Technical Note: Laser Damage Threshold

Laser damage to optical filters is strongly dependent on many factors, and thus it is difficult to guarantee the performance of a filter in all possible circumstances. Nevertheless, it is useful to identify a Laser Damage Threshold (LDT) of pulse fluence or intensity below which no damage is likely to occur.



Pulsed vs. continuous-wave lasers: Pulsed lasers emit light in a series of pulses of duration τ at a repetition rate R with peak power P_{peak}. Continuous-wave (cw) lasers emit a steady beam of light with a constant power P. Pulsed-laser average power P_{avg} and cw laser constant power for most lasers typically range from several milliWatts (mW) to Watts (W). The table at the end of this Note summarizes the key parameters that are used to characterize the output of pulsed lasers.

The table below summarizes the conditions under which laser damage is expected to occur for three main types of lasers.

Units: P in Watts; R in Hz; diameter in cm; LDT_{LP} in J/cm².

Note: λ_{spec} and τ_{spec} are the wavelength and pulse width, respectively, at which LDT_{LP} is specified.
** The cw and quasi-cw cases are rough estimates, and should not be taken as guaranteed specifications.*

Type of Laser	Typical Pulse Properties	When Laser Damage is Likely
Long-pulse	τ ~ ns to µs R ~ 1 to 100 Hz	$\dfrac{P_{avg}}{R \times (\pi/4) \times diameter^2} > \dfrac{\lambda}{\lambda_{spec}} \times \sqrt{\dfrac{\tau}{\tau_{spec}}} \times LDT_{LP}$
cw	Continuous output	$\dfrac{P}{(\pi/4) \times diameter^2} > \sim 10{,}000 \left(\dfrac{W}{J}\right) \times \dfrac{\lambda}{\lambda_{spec}} \times LDT_{LP}{}^*$
Quasi-cw	τ ~ fs to ps R ~ 10 to 100 MHz	$\dfrac{P_{avg}}{(\pi/4) \times diameter^2} > \sim 10{,}000 \left(\dfrac{W}{J}\right) \times \dfrac{\lambda}{\lambda_{spec}} \times LDT_{LP}{}^*$

Long-pulse lasers:
Damage Threshold Long Pulse is generally specified in terms of pulse fluence for "long-pulse lasers." Because the time between pulses is so large (milliseconds), the irradiated material is able to thermally relax—as a result damage is generally not heat-induced, but rather caused by nearly instantaneous dielectric breakdown. Usually damage results from surface or volume imperfections in the material and the associated irregular optical field properties near these sites. Most Semrock filters have LDT_{LP} values on the order of 1 J/cm², and are thus considered "high-power laser quality" components. An important exception is a narrowband laser-line filter in which the internal field strength is strongly concentrated in a few layers of the thin-film coating, resulting in an LDT_{LP} that is about an order of magnitude smaller.

cw lasers: Damage from cw lasers tends to result from thermal (heating) effects. For this reason the LDT_{CW} for cw lasers is more dependent on the material and geometric properties of the sample, and therefore, unlike for long-pulse lasers, it is more difficult to specify with a single quantity. For this reason Semrock does not test nor specify LDT_{CW} for its filters. As a very rough rule of thumb, many all-glass components like dielectric thin-film mirrors and filters have a LDT_{CW} (specified as intensity in kW/cm²) that is at least 10 times the long-pulse laser LDT_{LP} (specified as fluence in J/cm²).

Quasi-cw lasers: Quasi-cw lasers are pulsed lasers with pulse durations τ in the femtosecond (fs) to picosecond (ps) range, and with repetition rates R typically ranging from about 10 – 100 MHz for high-power lasers. These lasers are typically mode-locked, which means that R is determined by the round-trip time for light within the laser cavity. With such high repetition rates, the time between pulses is so short that thermal relaxation cannot occur. Thus quasi-cw lasers are often treated approximately like cw lasers with respect to LDT, using the average intensity in place of the cw intensity.

