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TECHNICAL COMPARISON: OL 770 VERSUS OCEAN OPTICS' USB 200

Although the Optronic Laboratories OL 770-LED and Ocean Optics' USB 2000 are both CCD spectrograph instruments, there are many significant differences between them. The impact and benefits of these differences may not be obvious from reading technical specifications of the two products. The OL 770-LED offers many important benefits over the Ocean Optics' USB 2000, including:

Higher Sensitivity

This means shorter measurement times and quicker results thanks to a 2-D back thinned, TE cooled CCD array and time delay integration. Not just slightly shorter, the USB 2000 requires 70 times the exposure to give the same quality of result as the OL 770-LED using a 600 µm fiber or 280 times the exposure when compared to the OL 770-LED with a 3 mm ϕ fiber. Dark current is measured, averaged and subtracted before each measurement.

Easier to use

Built-in calibration and intelligent software makes the OL 770-LED easy to use for untrained personnel. Measurements and reports can be made with a simple mouse click.

Higher Accuracy

The OL 770-LED provides unsurpassed accuracy for most applications. The USB 2000 does not even come close in terms of accuracy. Ocean Optics does not even state wavelength accuracy, whereas Optronic Laboratories does *(0.5 nm for 380 – 780 nm range).*

Higher Reliability

The OL 770-LED has much smaller uncertainties than the USB 2000 for all measurements, giving lower variability of results and greater confidence.

Lower Stray Light:

Stray light is responsible for most errors in color and low light measurements. The OL 770-LED is much better than the USB 2000 for these applications.

Better Technical Support

To save you time and money, Optronic Laboratories's staff of application experts and scientists can help with any question you may have.

Range of Measurement Types

The OL 770-LED provides several important measurements of LEDs including flux, intensity, and spatial distribution *(goniometry)*. The USB 2000 is limited to flux measurements only. The OL 770-LED is also much faster and more sensitive. It can measure lower light levels, in addition to making the same measurement in 1/200th the time.

Spectrograph Optical Bandwidth

We have assumed for comparison purposes that the USB 2000 has the visible grating # 3 in the Ocean Optics catalogue, with a spectral range of 650nm.

THE OPTICAL BANDWIDTH IS A FUNCTION OF:	OL 770-LED	USB 2000
Entrance Slit Width	100 µm	100 µm
Focal Length of the Spectrograph	140 mm	42 / 68 mm
Magnification of Entrance Slit at Detector	X1	X1.5
Groove Density of the Diffraction Grating	405 Lines/mm	600 Lines/mm
Dispersion at Detector Array*	16.25 nm/mm	22.6 nm/mm
Optical Bandwidth	~2 nm	~3.4 nm *(Theoretical)*

** This is a typical number, which will vary across the spectrum*

The combined effects of the dispersion, longer focal length, and X1 imaging of the entrance slit onto the detector array give the OL 770-LED a smaller bandwidth than the USB 2000 for the same input slit width. Smaller slit widths will reduce the bandwidth of both systems equally, as well as reduce their sensitivities.

Pixel Resolution

The pixel resolution is a function of the spectral dispersion *(nm/mm)* on the detector array and the pixel pitch.

	OL 770-LED	USB 2000
Dispersion at Detector Array*	16.25 nm/mm	22.6 nm/mm
Pixel Pitch	0.024 mm	0.014 mm
Pixel Resolution*	~0.39 nm	~0.32nm

** This is a typical number, which will vary across the spectrum*

Information Sheet: IS30 Jan 2019

Stray Light

After measuring the stray light of both systems in an identical set up, results showed the OL 770-LED had two decades lower straylight than the USB 2000. This was expected on a grating/ optics size comparison alone. Both systems offer software subtraction of stray light.

Relative vs. Absolute Measurements

The USB 2000 is used in many production applications where the only question is if the device under test *(DUT)* is the same or different from other units in production. The USB 2000 can do this type of relative measurement, but the OL 770-LED can do it better. If measurements of small change are required, the OL 770-LED may be a better choice for the application. When it comes to absolute measurements, whether it is quantities of light or color measurements, the OL 770-LED out performs the USB 2000. It has much better stray light, linearity error, stability, and other sources of uncertainty than the USB 2000.

