Modular Spectrometer Delivers High Performance in Compact Footprint

Application Note

KEYWORDS

- Modular spectrometer
- SNR performance
- Spectral acquisition

TECHNIQUES

- Absorbance
- Irradiance
- Transmittance

APPLICATIONS

- Molecular diagnostics
- Laser characterization
- Plasma monitoring

Since the introduction of the first commercially viable modular spectrometers in the early '90s, successive generations of these versatile instruments have demonstrated significant improvement across key performance indicators including signal to noise ratio (SNR), optical resolution, scan rates, stray light and linearity.

The SR2 spectrometer is part of the newest generation of modern modular spectrometers. The spectrometer has a proprietary linear CCD-array detector, enhanced electronics that provide high-speed spectral acquisition (integration times to 1 µs), and a novel optical bench design that delivers excellent SNR performance for absorbance measurements, plasma monitoring and other applications.

Absorbance of Optical Filters

Using an SR2 spectrometer with a balanced deuterium-tungsten halogen light source and an optical filter holder, we measured various combinations of optical color, balancing and UV blocking filters. When compared with a similar type of spectrometer for the same measurements, the SR2 demonstrated higher absorbance values, suggestive

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of lower stray light performance; and better SNR at longer wavelengths, the result of more balanced spectral sensitivity across the spectral range **(Figure 1**).

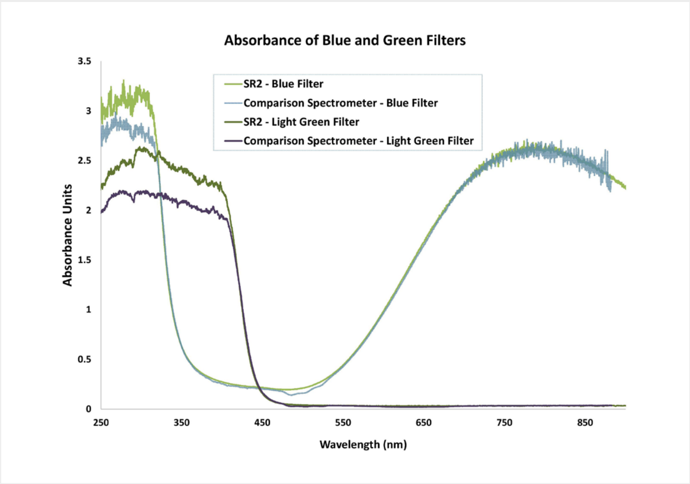

Figure 1. When blue filters are measured, the lower noise level of the SR2 delivers better SNR at longer wavelengths than a comparable spectrometer.

To ensure best results for similar measurements, begin by warming up the light source for the recommended amount of time (up to 30 minutes in some cases). Light source output will continue to change very slightly until the source is in thermal equilibrium; in this warm-up period, measurements can be misleading or inaccurate. Also, never turn off the light source or disconnect fibers to take a dark measurement. Instead, block the light source at its origin, or at the filter slot in the sample holder. Make sure the object used will block 100% of the light; metal works well.

Signal-to-Noise Ratio (SNR) and the SR2

In the context of absorbance measurements, spectrometer SNR can be the difference between excellent results and something less than that. We've observed how the SR2 outperforms a comparable spectrometer for absorbance measurements, especially in the UV. This makes the SR2 an appealing option for applications such as molecular diagnostics.

For context, SNR is the signal intensity divided by the noise intensity at a certain signal level, which means SNR can vary from measurement to measurement. Since system noise typically increases as a function of signal due to photon noise, the SNR function is a plot of individual SNR values versus the signal at which they were obtained. The value of a spectrometer's SNR reported by Ocean Optics is the maximum possible SNR value obtained at detector saturation. The SNR response curve for each pixel is assumed to be the same.

SNR can be improved by using signal averaging, as we did for most of our measurements here. For time-based averaging, the SNR will increase by the square root of the number of spectral scans used. For example, an SNR of 380:1 for a single scan increases to 3800:1 if 100 scans are averaged. For spatially based averaging (boxcar), the SNR will increase by the square root of the number of pixels averaged.

Also, SNR can be dramatically enhanced using the High Speed Averaging Mode available in OceanDirect. Visit our website for details.

Balanced Spectral Response

With the SR2, a more balanced spectrum across the wavelength range means that the user won't need to saturate some parts of the spectrum to get enough signal in another. With some setups, there can be high sensitivity in one region of the spectrum and lower signal levels in another region. Steps you take to increase signal in less sensitive regions – like increasing spectrometer integration time – can translate to more noise across those wavelengths and lead to saturation at wavelengths where sensitivity is already high.

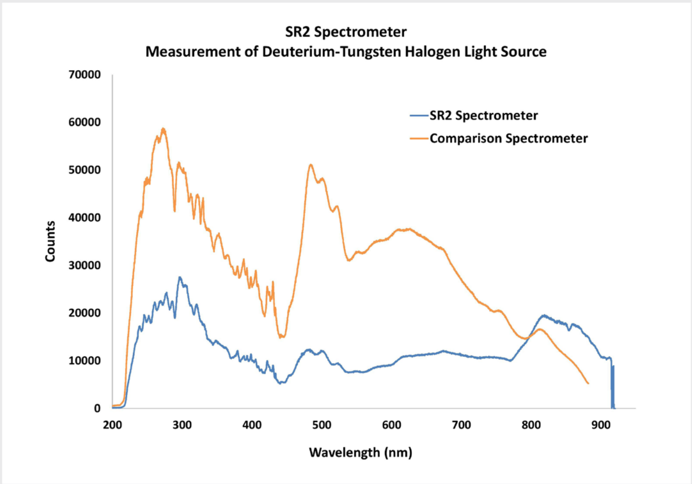

Figure 2. At ~250 nm, the comparison spectrometer is close to saturating, which will limit the integration time possible and yield a lower response throughout the spectral range. With SR2, the spectrum is more balanced across the spectral range, adding flexibility in optimizing measurement parameters.

However, if the response is flatter across the spectrum, then the integration time can be increased – provided you have sufficient light intensity – and SNR improves **(Figure 2)**.

For example, in absorbance measurements, you take a dark, then a reference, then a sample measurement. Essentially, you are comparing the reference to the sample. If both reference and sample measurements have good signal then your result has a much better level of certainty than if both are relatively weak signals, as the SNR will be greater.

Ultimately, with the relatively balanced sensitivity of SR2, you will achieve more consistent performance across the entire wavelength range of the spectrometer.

Additional Applications

While the SR2 is an excellent option for absorbance measurements, its versatility extends to other applications. For example, for irradiance calibrated measurements like solar irradiance, SR2 is able to detect high-resolution spectral peaks as well as less obvious features in the spectrum. The spectrometer is also useful for measuring high-intensity light sources and high-energy plasmas.