Illumination of Linear Variable Filters with a laser beam

The intensity distribution in the laser beam from a super continuum light-source is assumed to be purely Gaussian.

The spot size on the linear variable filter is assumed to be characterised by the diameter of the area containing $1 - 1/e^2 = 86.5\%$ of the energy in the laser beam.

According to the data sheet on the SuperK source from NKT Photonics the beam divergence is smaller than 5mrad = 0.29º. This is a very low value, and in the following we will omit taking the beam divergence into account.

According to the same data sheet, the beam diameter is around 1mm in VIS, around 2mm at 1100nm and around 3mm at 2000nm. In the following we will investigate the influence of the beam diameter on the spectral curves of the linear variable filters.

The filter system is assumed to consist of a linear variable SWP filter and a linear variable LWP filter in series. We will assume that the beam diameter is the same on both filters.

At present the light beam is assumed to be normal to the surface of the filters. However, in practice it is necessary to tilt the filters slightly to make a beam dump. On the other hand an angling of a few degrees does only make the spot slightly elliptical on the filters. An angling of 5 degrees in example makes the ratio between the two axes in the ellipse 0.996. At the same time polarisation effects in the coatings are marginal in this angular range. We will not take these things into account in this analysis.

Analysing the light-spot

The calculations take into account the variations in the thickness of the layers in the coatings in the length direction and normal to that on the substrate.

The spectral performance of the linear variable filter in a specific section is believed to be equal to a similar section on a line along the central part of the filter (x-axis). The part of the x-axis where the spot is present is split into 97 parts of equal size. The design software splits the total spot into millions of small sections. Each of those parts makes a weighted contribution to one of the 97 parts created on the x-axis.

Centring the laser spot at the X-axis at 60% of the full length of the coating on the filter, a spot with a diameter of 1mm gives us the calculated weighting along the x-axis shown in figure 1.
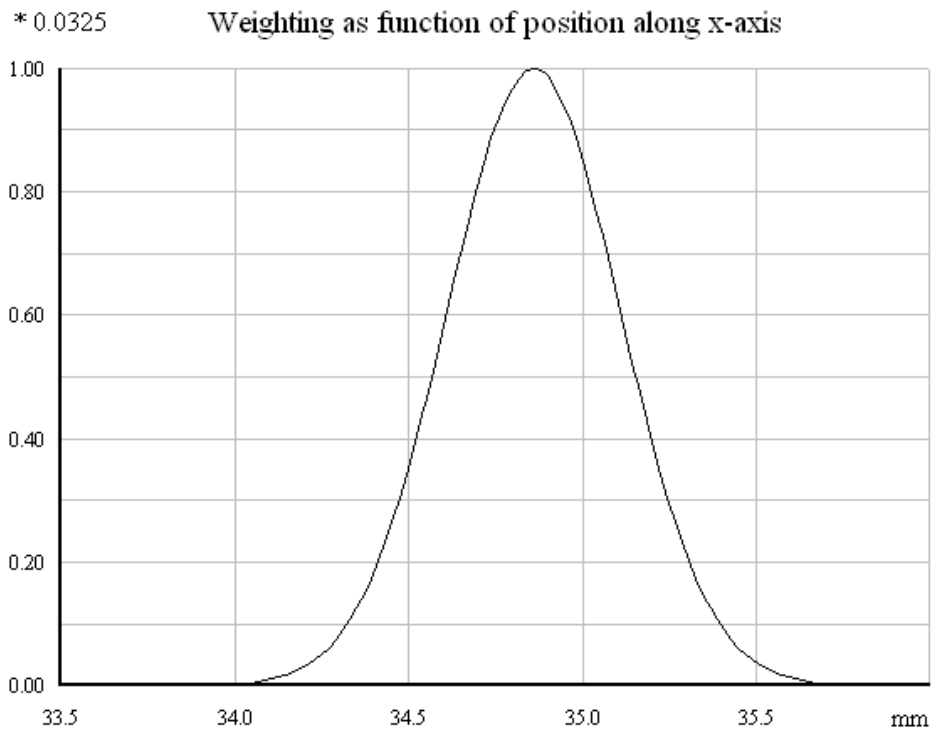
*Figure 1 Centring a laser spot with a spot diameter of 1mm at 60% of the full length of the coating on a 15mm * 60mm substrate, gives us this weighted power distribution at the x-axis (please see the text for further explanations).*