Example: Frequency-doubled Nd:YAG laser at 532 nm. Suppose τ = 10 ns, R = 10 Hz, and P_{avg} = 1 W. Therefore D = 1 x 10^{-7}, E = 100 mJ, and P_{peak} = 10 MW. For diameter = 100 µm, F = 1.3 kJ/cm², so a part with LDT_{LP} = 1 J/cm² will likely be damaged. However, for diameter = 5 mm, F = 0.5 J/cm², so the part will likely not be damaged.

Symbol	Definition	Units	Key Relationships
τ	Pulse duration	sec	$\tau = D / R$
R	Repetition rate	Hz = sec⁻¹	$R = D / \tau$
D	Duty cycle	dimensionless	$D = R \times \tau$
P	Power	Watts = Joules / sec	$P_{peak} = E / \tau$; $P_{avg} = P_{peak} \times D$; $P_{avg} = E \times R$
E	Energy per pulse	Joules	$E = P_{peak} \times \tau$; $E = P_{avg} / R$
A	Area of laser spot	cm²	$A = (\pi / 4) \times diameter^2$
I	Intensity	Watts / cm²	$I = P / A$; $I_{peak} = F / \tau$; $I_{avg} = I_{peak} \times D$; $I_{avg} = F \times R$
F	Fluence per pulse	Joules / cm²	$F = E / A$; $F = I_{peak} \times \tau$; $F = I_{avg} / R$

TECHNICAL NOTE

Sputtered Thin-film Coatings

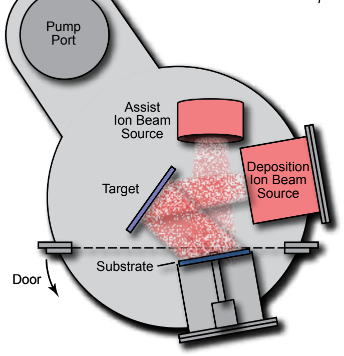
Optical thin-film coatings can be deposited by a variety of methods. Traditionally the most popular methods for depositing multilayer coatings – required for higher-performance mirrors and filters – include thermal and electron-beam (e-beam) evaporation and ion-assisted e-beam evaporation (IAD). These have been in use for many decades. Films evaporated without ion-assist have several significant shortcomings that largely stem from the porosity of the resulting films. They are often referred to as "soft" coatings, because they are not very durable, they absorb water vapor which results in wavelength shifting, they also shift with temperature changes, and they can exhibit noticeable scattering. With additional energy from an ion gun directed at the substrate during the physical vapor deposition process, IAD coatings are sometimes referred to as "semihard" since they are appreciably more dense, resulting in significantly better durability and lower moisture absorption, temperature shifting, and scattering. With all evaporated film processes, variations in the vapor "plume" during the deposition process make it challenging to control the rate and uniformity with high precision, thus making it difficult to manufacture large volumes of complex filters with a high number of precise-thickness layers.

	Electron-beam / Thermal Evaporation	Ion-assisted Electron-beam Evaporation (IAD)	Sputtering
Deposition Process	Physical Vapor Deposition	Energetic Physical Vapor Deposition	Energetic Physical Vapor Deposition
	Variable deposition rates	Variable deposition rates	Extremely stable deposition rates
	Variable spatial uniformity	Variable spatial uniformity	Controllable spatial uniformity
Resulting Thin Films	Soft coatings	Semi-hard coatings	Hard, dense coatings
	Low durability	Moderate to high durability	Very high durability
	Hygroscopic (absorb moisture)	Minimally hygroscopic	Impervious to humidity
	Appreciable temperature shifting	Low temperature shifting	Very low temperature shifting
	Some scattering	Low scattering	Very low scattering
	Some absorption	Low absorption	Very low absorption
	Low film stress	Film stress	Reproducible film stress

