Creating Your Own Bandpass Filter

A dynamically customizable solution for the microscope or optical table

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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, or if intensity balancing between fluorophores is needed to reduce eye fatigue of an operator reading assays.

Even with more than 350 different single passband filters available off the shelf from Semrock, we've found that some of our customers aren't able to identify what bandpass they need without doing some testing first. Other customers are looking for a bandpass that doesn't yet exist, but they don't require the volume quantities needed to support a custom filter run. Our VersaChrome Edge™ Tunable Filters seek to fill that gap, allowing both researchers and instrument developers to dynamically create and optimize their own bandpass filter shapes by combining three simple, versatile filters.

The Anatomy of a Bandpass Filter

A traditional bandpass filter is defined by its two edges, and by the blocking it provides out of band. Each edge is a transition from deep blocking to high transmission – a long-wave pass (LWP) edge and a short-wave pass (SWP) edge. The wavelengths at which these two edges transition to high transmission defines the passband, which is then matched to the fluorescence peak of interest.

Out of band blocking is equally important to achieve high signal to noise, and often needs to extend across a wide range of wavelengths. To determine how much blocking is needed and at what wavelengths, one needs to consider the spectrum of the light source being used for excitation, the responsivity of the detector or camera, and the transmission or blocking of any other optical components in the system.

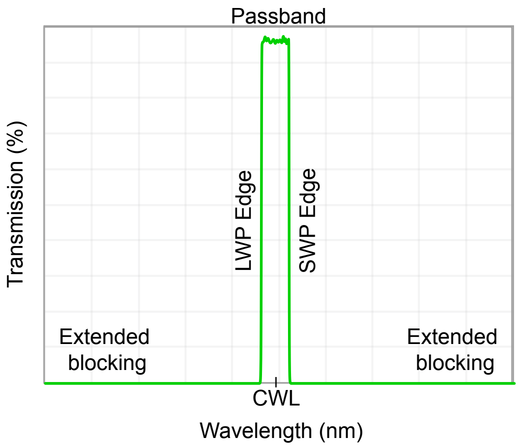


Figure 1: Transmission versus wavelength for a generic single passband filter of center wavelength CWL. The passband is defined by two edges, with blocking near each edge and extended blocking covering a wide range of wavelengths beyond each edge.

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 our online tool SearchLight (http://searchlight.semrock.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.

Our 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 Filters, each edge can be angle-tuned to the precise cut-on or cut-off wavelength you need.