Figures 2 and 3 show the corresponding plots for a diameter of the laser spot of 2mm and 3mm.
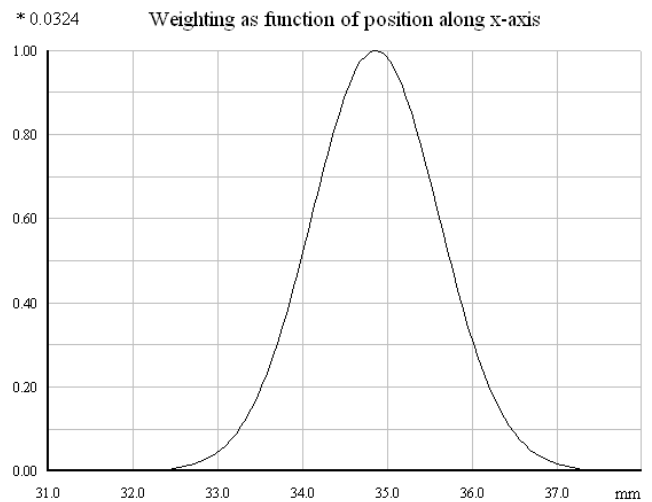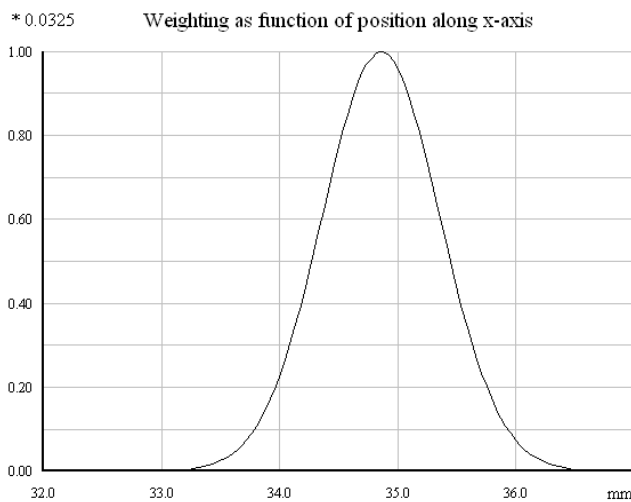
Figures 2 and 3 Plots of the derived weighted power distributions along the central x-axis, for spot-diameters of 2mm and 3mm.

Predicted transmission curves

The linear variable LWP filter corresponds to the present product LVLP [301-845]nm LF102064.

The Linear variable SWP filter corresponds to the present product LVSP [300 – 850]nm LF102155.

It is necessary to offset the position along the x-axis on the linear variable LWP filter slightly in respect to the position along the x-axis on the linear variable SWP filter in order to form a band. We will refer to the position along the X-axis in the form of a factor X_L running from 0 to 1.

Forming a band peaking at around 630nm

In the following we will assume that X_L is 0.56 in case of the LWP-filter and 0.6 in case of the SWP filter, corresponding to a mechanical offset of around 58.1mm * 0.04 = 2.3mm.

Figure 4 shows the best possible result corresponding to NO spot-size and pure collimated light.
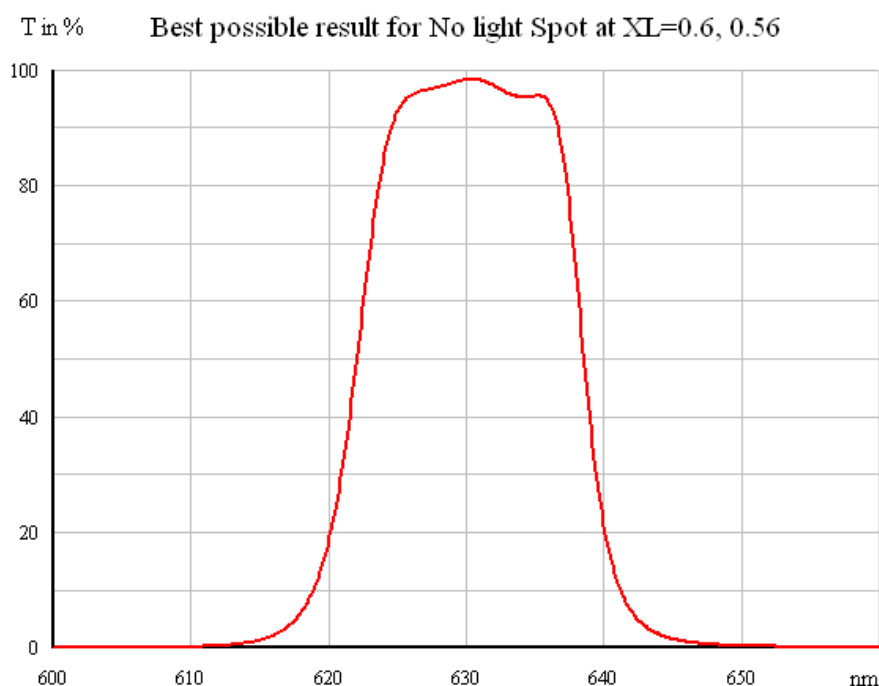
Figure 4

Figure shows the best possible result for No Spot size at the Linear variable filter LVSP [300 – 850]nm (X_L = 0.6) and the linear variable filter LVLP [301 – 845]nm (X_L = 0.56). In future it may be possible to produce filters enabling even steeper edges than this. However in a real system the light spot has a final size. It is the purpose of this tech note to analyse on this important subject.

