Optical Filters: Specifying Filter Spectra

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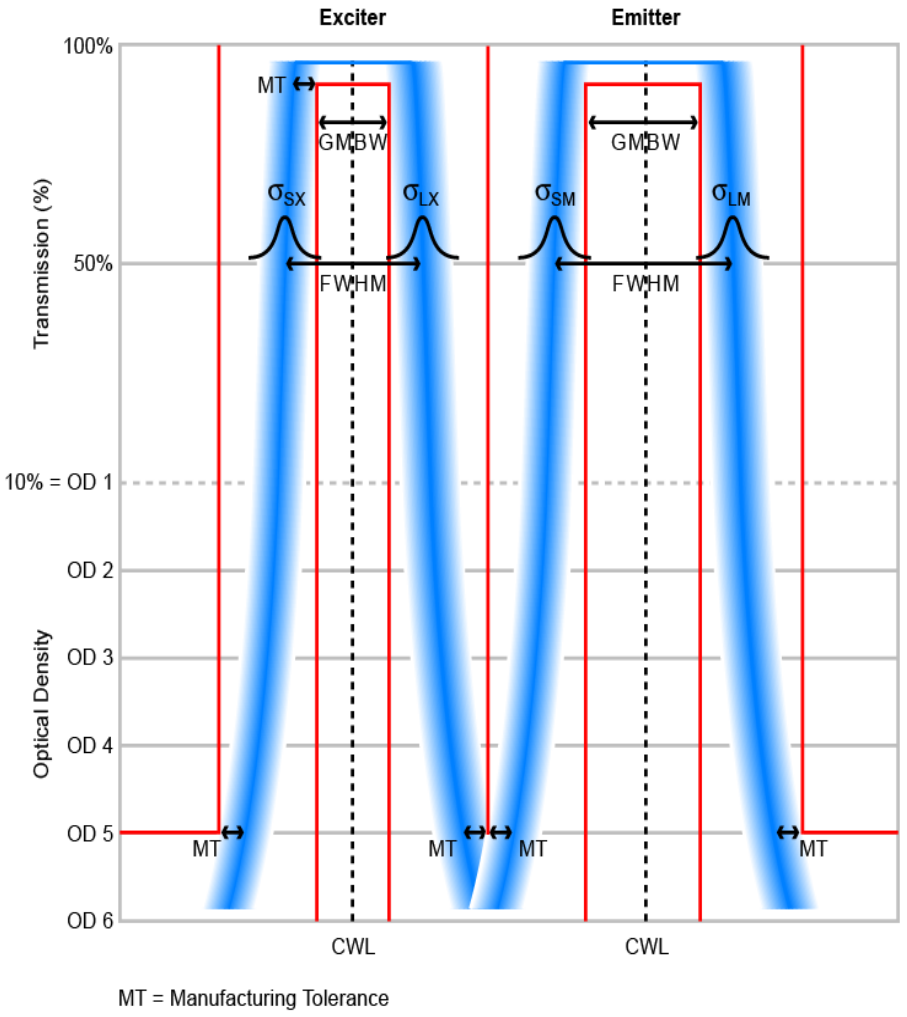
Spectral specifications

- Semrock always provides “manufacturable specifications” to customers – we guarantee the delivered filters will meet the specified performance
  - Some filter manufacturers use “design specifications” – these describe what the design will do, and not necessarily what all delivered filters will do
- Example: passband region of exciter and emitter filter pair
  - Note that our knowledge of variations like edge position are taken into account when formulating specifications



