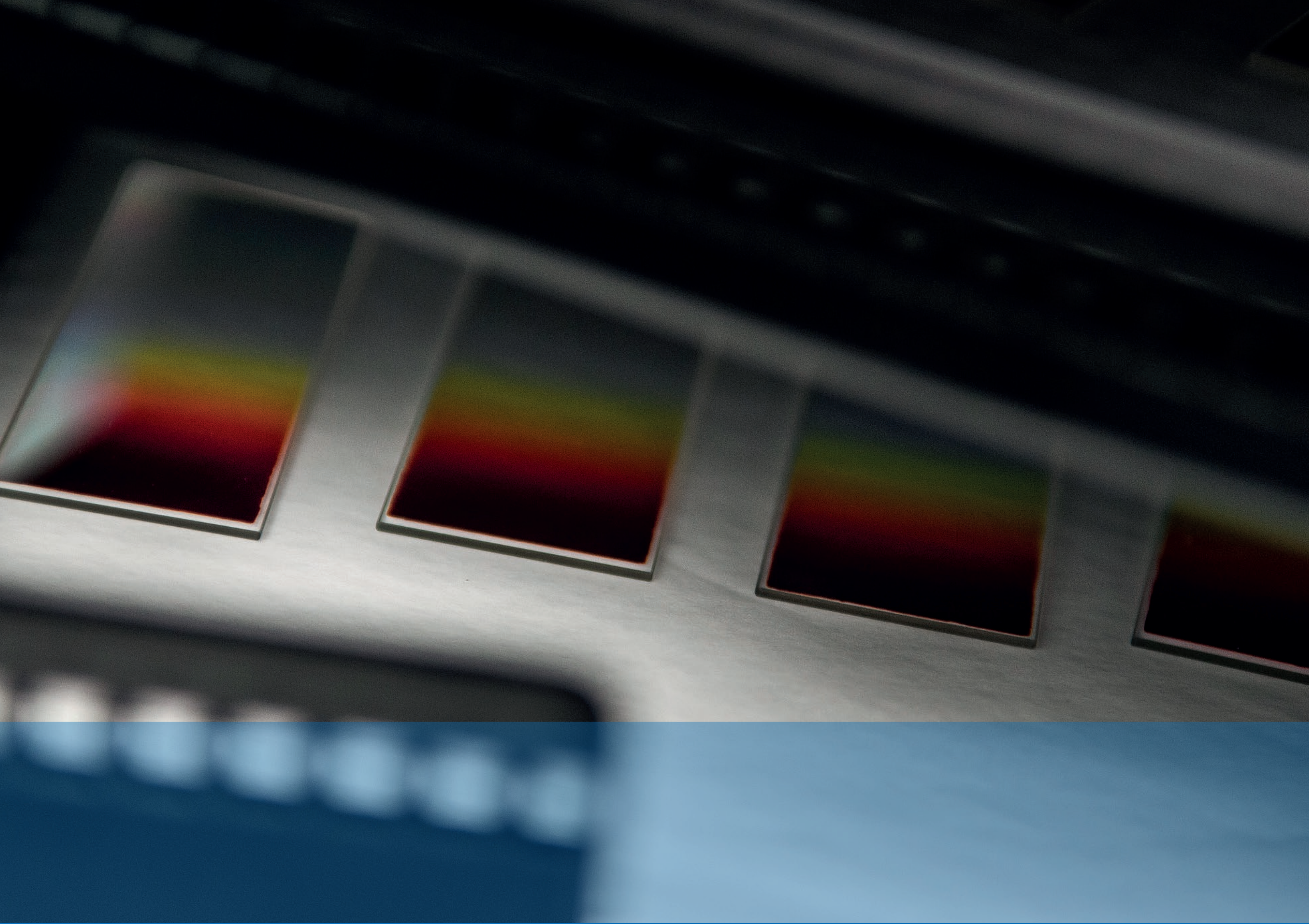


# The rise of continuously variable filters

Produced by Europa Science in conjunction with:

In mini-spectrometers, gratings – the wavelength dispersive element – generate wavelengths at higher orders than the primary wavelengths to be detected. These higher order wavelengths are fractions of the primary wavelength, and, if the spectrometer covers less than one octave, are spatially separated by angle. If the ratio of upper to lower wavelength is larger than two, the orders begin to overlap and must be removed or sorted out before they reach the detector. This is demonstrated in the diagram below.

This 'sorting' can be carried out by a simple long wave pass filter with a fixed cut-on wavelength, but only if the spectrometer covers less than one octave – i.e. the cut-on wavelength is a little smaller than the lower wavelength of the spectrometer.