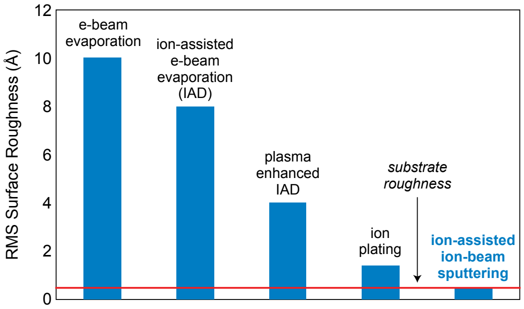
In contrast, Semrock manufacturers all of its optical filters with a deposition process called sputtering. This state-of-the-art technology was originally developed for coating precise ferrite thin films for magnetic disk drive heads, and then gained a reputation in the optics arena for fabrication of extremely low-loss mirrors for ring-laser gyroscope applications. In the late-1990's it was adapted to manufacture the highest-performance optical filters for wavelength-division multiplexing in the booming fiber-optic telecommunications industry. Sputtering produces hard refractory oxide thin films – as hard as the glass substrates on which they are coated. This stable process is renowned for its ability to reproducibly deposit many hundreds of low-loss, reliable thin-film layers with high optical-thickness precision.

One way to clearly see the difference among soft evaporated films, the more robust films produced with IAD, and the very dense, low-scattering films resulting from the sputtering process is to study the film surface morphology closely. Atomic force microscopy reveals surface characteristics indicative of the packing density of the films. The graph below shows results from a study that compared the three main deposition methods as well as two other less-common modified processes [1]. Films were coated on substrates with a starting root-mean-square (RMS) surface roughness below 0.5 Å. Only sputtering produces highly multi-layered films with sufficient packing density to result in surface roughness comparable to that of the starting substrate.

Ion-assisted Ion-beam Sputtering



A perceived limitation of the sputtering process has always been throughput – the excellent performance came at the expense of slow deposition rates and limited coating areas. For the established applications of disk drive heads and telecom filters with dimensions of only one to several mm at most this limitation was not too severe. However, it was considered a show-stopper for cost-effective production of larger filters in higher volumes. Semrock broke through this limitation by turning sputtering into a true high-volume manufacturing platform for large (dimensions of inches) very high layer count optical filters. And we did this without compromising the optical performance for which sputtering was renowned, resulting from dense, low-scattering thin film layers of extreme optical-thickness precision. Semrock made ground-breaking developments in process technology to boost rates and uniformity, and we are continually improving the process even today. And our highly advanced deposition-control technology based on the proprietary hardware, algorithms, and software of Semrock's "optical monitoring" system enables repeatable deposition of many hundreds of thin film layers of even arbitrary thickness for complex filters with superb spectral features.



[1] "Optical Morphology: Just How Smooth Is That Surface?," C. Langhorn and A. Howe, Photonics Spectra (Laurin Publishing), June 1998.

TECHNICAL NOTE

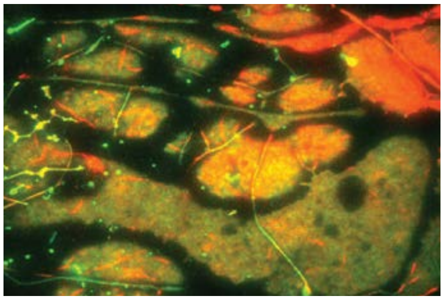
TIRF using 1 λ RWE Super-resolution Microscopy Cubes

Super-resolution Microscopy Cubes set the new standard for laser based microscopes. These cubes are optimized for mounting 1 λ RWE 1 mm thick super-resolution laser dichroic beamsplitters. Maximize SNR and minimize artifacts in TIRF, confocal, PALM, STORM, SIM, and other super-resolution techniques.