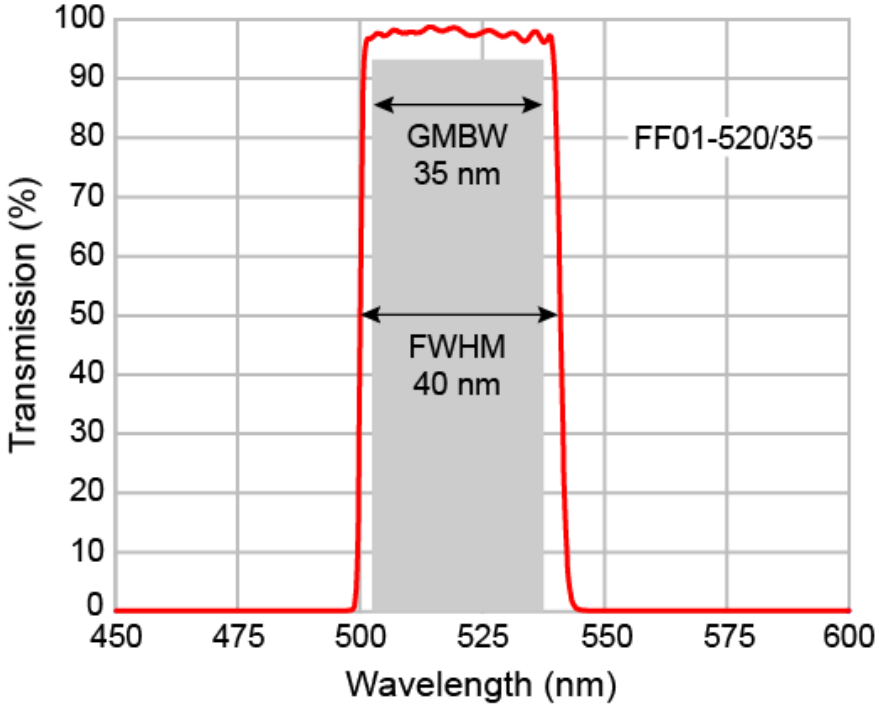
Spectral specifications

- Semrock uses a “manufacturable specification” approach to define the bandwidth of a filter passband
- A BrightLine fluorescence filter with a part number FF01-{CWL}/{BW} has a center wavelength of CWL and a **guaranteed minimum 93% bandwidth** (**GMBW**) of BW
- Full Width at Half Maximum (FWHM) bandwidth is typically 1% of the CWL wider than the GMBW bandwidth

  FWHM = GMBW + 0.01 x CWL

  Example – find the FWHM of FF01-**520**/**35** filter (GFP Em):

