Steep Edges for the Finest Fingerprints

EDGE FILTERS FOR GROWING NEEDS IN RAMAN DETECTION SYSTEMS

Optical edge filters are critical to the performance of Raman detection systems. This article describes two families of long-wave-pass (LWP) edge filters that Semrock has developed specifically for Stokes-shift backscattered Raman signal detection systems. These filters are used in commercial Raman systems for polymer science, thin film analysis, geoscience, and the pharmaceutical industry.

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Raman detection takes advantage of the fact that each molecular species, when suitably optically excited, emits a unique set of Raman signal amplitudes at specific wavelengths. This spectrum is referred to as the Raman “fingerprint” (Figure 1). The Raman system uses an intense laser beam to excite a sample, and the much weaker backscattered Raman "fingerprint" spectrum is measured by a spectrometer. The optical filter is critical for two reasons: it must (1) efficiently prevent stray laser light from entering the detection system, as this light is typically a million times brighter than the emitted light, and (2) pass as much of the fingerprint light as possible.

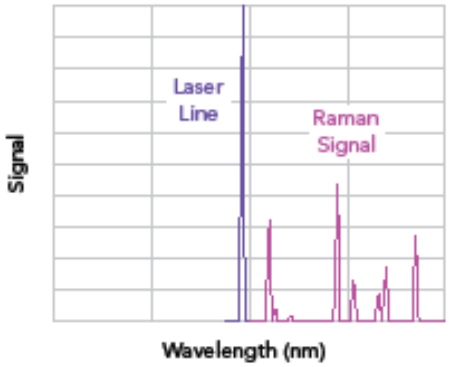

Figure 1. A Raman “fingerprint” spectrum

Semrock offers two LWP filter families used in Raman detection systems. The **RazorEdge®** filter series (see above, left) has very short transition width and high edge steepness, and is optimized for detecting Raman signals extremely close to the laser wavelength. In contrast, the **EdgeBasic®** edge filter series (above, right) has a longer transition width and lower edge steepness than RazorEdge, but is designed for high performance at economical pricing. This lower-priced solution is increasingly used in Raman detector systems that do not require detection of signals very close to the laser line.

Semrock edge filters are used by WITec (www.WITec.de) in their *alpha300 R* Raman microscope, which is capable of 3D confocal imaging of Raman signals at down to the resolution limit of light (circa 200 nm). This instrument allows imaging deep into the material, which is in its natural state, as Raman spectroscopy does not require specialized sample preparation.

Key specifications for the finest performance

When choosing edge filters for Raman detectors, the Transition Width and Edge Steepness are of special importance (Figure 2). The Transition Width is the maximum spectral distance "window" between the laser line (where OD > 6) and the 50% transmission wavelength. The Edge Steepness is the filter's actual spectral performance, and is measured between the wavelengths where OD = 6 and where the filter transmission reaches 50%. The detection of Raman signals close to the laser line requires a short transition width, which requires very high Edge Steepness. Table 1 outlines the key characteristics of the RazorEdge and EdgeBasic filter families. RazorEdge LWP filters are available in E- and U-grades. E-grade filters are used for the most demanding Raman applications, having the smallest Raman shifts. The transition widths are guaranteed to be less than 0.5% of the laser wavelength, corresponding to < 2.7 nm (< 90 cm^{-1}) at 532 nm. This requires a very steep edge, which in the RazorEdge has been reduced to 1.1 nm at 532 nm.

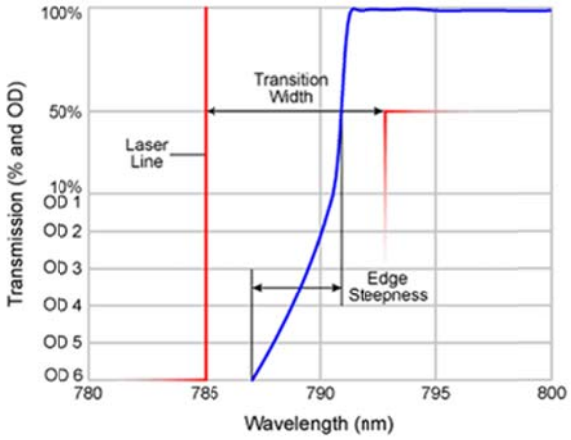

Figure 2. An illustration of Transition Width and Edge Steepness for an example 785 nm LWP filter

U-grade filters have a greater transition width than E-grade, as well as slightly reduced edge steepness, but are lower in price. E-grade filters are available at 14 laser wavelengths, with U-grade filters offered at 24 wavelengths.

The WITec alpha300 R uses the highest grade RazorEdge filters, as it has been designed for applications requiring detection of the shortest possible Raman shifts.

Series Name	Transition Width, of Laser Wavelength	Example Transition Width (532 nm)	Typical Edge Steepness, of Laser Wavelength	Example Edge Steepness (532 nm)	Transmission Averaged over the Passband	Blocking at Laser Wavelength	Permitted AOI, CHA
RazorEdge E-Grade	< 0.5%	< 2.7 nm < 90 cm^{-1}	0.2%	1.1 nm	> 93% (guaranteed) > 98% (typical)	> 6 OD	0.0° ± 2.0° < 5°
RazorEdge U-Grade	< 1.0%	< 5.30 nm < 186 cm^{-1}	0.5%	2.7 nm			
EdgeBasic	< 2.5%	< 13.3 nm < 458 cm^{-1}	1.5%	8.0 nm			

Table 1. Parameters of RazorEdge and EdgeBasic filters

EdgeBasic LWP filters are used in cost-sensitive Raman systems, in which only one or several Stokes-shift Raman lines are to be detected, typically several hundred wavenumbers away from the laser wavelength. EdgeBasic still provides high blocking of the laser light, with OD > 6, and blocks down to the UV region, so they can be used in fluorescence systems. The average transmission level exceeds 93% over the passband (typically 300 to 800 nm beyond the laser wavelength) with transmission levels typically exceeding 98%. EdgeBasic filters are available at 24 popular wavelengths from 325 to 1550 nm.

The hard filter coatings in both filter families provide high laser induced damage thresholds, > 1 J/cm^2 at 532 nm, for pulse widths of 10 ns at 20 MHz repetition rates. The filters have less than a 5 ppm wavelength shift per °C, and have been rigorously tested and proven to meet tough environmental standards.

Summary

Semrock supplies two LWP filter solutions for Raman spectroscopy. The RazorEdge filters are ideal for demanding Raman applications, and the EdgeBasic filters are appropriate when cost is important. Both families of filters resist laser-induced damage, have a factory warranty of 10 years, and can be used in inhospitable environments without suffering any performance degradation.

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