What is Optical Density (OD)?

And what it is not!

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This short presentation wants to clarify the notion of optical density (OD) and put it into context with signal to noise ratio (SNR).

In our daily work as filter manufacturer we often talk to customers with an electrical engineering or imaging background. In these and other fields SNR is an important quantity to describe system or detector performance. Filters on the other hand are described by transmission and rejection performance. The former often on a scale from 0 to 1 (preferably) or on a %-scale. The latter is often described as optical density.

Definition

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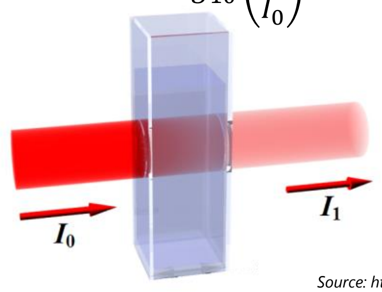
"Absorbance [or optical density] is a quantitative measure expressed as a logarithmic ratio between the radiation falling upon a material and the radiation transmitted through a material."

$$OD = -log_{10}\left(\frac{I_1}{I_0}\right)$$



Source: http://en.wikipedia.org/wiki/Optical_density

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Optical density is a quantitative measure expressed as a logarithmic ratio between the radiation falling upon a material and the radiation transmitted through a material (*Source: http://en.wikipedia.org/wiki/Optical_density*). In the case of filters, optical density is a quantity that is dependent on wavelength (see typical transmission and blocking curves).

Optical Density – Transmittance – %

Optical Density	Transmittance ($\frac{I_1}{I_0}$)	Transmittance (%)
0	1	100%
0.1	0.79	79%
0.5	0.32	32%
1	0.1	10%
2	0.01	1%
3	0.001	0.1%
4	0.0001	0.01%
5	0.00001	0.001%
6	0.000001	0.0001%

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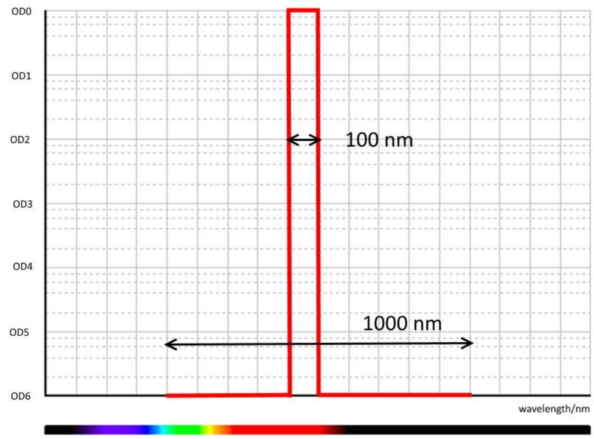
An optical density of six (or OD6) for example describes that at a given wavelength a filter transmits only one millionth of the incident radiation. Please note that optical density is always calculated from the transmittance value on a scale from 0 to 1, not from the %-value that is listed for correspondence in the table above.

Optical Density vs. Signal to Noise Ratio



$$SNR = \frac{Signal\ strength}{Noise}$$

$$SNR = \frac{1*100\ nm}{10^{-6}*900nm}$$

$$SNR = 111{,}111$$

$$SNR_{dB} = 10\ log_{10}\left(\frac{S}{N}\right)$$

$$SNR_{dB} \approx 50\ dB$$

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Let us look at two bandpass filters in order to exemplify how optical density and SNR are related. The first filter transmits all of the incident radiation (T=1) within a 100 nm wide passband and blocks to a level of OD6 within the remaining 900 nm. As the name suggests SNR is the ratio of the (desired) signal to the (undesired) noise. Please note, that we need to calculate the integral below the red curve for the purpose of SNR calculation. SNR is often given in decibel, in this example the filter has an SNR of 50 dB.

Optical Density vs. Signal to Noise Ratio

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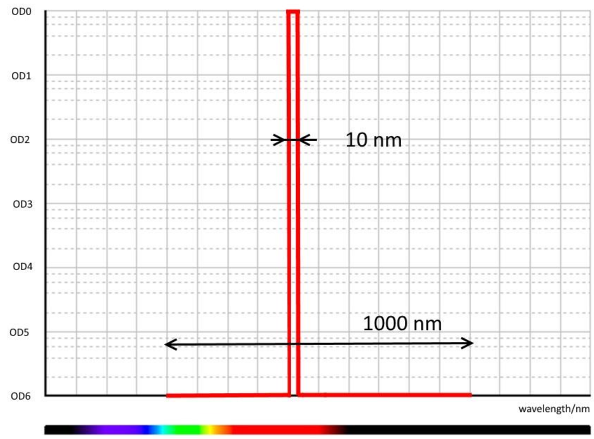

$$SNR = \frac{Signal\ strength}{Noise}$$

$$SNR = \frac{1 * 10\ nm}{10^{-6} * 990 nm}$$

$$SNR = 10{,}101$$

$$SNR_{dB} = 10\ log_{10}\left(\frac{S}{N}\right)$$

$$SNR_{dB} \approx 40\ dB$$

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The second filter transmits all of the incident radiation within a 10 nm narrow passband and blocks to a level of OD6 within the remaining 990 nm. Please note that the OD level is the same as for the first filter! Only the passband is ten times more narrow. In this case the SNR calculation yields 40 dB, which seems to indicate that the filter is not as good as the first one. But this is not the case! The blocking performance is the same but the narrower band lets pass 10 times less light. This effect should be considered when specifying optical filters.

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Thank you very much for reading this presentation!

Questions?

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