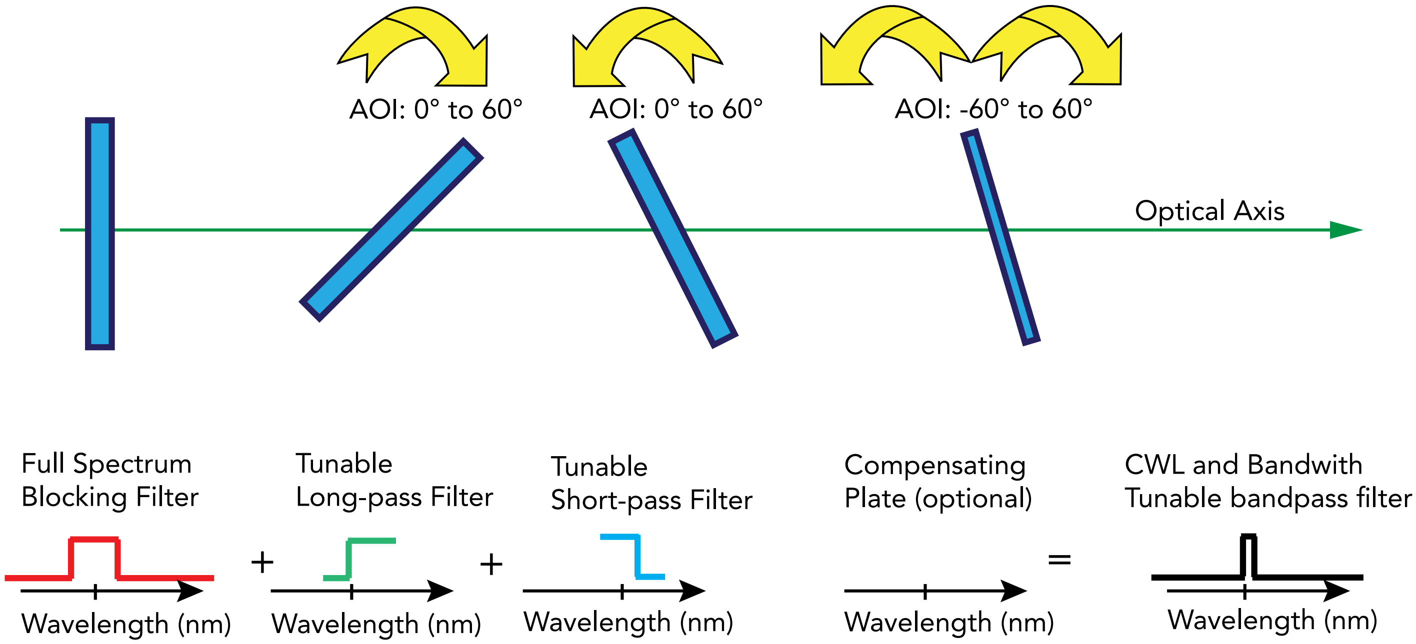


Figure 2: Combining VersaChrome Edge Tunable Filters will allow any single-band filter in the visible or near infrared to be created.

Harness the Power of Angle Tuning

All interference filters shift to the blue as the angle of incidence (AOI) is tilted away from 0°. This technique of "angle tuning" can be used to adjust the edge or bandpass of a filter, but typically results in polarization splitting at larger angles of incidence (the interference condition shifts by different amounts for s- and p-polarized light, which translates into a "split" edge for unpolarized light like fluorescence, degrading the bandpass shape).

By using advanced proprietary design techniques, Semrock has created optical filters that are insensitive to polarization from 0° to 60° AOI, allowing angle-tuning over a wide range without degrading edge steepness or high transmission. The popular VersaChrome® Tunable Bandpass Filters already allow you to shift center wavelength (CWL) by up to 12% to the blue through angle-tuning, and are offered in center wavelengths (CWL) from 378 to 900 nm.

With the addition of VersaChrome Edge Tunable Filters to our catalog, not only can you vary the CWL of the bandpass filter you create, but you can also independently control each edge to generate the exact passband you require.

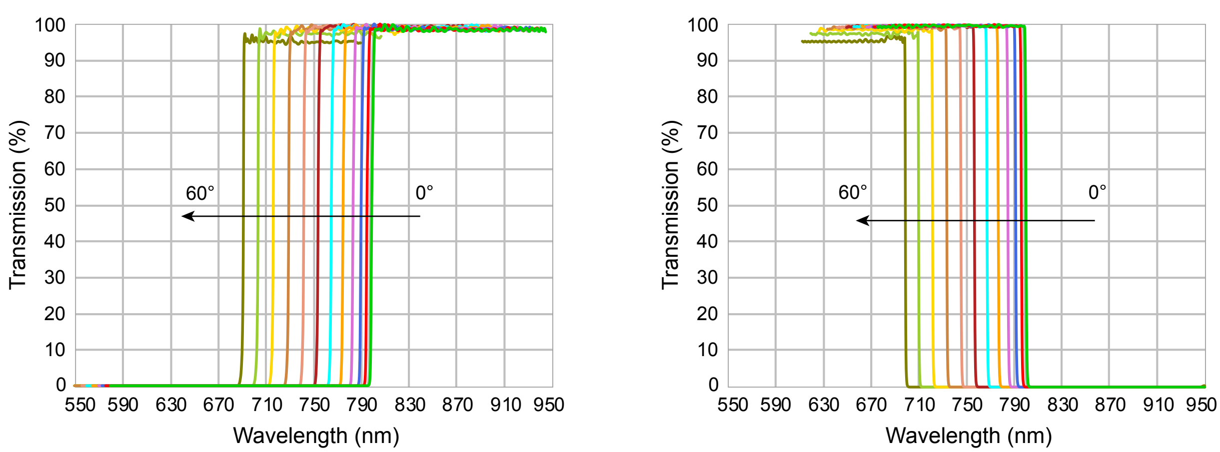


Figure 3: A typical edge filter shows polarization splitting as AOI is increased. A VersaChrome long-wave pass tunable edge filter, however, maintains its steep edge from 0° to 60° AOI, while shifting its edge position by more than 12% to shorter wavelengths.