  40 nm = 35 nm + 1% x 520 nm

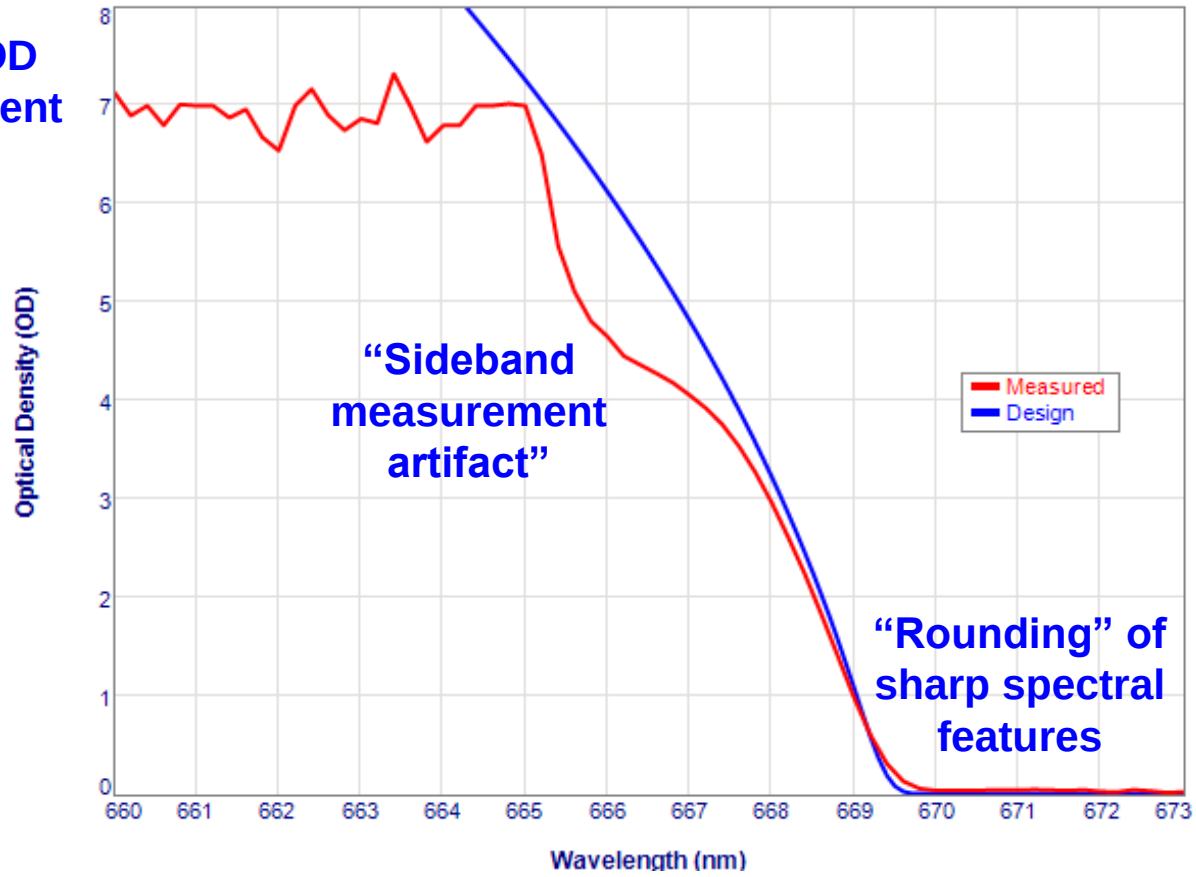


Discrepancy between real and measured data

- Semrock makes filters with steep edges and deep blocking that “push the limit” of most optical instruments, such as spectrophotometers
- As a result, it can be difficult to measure the filter transmission spectra accurately using established measurement instruments
- There are 3 main discrepancies that appear between the real filter spectrum and the measured spectrum:
  - “Rounding” of sharp spectral features
    - Results from non-zero bandwidth of the spectrophotometer probe beam OR
    - Results from a converging beam used to measure the filter (high cone half-angle)
  - Limited OD measurement range
    - Results from the spectrophotometer “noise floor” – detection noise limits how small of a signal can be reliably measured
  - “Sideband measurement artifact” that occurs when measuring filters with a very steep transition from high blocking to high transmission
    - Caused by sidebands of the not perfectly monochromatic probe beam

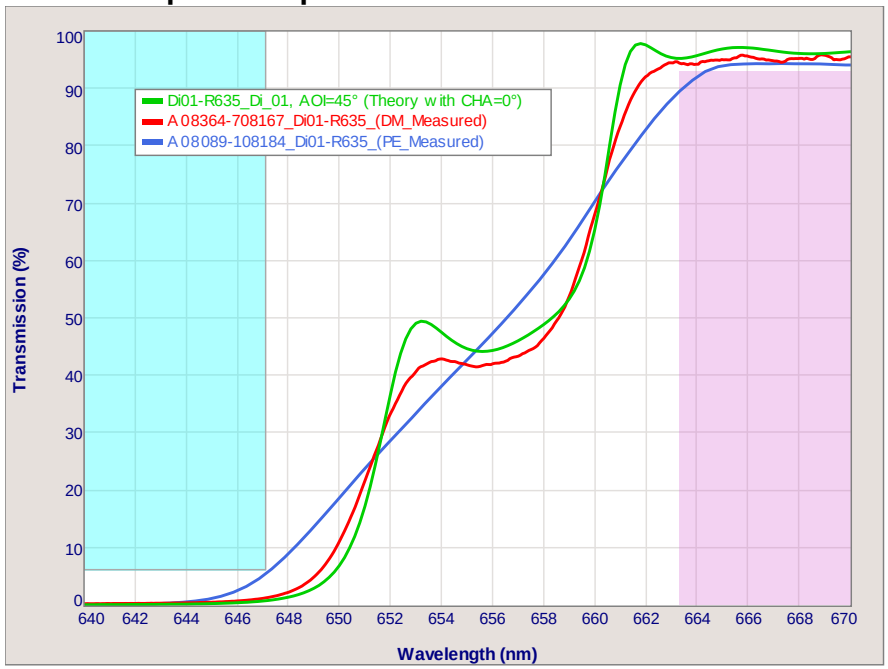
Discrepancy between real and measured data