In the following we will investigate what happens when a Gaussian shaped laser beam with a final diameter illuminate the same set of filters.

Figure 5 shows the predicted band formed as function of the beam diameter. The red curve belongs to the 1mm beam diameter – the black curve to the 2mm beam diameter and the blue curve to the 3mm beam diameter.
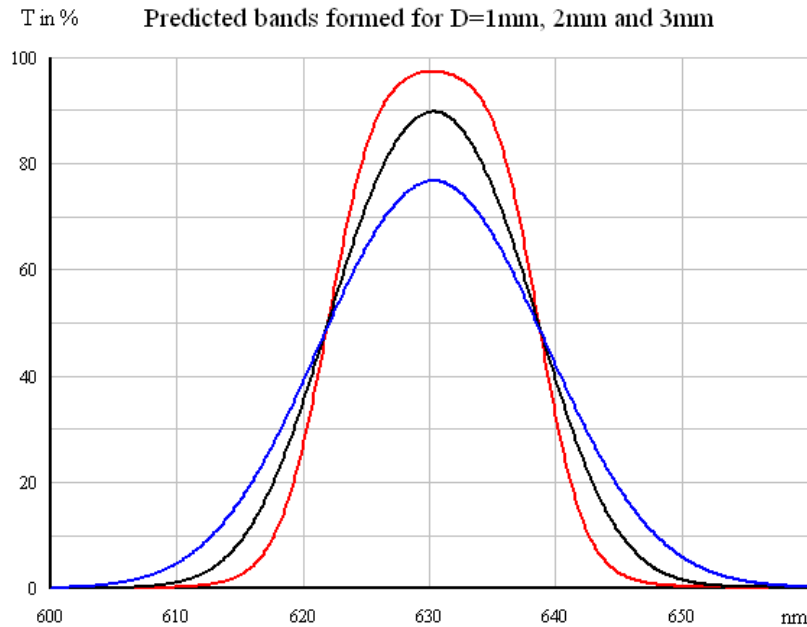

Figure 5

The figure shows the predicted bands formed by the linear variable LWP and SWP filters as function of the diameter of the laser-beam. The position of the spot on the two filters is described by $X_L(LWP) = 0.56$ and $X_L(SWP) = 0.6$. The red curve corresponds to a diameter of 1mm. It would be possible to obtain the same peak transmission in all cases by increasing the bandwidth further.

It is seen that it is realistic to form a band with a bandwidth of less than 20nm in case the diameter of the laser beam is only 1mm. However, the shape of the band is clearly less box shaped than in figure 4 – especially at diameters larger than 1mm. The system does not get the best possible performance out of the filter system.

Forming a band peaking at around 433nm

In the following we will assume that X_L is 0.18 in case of the LWP-filter and 0.22 in case of the SWP filter, corresponding to a mechanical offset of around 58.1mm * 0.04 = 2.3mm. Figure 6 shows the predicted band formed as function of the beam diameter. The red curve belongs to the 1mm beam diameter – the black curve to the 2mm beam diameter and the blue curve to the 3mm beam diameter.

It is seen that it is realistic to form a band with a bandwidth of less than 12nm in case the diameter of the laser beam is only 1mm, in the low wavelength range.

By comparison of figures 5 and 6 it is clearly seen that for a given peak transmission, the minimal bandwidth of the band increases proportionally with the centre wavelength.
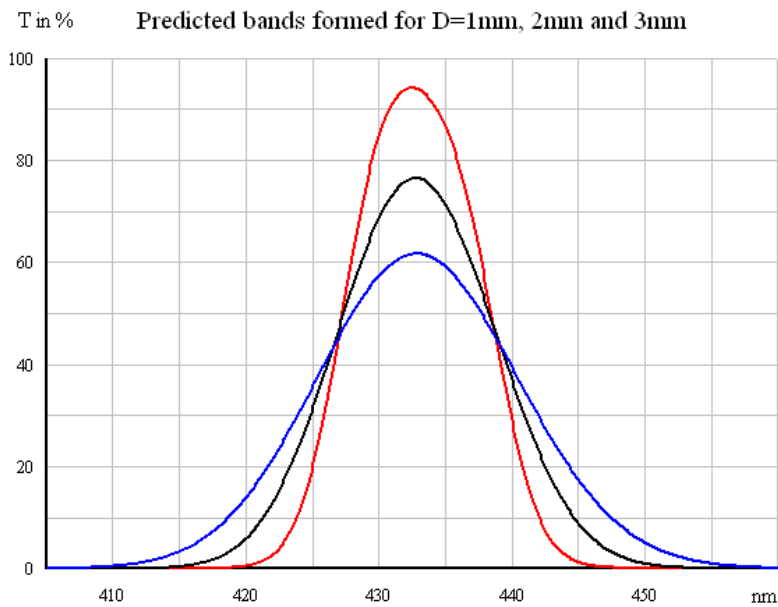
Figure 6