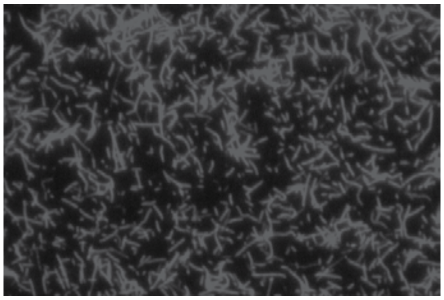
Conventional microscopy cubes can significantly compromise the flatness of the dichroic beamsplitters thereby introducing aberrations. But super-resolution imaging systems are highly sensitive to optical wavefront distortion and demand the highest quality components for best instrument sensitivity. Our industry-leading 1λ RWE 1 mm thick laser dichroic beamsplitters minimize focus shift and aberrations in the reflected beam compared to standard dichroic beamsplitters. However, in order to realize their full flatness potential, these dichroic beamsplitters need to be carefully mounted in microscopy cubes. Semrock has developed proprietary methods of installing 1 λ RWE super-resolution 1 mm thick dichroic beamsplitters in cubes that guarantee the flatness performance. Offered as standard catalog products, cubes compatible with popular microscopes are available. 1 λ RWE 1 mm dichroics installed in standard microscopy cubes eliminate the need to re-align a 2 mm thick dichroic.

"The new TIRF & super-resolution microscopy cubes from Semrock definitely provide more homogeneous and flat illumination in all excitation/emission bands, compared to other cubes I have seen so far"

– Dr. Peker Milas, Ross Lab, University of Massachusetts Amherst



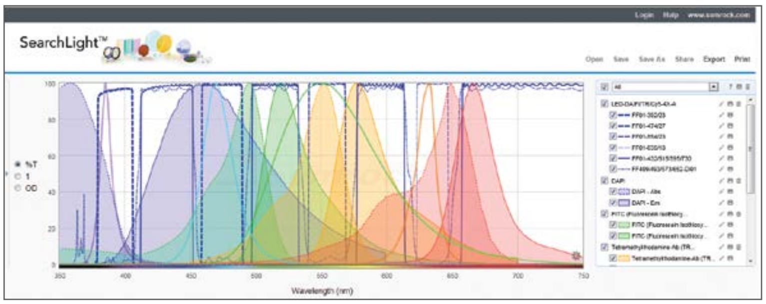
Xenopus laevis embryos transfected with GFP-cadherin and RFP-actin imaged with TIRF using Semrock's Di03-R405/488/561/635-t1 super-resolution dichroic in a full-multiband configuration. Image courtesy of Keck Imaging Center, University of Virginia.



Actin filaments imaged in TIRF using Semrock's Di03-R405/488/532/635-t1 super-resolution dichroic in a full-multiband configuration. Image courtesy of Ross Lab, University of Massachusetts Amherst

SEARCHLIGHT

SearchLight allows fluorescence microscope users and optical instrument designers to predetermine the optimal fluorophore, light source, detector, and optical filter combinations for their microscope or system. By removing the guesswork and hours of searching multiple sources for spectral data, SearchLight users will be able to eliminate trial-and-error headaches and work more efficiently. Users may select from an extensive collection of preloaded spectra or upload their own spectral data in this free and openly accessible tool. Users can also save and share their data securely.



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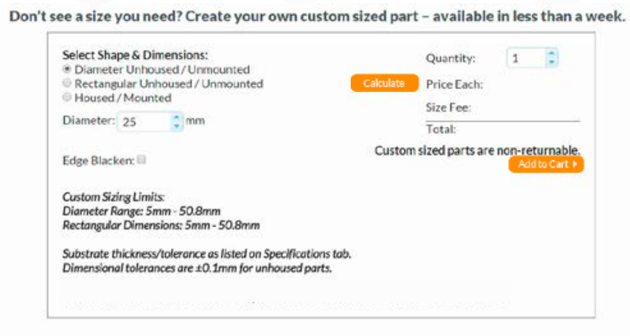
CUSTOM SIZING

Semrock offers custom sizing of most catalog filters right on our website. Whether you need an unhoused / unmounted round or rectangular filter, or the filter mounted into one of Semrock's standard-size aluminum housings, use our custom sizing tool to calculate the price for the quantity you require and add the part number to your cart for purchase. This feature is available for OEM customers with an account. For all other inquiries, please visit www.avr-optics.com.