For spectrometers that cover more than one octave, a second or third order sorting filter with a different cut-on wavelength is needed to cover the required spectral range. So, a typical spectrometer from 190nm to 1,100nm would need three different order sorting filters. This means there would always be a transition region where the detector would collect meaningless signals – and this would happen whether the three different filters were mechanically assembled or directly coated onto one substrate.

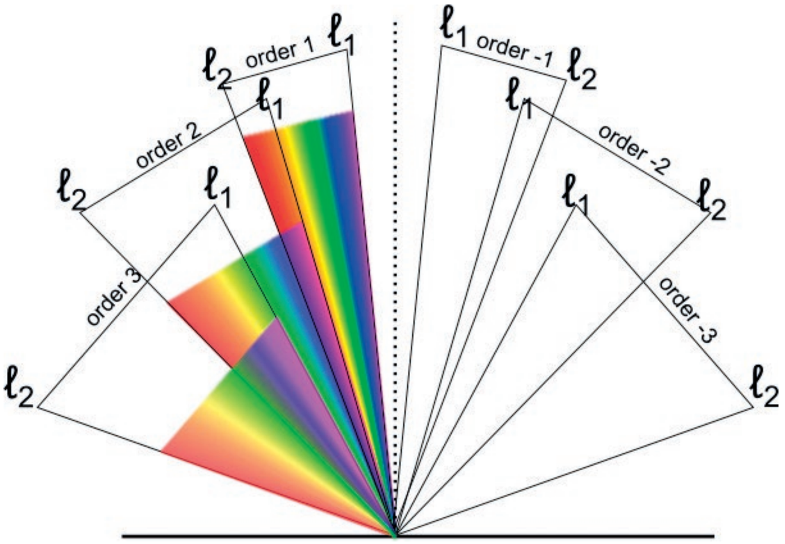


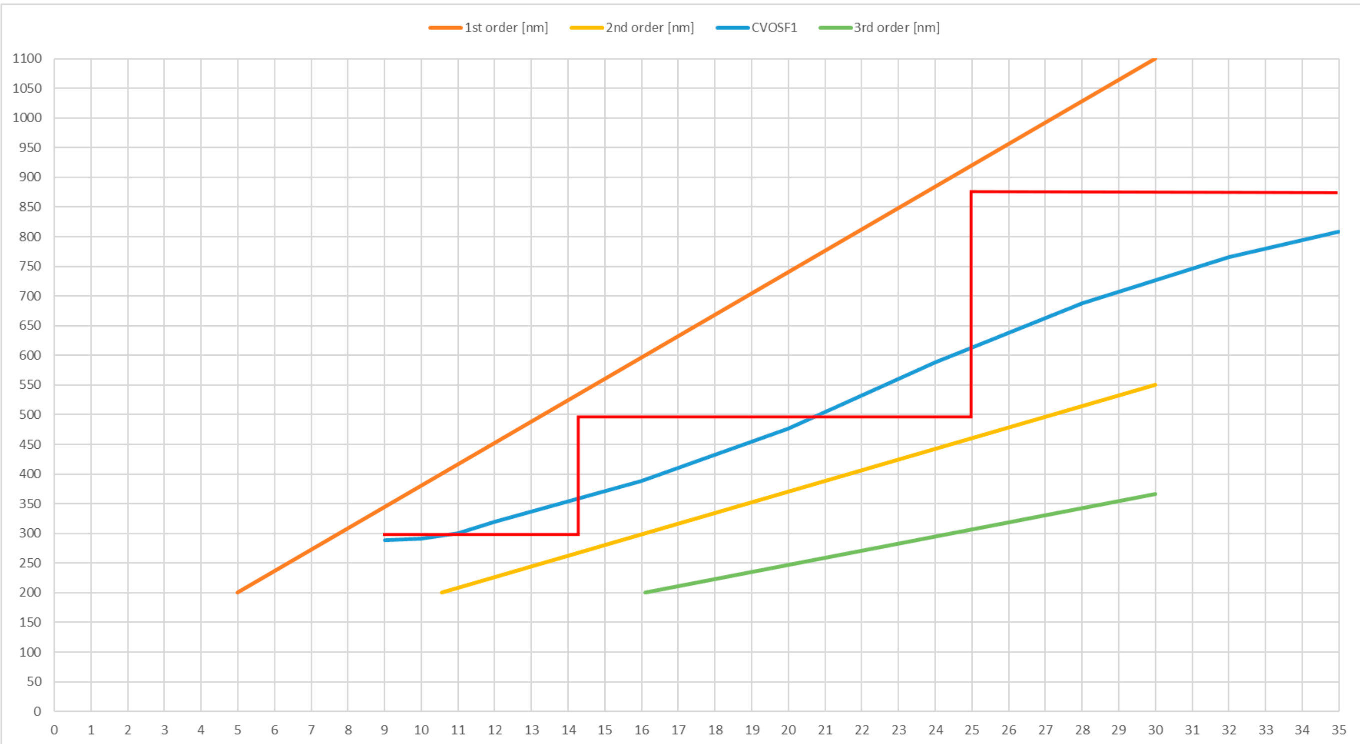

**Diagram depicting overlap of the spectral orders**

*Credit: Physical Chemistry Laboratory*

Traditionally, interference filters for use with spectrometers were designed and manufactured to be spatially-homogeneous and of a fixed wavelength.