- Example shows design and measured spectra of an LP02-664RU-25

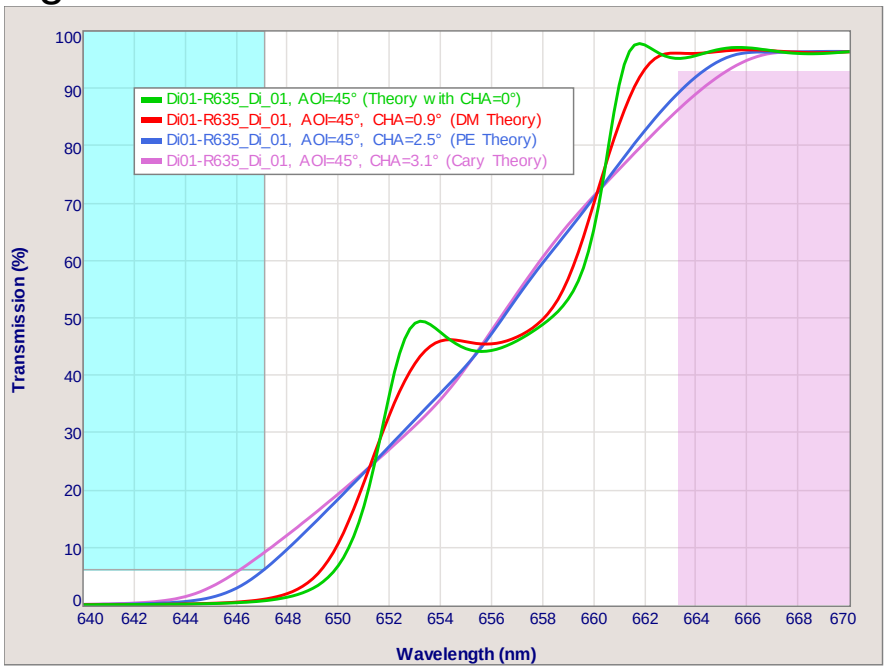


How do we handle these data discrepancies?

- **"Rounding" of sharp spectral features**
  - We use the finest possible resolution near sharp features and "stitch" the data to more coarse/ efficiently measured data at other wavelengths – never perfect!
  - We managed to minimize the cone-half angle of the measurement beam to ~1.0° on Semrock's proprietary spectrophotometer. Note that commercial spectrophotometers have CHAs as large as 2.5° – 3.1°.



Theory vs. **Semrock** and **PE** Measured Data



Theory vs. **Semrock**, **PE**, & **Cary** nominal CHAs

How do we handle these data discrepancies? (2)

- **Limited OD measurement range**
  - Our in-house developed spectrophotometer has improved the range we can measure to (traditionally was OD 5.5). The Near-IR region can be a challenge (requires equipment optimization). Depending on the requirement, it can be costly (in terms of time/ effort) to get precise measurements.
    - Between 320 and 1120 nm, values near or below 3e-7 (OD 6.5) are noise limited
    - For < 320 nm and > 1120 nm, values near or below 3e-6 (OD 5.5) are noise limited
- **"Sideband measurement artifact"**
  - We rely on our knowledge of the spectrophotometer performance and the filter design curve to determine what the actual filter performance is – these measurements are verified periodically using lasers to make single-wavelength OD measurements with a much higher dynamic range (OD values between 8 and 9 can be measured at certain laser wavelengths)

Thank you!