Accuracy

The OL 770-LED and the USB 2000 each offer an integrating sphere for total flux measurements. However, Ocean Optics offers a 1.5-inch Spectrolon sphere, the FOIS-1, as optional. Its size and design is unsuited for accurate LED total flux measurements. It has poor angular response and no LED self-absorption correction, opening the possibilities of extremely large errors. The OL IS-670-LED, which comes standard with the OL 770-LED, is a 6-inch integrating sphere with a highly stable and reflective pressed PTFE coating. It has a fiber optic coupling to the OL 770-LED internal reference lamp to enable system calibrations with the test LED fitted to the sphere. This ensures that the self-absorption of the LED and its holder is accounted for and corrected in the calibration measurements.

Both systems use a software correction for the wavelength scale. The accuracy of this depends on the method for calculating this correction, order number in the polynomial, optical resolution of the spectrograph, and thermal stability of the spectrograph. However, the OL 770-LED uses a differential method of smoothing and sub pixel calculations to improve the wavelength accuracy to better than 0.3nm.

System Sensitivity

THE SYSTEM SENSITIVITY IS A FUNCTION OF:	OL 770-LED	USB 2000
Input Optics	Numerous	Limited
Optical Bandwidth	~ 2 nm	~ 3.4 nm
Spectrograph Numerical Aperture	f/2	?
CCD Size	2.9 x 24.6 mm	0.2 x 28.7 mm
Pixel Layout	122 x 1024	1 x 2048
Pixel Size	0.024 x 0.024 mm	0.2 x 0.014 mm
System Sensitivity *(Typical)*	0.1 Counts / Photon	0.012 Counts / Photon
CCD Maximum Dynamic Range	75,000	267
CCD Regulation Temperature	TE Cooled	No Temp. Regulation
ADC Resolution	16 Bit	12 Bit
System Noise	±13 Counts	±8 Counts
Maximum CCD Integration Time	60 S	65 S

Actual measurements with both systems configured to have similar optical bandwidth show the OL 770-LED to have almost an order of magnitude better signal to noise with a 600 µm fiber optic input probe. A further factor of four more sensitivity is achieved when using the 3 mm diameter fiber optic probe supplied as standard with the OL 770-LED. For the USB 2000 to give measurements of similar quality to one scan of the OL 770-LED at 1 second, for example, it would have to average 280 scans at 1 second each. That is 1 second versus 4 minutes and 40 seconds.

Dynamic Range

The dynamic range is often taken from the noise level or ten times the noise level to the maximum possible signal within the linearity limits set. In both systems, the maximum signal can be set as high as preferred with the use of neutral density filters or other optical attenuators. The minimum level will depend on the system sensitivity, maximum integration time, system noise, and ADC resolution. Key differences between the two systems are the CCD size, CCD dark noise level, and the CCD thermoelectric cooling.

With the OL 770-LED there is more than two decades dynamic range available beyond the lower limit of the USB 2000.

Linearity

An ideal measurement system will have a zero linearity error over its entire dynamic range. However, linearity error is introduced into the system through the following areas:

- Shutter Timer Accuracy
- CCD
- ADC

The OL 770-LED has a linearity error of < 2% of reading across its dynamic range. The USB 2000 does not indicate its linearity error.

Ease and Accuracy of Calibration

Calibration of the OL 770-LED is much quicker and easier than the USB 2000 due to its built-in internal reference source. Although an optional calibration source for LED flux calibration can be purchased, the USB 2000 does not operate with the LED and holder in place, and therefore cannot compensate for LED self-absorbtion of LED holder reflection. The OL 770-LED does not have this problem.

Repeatability:

Both systems use no or few moving parts. This greatly enhances the system repeatability, but there are many other factors that will affect the measurement repeatability:

- Shutter Speed Accuracy – The OL 770-LED is equipped with a microprocessor-timed mechanical shutter, where as the USB 2000 has an all-electronic shutter.
- Signal Noise – The OL 770-LED has superior sensitivity and signal to noise ratio.

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- Dark Current Stability – The OL 770-LED uses a low noise CCD with thermo-electric cooling, with a ΔT up to 50°C. TEC cooling of the USB 2000 CCD is an optional extra but with a maximum ΔT of only 15°C and additional cost of $999.

Fiber Optic Probe

Optronic Laboratories utilizes a 3mm diameter glass fiber bundle as a standard fiber optic probe. The fiber optic probe can be designed to optimize the input optics and maximize the signal at the input slit of the spectrograph.

Ocean Optics uses SMA terminated single fiber light guides with a choice of fiber diameters.