Simply input your required diameter, rectangular dimensions or required housing diameter. Semrock can size to any diameter from 5 mm to 50 mm in whole 1 mm increments, along with the most common English sizes, 12.7 mm (1/2 inch), 25.4 mm (1 inch), and 50.8 mm (2 inches). Gotta have that 31.4 mm unmounted diameter? We can accommodate that as well, our Inside Sales team will quote the lead time with your order acknowledgement. Semrock also carries standard-size aluminum housings for the following dimensions: 12.5 mm, 25 mm, 25 mm Sutter Threaded Rings, 32 mm, and 50 mm.



Each filter which is available for custom sizing lists the dimensional range which can be accommodated for that filter on the product page. The substrate thickness and tolerance will be the same as for the standard size part for the filter of interest, simply click on the Specifications tab for details.

Need a size outside of these limits? Contact Semrock at Semrock@idexcorp.com to inquire.

ADDITIONAL INFORMATION

Ten Year Warranty:
Be confident in your filter purchase with our comprehensive ten-year warranty. Built to preserve their high level of performance in test after test, year after year, our filters reduce your cost of ownership by eliminating the expense and uncertainty of replacement costs.

30 Day Return Policy:
Semrock is committed to ensuring our customers are completely happy, but if you are not fully satisfied with your purchase simply complete our online form to request an RMA number.

Semrock offers its customers the ability to return new unused, undamaged standard sized Catalog products in original packaging within 30 days of original date of purchase for full credit. OEM volumes of products returned after 30 days may be subject to a restocking fee. Custom sized parts may not be returned as part of the 30 day trial.

Product returned without an RMA number will not be accepted and will be returned at sender's expense.

Products purchased through Semrock's Distribution channel must be returned through the purchasing Distributor. Please contact your Distributor for any quality issues.

Returned products are subject to inspection.

Custom-sizing Service:
Semrock has refined its manufacturing process for small volumes of custom-sized parts. Most catalog items are available in a wide range of circular or rectangular custom sizes. Please contact us directly to discuss your specific needs: Semrock@idexcorp.com.

RoHS & REACH Compliant:
Semrock is RoHS & REACH compliant. A copy of Semrock's RoHS & REACH compliance statement can be found on our website: www.idex-hs.com/about/environmental-policy.

ISO 9001:2015 Certified:
Semrock's quality management system is certified to ISO 9001:2015

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Credit Cards:
For OEM customers purchasing online, Semrock accepts VISA, MasterCard, and American Express (IDEX Health & Science website account required, www.idex-hs.com).

Pricing & Availability:
All prices are domestic USD and subject to change without notice. For current pricing and availability please check our website. For Warranty returns, custom sizing, and certifications please see the inside back cover.

Purchase Orders:
OEM customers with an active IDEX Health & Science account may send POs to IHSOpticsOrders@idexcorp.com.
OEM customers without an active IDEX Health & Science account may send requests for account activation to IHSOpticsOrders@idexcorp.com. Please visit the IDEX Health & Science website for details on setting up your account. Credit approval is subject to review by IDEX Health & Science.

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● Denotes stocking distributors.

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- OEM customers in the USA and Canada can generate quotes online (IDEX Health & Science website account required, www.idex-hs.com).
- North American Government, University, and National Laboratory customers can generate quotations for Semrock Optical Filters through our domestic distribution partner, AVR Optics (AVR Optics website account required, www.avr-optics.com).
- International customers purchasing through Semrock's distribution network may send shopping cart contents to their local distributor (IDEX Health & Science website account required, www.idex-hs.com).

Ordering:

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