

## How to choose a spectrometer

The basic parameters you need to know before choosing a suitable spectrometer are:

- Wavelength range
- Resolution

For instance, if you need to analyze color you need a spectrometer that covers the visible spectrum from approx. 400 – 700 nm.

The resolution is the spectrometer's ability to distinguish between two closely spaced wavelengths. So, if your spectrum has some sharp peaks that are separated by say 0.5 nm or more, you need a spectrometer with at least 0.5 nm resolution.

Some applications (like Raman and IR spectroscopy) will not list the wavelength range and resolution in nanometer (nm) directly but rather in terms of inverse cm ( $\text{cm}^{-1}$ ). For Raman you can use our [RamanShift converter](#) to convert back and forth between nm and  $\text{cm}^{-1}$ .

Even though you know your wavelength range and resolution there are still a lot of possible spectrometer design options. So your final choice of spectrometer will depend on the importance of parameters such as overall **Size**, **Cost**, **Speed**, **Sensitivity**, **Signal-to-Noise Ratio**, **Dynamic range**, **Linearity**, **Thermal Stability**, and **Robustness**. Below, you can find some general guidelines that may help you determine what kind of spectrometer parameters you should focus on for your application.

### Size

If you need a compact spectrometer you should in general go for:

- a) High grating dispersion
- b) Small detector size
- c) Low numerical aperture/high f-number

### Cost

If you need a low cost spectrometer you should in general go for:

- a) Small size spectrometer
- b) Low-end, non-cooled CCD/CMOS-based detector or a Photo-Diode array
- c) Low resolution spectrometer

### Speed

If you need a fast spectrometer you should in general go for:

- a) High through-put spectrometers
  - a. Transmission grating based
  - b. High NA / Low f-number
  - c. Few optical elements (preferably lenses)
- b) High-speed, non-cooled cameras

### Sensitivity

If you have very little light from your sample you need a highly sensitive spectrometer and you should in general go for:

- a) High throughput spectrometers
  - a. Transmission grating based
  - b. High NA / Low f-number

- c. Few optical elements (preferably lenses)
- d. A wide and tall input slit
- b) Cooled camera/detector that enable long integration time
- c) Highly sensitive CCD (or CMOS) detector with tall pixels

### Signal-to-Noise Ratio

If signal levels have to be very stable over time you have several options depending on the actual signal level and balance of cost versus performance:

If your signal level is very weak and tends to drown in the noise:

- a) High through-put spectrometers
  - a. Transmission grating based
  - b. High NA / Low f-number
  - c. Few optical elements (preferably lenses)
  - d. A wide and tall input slit
- b) Cooled CCD/CMOS detectors with tall pixels that allow long integration time with low noise

If your signal level is very weak but, you also need a low cost solution:

- a) High through-put spectrometers
  - a. Transmission grating based
  - b. High NA / Low f-number
  - c. Few optical elements (preferably lenses)
- b) Non-cooled CCD/CMOS detectors where you average over many short integration periods

If your signal level is stronger:

- a) High through-put spectrometers
- b) CMOS detectors with very low noise

### Dynamic range

If there are large (several orders of magnitude) variations in your signal levels you should in general go for:

- a) Low stray-light spectrometers
  - a. Holographic, Master gratings rather than replicated, ruled gratings
  - b. As few optical surfaces as possible
  - c. Bandpass filters to block un-wanted light
- b) CMOS detectors with very large dynamic range or Non-cooled CCD/CMOS detectors where you average over many short integration period.

### Linearity

If you require a linear relation between signal level and integration time you should in general go for:

- a) CMOS/BT-CCD detectors with very good linearity or CCD/CMOS detectors where you make a software correction for linearity.

### Thermal stability

If your spectrometer should operate under varying temperature conditions you should in general go for:

- a) Spectrometers with low wavelength and power shift vs. temperature
  - a. Lens-based, tele-centric rather than mirror-based spectrometers

- b. All-dielectric, transmission grating based rather than reflection grating based spectrometers
- c. Thermally stable mounting methods
- b) Short integration time or temperature controlled detectors if you need longer integration time

### **Robustness**

If your spectrometer should operate under demanding environmental conditions you should consider some of the following:

- a) Spectrometers with low wavelength and power shift vs. external impacts
  - a. Lens-based, tele-centric rather than mirror-based spectrometers
  - b. Transmission grating based rather than reflection grating based
  - c. Environmentally qualified mounting methods for optics and gratings

Short integration time and/or temperature controlled detectors if you need longer integration time