Available Accessories

Apart from the greater sensitivity and lower noise in the OL 770-LED spectroradiometer, there are significant differences in optical accessories as well:

- The OL 770-LED uses a 6" diameter integrating sphere *(OL IS-670-LED)* for total luminous and spectral flux measurements, compared to the Ocean Optics 1.5" sphere. The larger sphere provides greater accuracy and repeatability.
- The OL IS-670-LED integrating sphere has a fiber optic coupling to the OL 770-LED internal reference lamp to enable system calibrations with the test LED fitted to the sphere. This ensures that the self-absorption of the LED and its holder is accounted for and corrected in the calibration measurements.
- The OL 15AB LED Receptor is designed to comply with CIE Publication 127 for Average Luminous Intensity - Conditions A & B. Ocean Optics does not offer an accessory for these measurements.
- The OL 700-30 Goniometer Measurement Assembly is available for spatial distributions measurements. Ocean Optics does not offer this option.

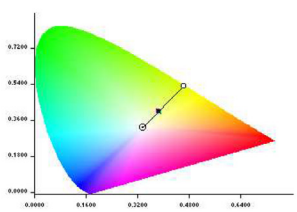
OL 770-LED SOFTWARE VS. USB 2000 SOFTWARE

The OL 770-LED has powerful, easy to use software. Technically savvy users are able to set different conditions of measurements, while inexperienced users are able to make measurements as soon as the program is started. Automatic routines ensure users of the best results every time. Results can be downloaded automatically to MS Excel® spreadsheets, MS Word® documents, and reports with the single click of a mouse.

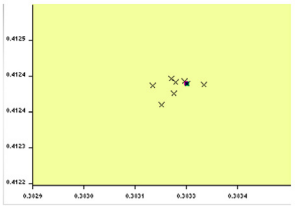
Report Generation

The OL 770-LED provides the ultimate versatility in report generation by seamlessly integrating spectral data, calculated values and graphic plots into MS Word® and MS Excel®. The OL 770-LED software simplifies the generation of templates for test reports and certificates. Spectral data can be automatically saved into an MS Excel® file or immediately transferred directly into an MS Excel® spreadsheet for analysis at the touch of a button. Large volumes of calculated data values could be saved into a custom MS Excel® template where, for example, trends or variances can be calculated and stored. The USB 2000 generates only compatible text files, which then must be imported into MS Excel®.

The C.I.E. Chromaticity Diagram



1931 Chromaticity Diagram



Chromaticity Diagram zoomed

The Chromaticity diagram is a light measurement user's method of graphically identifying the color of the object being measured. It ideally provides mechanisms to identify trends and comparisons of chromaticity coordinates of numerous measurements. The OL 770-LED application provides this through many ways.

The OL 770-LED supports both 1931 and 1976 chromaticity diagrams. Ocean Optics provides only 1931.

The chromaticity diagram provided by the OL 770-LED software is in full color. This allows the user to get a better feel for the color of the object in question. Ocean Optics provides no color for their chromaticity diagrams, only a chromaticity outline.

With the OL 770-LED, the user can zoom in on the chromaticity diagram and see detailed differences between consecutive measurements. The USB 2000 has no zooming capability.

The OL 770-LED can accumulate multiple measurements. Thousands of measurements can be automatically plotted onto the chromaticity diagram. Each successive measurement is then denoted with an "X." This feature facilitates time studies and variance tests of different LEDs. The OL 770-LED is able to show gamuts with this feature by transitioning tri-colored LEDs over a short time span. Ocean Optics does not have this.

The Spectral Plot

A spectral plot, a very powerful tool, is a means of determining the spectral characteristics of a source. The OL 770-LED spectral plot allows the user to snap to multiple peaks automatically, then compare those peaks for wavelength and magnitude. They can also be moved manually with a simple mouse drag. They are available in all levels of zooming, and their values can be sent to MS Excel®. The first two cursors can also be used to limit wavelength ranges in chromaticity calculations, which is particularly useful when separating of the excitation and emission regions in phosphor coated white LEDs. This level of control is not available in the USB 2000 software.

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The Value Monitor

The OL 770-LED has the ability to monitor PASS/FAIL of values through its Value Monitor. This feature allows the user to monitor up to any six values. These values can be anything from Peak Wavelength to the 2 degree x,y,z to the Color Rendering Indexes. The user specifies a range for that value, and the software monitors it. It will turn the on-screen display to green or red based upon PASS or FAIL and can be setup to make an audible notification on a FAIL. Ocean Optics does not have this.

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