No Need to Sacrifice Blocking

Out of band blocking is as important as high transmission when designing a bandpass filter, as it plays a large role in defining the contrast or signal to noise that can be achieved. While angle-tuning a traditional edge filter can degrade the depth and breadth of blocking adjacent to the edge, our VersaChrome Edge Tunable Filters have been designed to maintain $OD_{ave} \geq 6$ to a fixed wavelength regardless of AOI, carefully matched to overlap with the deep blocking of its complementary full spectrum blocking filter. For a tunable short-wave pass filter (TSP series) with an edge centered at 704 nm, for example, adjacent blocking extends to 808 nm for 0° to 60° AOI inclusive.

For the equivalent tunable long-wave pass filter (TLP series), $OD_{ave} \geq 6$ blocking extends to 547 nm for 0° to 60° AOI inclusive.

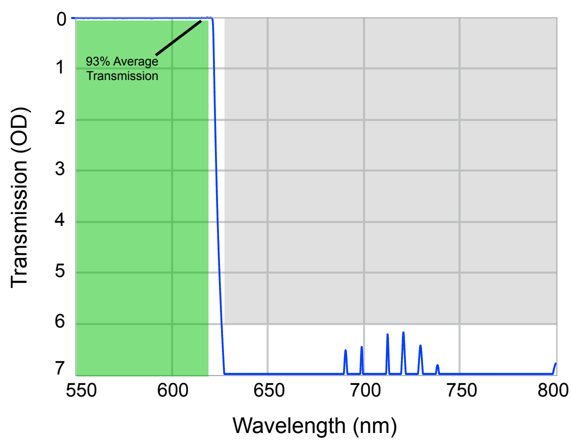


Figure 4: VersaChrome short-wave pass tunable edge filters maintain high transmission and deep blocking, even at AOI = 60°.

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. NIR blocking options extend to either 1200 nm or 1700 nm, dependent on the tuning wavelength region and the expected detector used within an optical system. Passbands for the full spectrum blocking filters vary from 95 to 263 nm, increasing with center wavelength to match the full available bandpass range of a combined TLP/TSP filter pair.

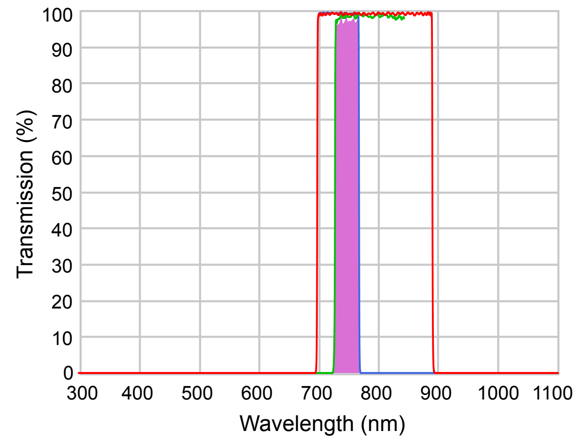


Fig 5: A tunable bandpass filter created with VersaChrome TLP and TSP filters, matched with the appropriate full spectrum blocking filter. The effective composite bandpass filter created is shown in solid purple.

Seamless Transitions

Each family of VersaChrome TLP and TSP filters is created such that where the tuning range for one edge filter ends, the adjacent filter in the family has a guaranteed overlap in coverage to allow you to tune each edge to any wavelength you need. Similarly, the high-transmission passband and the deep-blocking ranges covered by the full spectrum blocking filters are coordinated with the passbands and blocking provided by the tunable edge filters.

The result is that, by combining angle-tuned TLP and TSP filters with a full-spectrum blocking filter, it will be 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). Options for creating bandpass filters from 560-790 nm are available initially, with expansion thereafter to cover the full 400-1100 nm range.

Beam walk-off created due to the use of different angles for the TLP and TSP filters can be corrected simply by adding a compensating plate at a complementary degree of tilt, as shown in figure 2. Our applications engineers can assist you with recommendations on filter selection and fixturing for use in microscopy and tabletop setups.