Regardless of whether manufacturers were making short wave pass, long wave pass or bandpass versions, the logistical aim was to produce filters with a uniform thickness and spectral characteristic across their clear aperture – and, for the sake of consistency of use, to produce batches of filters that contained as many identical parts as possible.

However, a more modern development has been the arrival on the scene and further development of continuously variable filters (CVFs), which can be used in place of multiple fixed filters and are able to maintain the same quality of spectral performance.




**Comparison of segmented and continuously variable order sorting filters (horizontal axis: detector length in mm, vertical axis: wavelength in nm): first order (orange curve), second order (yellow curve), third order (green curve), cut-on wavelength of segmented order sorting filter (red curve), cut-on wavelength of continuously variable order sorting filter (blue curve).**

*Credit: Delta Optical Thin FIlm*

In fact, CVFs have existed for many years but only in recent times – developed by companies such as Delta Optical Thin Film – have they reached the required level for spectroscopy applications due to advances in design and production technology. Earlier versions of CVF were often produced with colour glass or included thin metal layers (induced transmission filters) to achieve out-of-band blocking. This limited transmission, lifetime and laser induced damage threshold (LIDT).

A bandpass filter's centre wavelength is dependent on the thickness of the thin film layers that make up the coating stack – and so variable filters can be created by changing the thickness of the stack continuously within one spatial dimension of the filter in question, to form a profile resembling a wedge.

The filters therefore do not have individual segments and provide a continuous variety of spectral characteristics along one spatial dimension, allowing the user to adjust the centre or edge wavelength by sliding the filter as required.


**Ibsen's spectrometer with sensor removed showing filter**

*Credit: Delta Optical Thin FIlm*

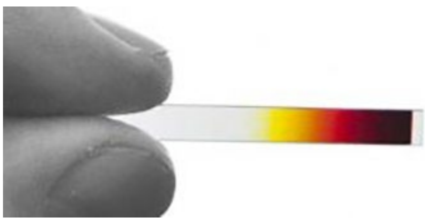
The technology has advanced enough that the transmission and blocking levels of modern CVFs, along with their edge steepness, are sufficient to carry out precise fluorescence measurements with a spectral performance comparable or surpassing that of traditional fixed-wavelength filters.

Delta Optical Thin Film has lifted the quality of variable filters to new levels with a powerful combination of continuously variable filters. The company offers Continuously Variable Long Wave Pass filters (CVLWP), corresponding Continuously Variable Short Wave Pass filters (CVSWP) together with Continuously Variable Dichroics. Each of the filters can be used separately.

Combining CVLWP and CVSWP enables the construction of bandpass filters that can be tuned continuously with centre wavelengths ranging from 320nm to 850nm, with the added benefit of having a tunable bandwidth.

Delta's CVFs suppress more stray light – which improves accuracy – because the cut-on wavelength moves together with the dispersion of the grating. With discrete filters, the distance from the cut-on wavelength to the first order one wants to transmit gets gradually bigger and allows more stray light to pass through the filter.

As well as setting new standards in transmission level and edge steepness, the filters offer blocking better than OD4 over the complete reflection range (OD stands for optical density and is a quantitative measure expressed as a logarithmic ratio between the radiation falling upon a material I0 and the radiation transmitted through a material I1, more specifically $OD = -\log10(I1/I0)$). In fact, users can create blocking beyond OD6 by using two identical variable filters in series.



**CVOSF**

*Credit: Delta Optical Thin FIlm*

The filters are coated on single fused silica substrates for minimal auto-fluorescence and high laser damage threshold. All of Delta Optical Thin Film's Continuously Variable Filters are coated with ultra-hard surface coatings that are also used by Delta Optical Thin Film in traditional fluorescence filters.

Delta Optical Thin Film's Continuously Variable Filters are especially suited for applications in spectroscopy including fluorescence and hyperspectral imaging applications. They can be supplied with different dispersions matched to a specific detector and in different sizes. They can be manufactured either with a coating that covers the whole length of the filter or with a section that allows UV light to pass.