T in % Predicted bands formed for D=1mm, 2mm and 3mm

The figure shows the predicted bands formed by the linear variable LWP and SWP filters as function of the diameter of the laser-beam. The position of the spot on the two filters is described by $X_L(LWP) = 0.18$ and $X_L(SWP) = 0.22$. The red curve corresponds to a diameter of 1mm. It would be possible to obtain the same peak transmission in all cases by increasing the bandwidth further.

Adding lenses to reduce the diameter of the laser beam

Alternatively it is possible to reduce the diameter of the laser beam by adding a lens system to do so. This would increase the divergence angle – however it would still be very small – typically less than 1 degree. This is not causing any problems.

In case we use a lens system to reduce the diameter of the laser beam with a factor of 3, the predicted performance of the present filter set with 58.1mm long coatings is predicted to be as shown in figure 7.
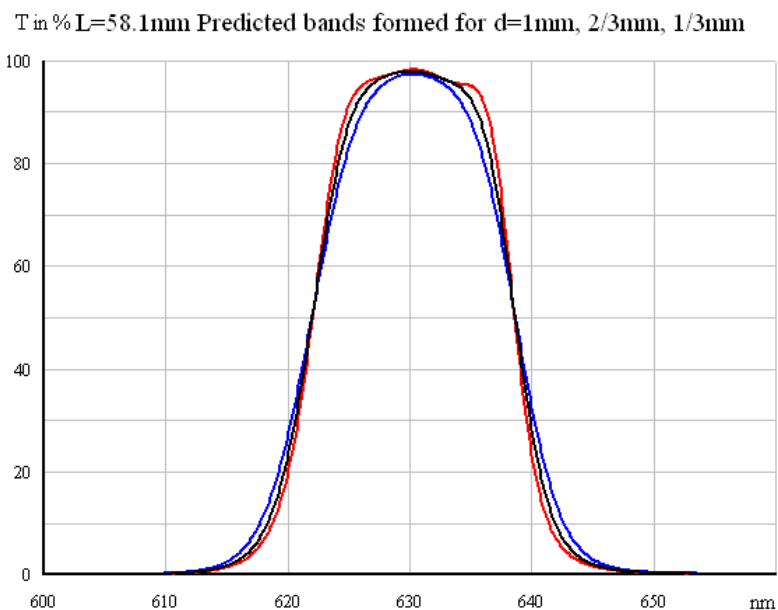
T in % L=58.1mm Predicted bands formed for d=1mm, 2/3mm, 1/3mm

Figure 7
The figure shows the predicted bands formed by the linear variable LWP and SWP filters as function of the diameter of the laser-beam on the present filters. It is assumed that the diameter of the laser beam is reduced by a factor of 3 by focussing the beam with a lens system. The position of the spot on the two filters is described by $X_L(LWP) = 0.56$ and $X_L(SWP) = 0.6$. The red curve corresponds to a diameter of 0.33mm.

By comparison with figures 4 and 5 it is seen that it is possible to obtain an even more box shaped band, and hence an even narrower bandwidth without losing peak transmission, with

the present short filter, by inserting a focussing lens in the wavelength selector. The predicted result is not far from the best possible result with the present coating designs.

Final comments

It is unavoidable to use lenses in most wavelength selectors based on linear variable filters. The reasons are as follows:

1) A lens system is needed to couple the filtered light into an optical fibre, in case the customer prefers the system to deliver light through an optical fibre.
2) A lens less system is only possible in case the light source is a laser. In case the laser is replaced by a xenon flash bulb or any other classical light source, lenses and mirrors are unavoidable in order to catch a reasonable amount of light from the light source itself.

This tech note shows that it is recommended to focus the light beam of the super continuum light source by a factor of 3, in order to make the present 58.1mm long filters (60mm substrates) work well.

It would be possible to avoid the lenses in case the length of the filters is increased to 140mm or more. However this would double the prize of the filters, and the system would not be able to take advantage of future improvements of the spectral characteristics of the linear variable filters.

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