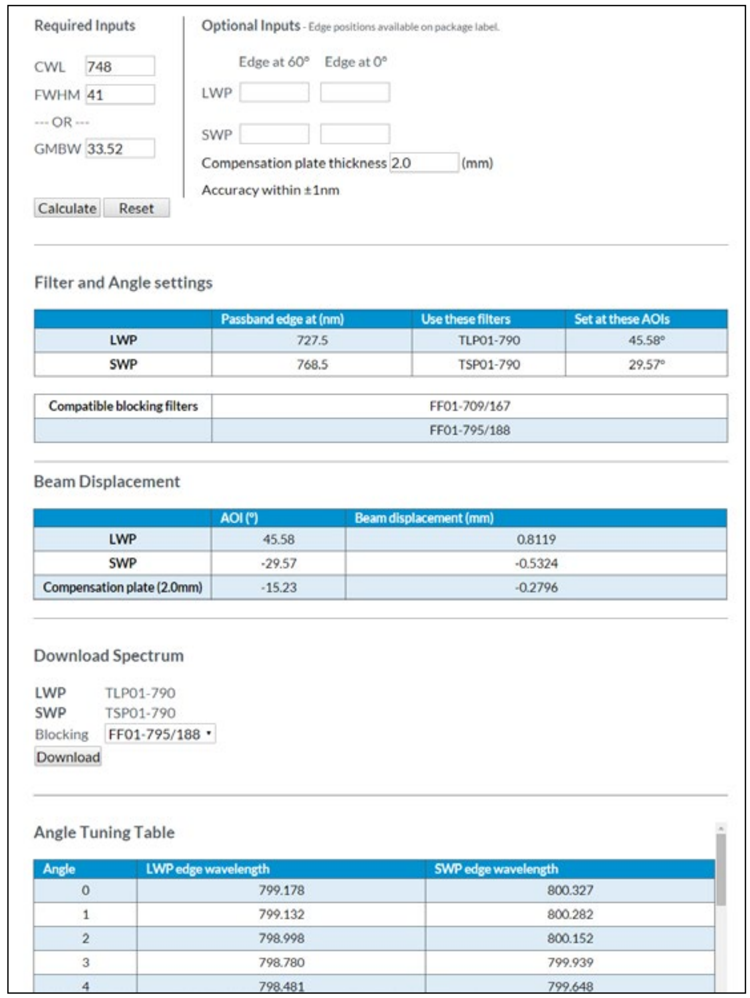
Maximum Flexibility at a Fraction of the Cost

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. With the VersaChrome Edge Tunable Filters, Semrock is offering a new way to prototype filters. 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 fine-tune edge positions and passband width to maximize brightness and contrast/signal-to-noise in real time, within their measurement setup.

The ability to dynamically design a bandpass filter and optimize its spectral characteristics at the point of measurement not only has the potential to improve system performance and adapt rapidly to new fluorophores, but it can also significantly reduce the time needed to identify the optimal bandpass filter shape for a given application and minimize new filter development costs for OEM instrumentation applications.

Creating a VersaChrome Tunable Bandpass Filter Set

1. https://www.semrock.com/versachrome-calculator.aspx
2. Determine the CWL & FWHM for the passband filter you want to create.
3. The resulting SWP edge location will determine the TLP filter and AOI.
4. The resulting LWP edge location will determine the TSP filter and AOI.
5. Match a blocking filter to the TLP & TSP being used.
6. Use a compensating plate to cancel beam displacement, if needed.



Required Inputs

CWL 748
FWHM 41
--- OR ---
GMBW 33.52

Calculate Reset

Optional Inputs - Edge positions available on package label.

	Edge at 60°	Edge at 0°
LWP		
SWP		

Compensation plate thickness 2.0 (mm)

Accuracy within ±1nm

Filter and Angle settings

	Passband edge at (nm)	Use these filters	Set at these AOIs
LWP	727.5	TLP01-790	45.58°
SWP	768.5	TSP01-790	29.57°

Compatible blocking filters	FF01-709/167
	FF01-795/188

Beam Displacement

	AOI (°)	Beam displacement (mm)
LWP	45.58	0.8119
SWP	-29.57	-0.5324
Compensation plate (2.0mm)	-15.23	-0.2796

Download Spectrum

LWP TLP01-790
SWP TSP01-790
Blocking FF01-795/188
Download

Angle Tuning Table

Angle	LWP edge wavelength	SWP edge wavelength
0	799.178	800.327
1	799.132	800.282
2	798.998	800.152
3	798.780	799.939
4	798.481	799.648

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