# Spectrometers





User-configured Spectrometers are for those who wish to select components and options in their spectrometer, from the wavelength range and grating type to the size of the entrance aperture and type of coatings on the detector.

# Overview: Spectrometers

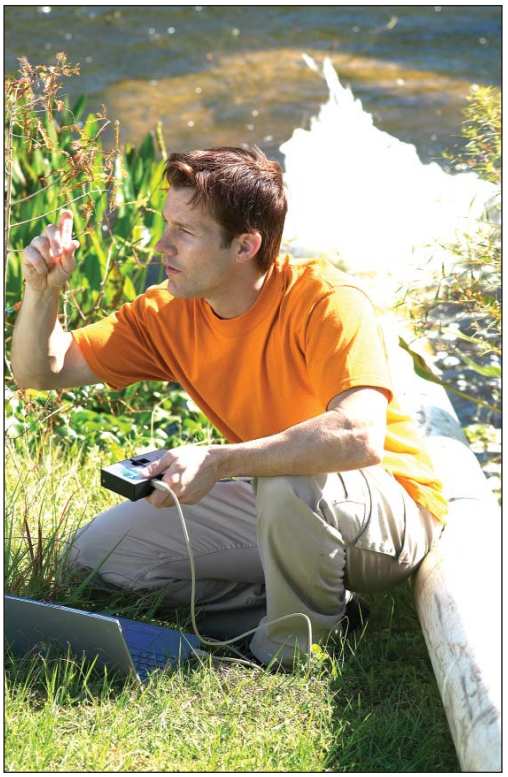
## We Have Your Spectrometer!

Since we introduced the world's first miniature spectrometer 15 years ago, we've sold more than 85,000 spectrometers and enabled thousands of applications. We pioneered the notion of flexible, modular spectroscopy, making it possible for users in many industries to configure systems for very different applications.

For those who wish to select the components in their spectrometer, we offer a complete range of options. You can make it your way:

- The size of your entrance aperture helps determine how much light enters your optical bench and is a factor in determining optical resolution. We have six sizes of entrance apertures.
- Our filters block second- and third-order effects or balance color.
- You can opt to install standard collimating and focusing mirrors or SAG+ mirrors, which increase reflectance and sensitivity.
- We offer 14 different gratings. Your choice helps determine your resolution and wavelength range.
- An optional collection lens increases light-collection efficiency.
- Our OFLV filters precisely block second- and third-order light from reaching specific detector elements.
- A UV upgrade enhances the spectrometer's performance in the UV.

Our Applications Scientists have configured thousands of spectrometer setups. Simply tell us what you want to measure and why and we'll configure the optimum system for your application.



## Detector Type

**CCD Detectors**
We use a 3648-pixel CCD-array detector from Toshiba in both our "USB" and "HR" optical benches that's ideal for general-purpose applications. The Sony ILX511 is a 2048-pixel linear CCD-array detector that's still used in a couple of our specialized spectrometer offerings.

**Photodiode Detectors**
Less-sensitive photodiode detectors provide a high signal-to-noise ratio for applications with high light levels. We use Hamamatsu's S3903 and S3904 photodiode silicon linear arrays for our Deep-well Spectrometers.

**Back-thinned TE-cooled Detector**
The Hamamatsu S7031-1006 detector in the "QE" optical bench provides high quantum efficiency, fast signal processing speed and a high signal-to-noise ratio. This TE-cooled detector generates virtually no dark noise.

**InGaAs Detectors**
We use three different Hamamatsu linear array InGaAs detectors in our "NIR" optical bench for general-purpose NIR applications.

## Bench Type

**General-purpose "USB" Bench**
The "USB" optical bench (also called the "S" bench) is ideal for absorbance, reflectance, fluorescence and color measurements. It's a versatile bench that is used in tens of thousands of spectrometers around the world.

**High-resolution "HR" Bench**
The "HR" optical bench is designed for applications requiring sub-angstrom optical resolution, such as laser characterization and atomic emission spectroscopy.

**Scientific-grade "QE" Bench**
The "QE" optical bench is designed for demanding applications with low light levels such as Raman and fluorescence.

**Near-Infrared "NIR" Bench**
The "NIR" optical bench is designed for applications that require sensitivity in the NIR region, such as moisture analysis, tunable laser wavelength characterization and general NIR spectroscopy.

## Spectrometer Type

**Spectrometers**
You select the optical bench options, such as the grating, entrance aperture size, detector, wavelength range and more to create the optimum spectrometer for your application.

**Spectrometer Systems & Setups**
Systems are turnkey spectrophotometers where all the components are included in one integrated enclosure. Setups provide a list of tools necessary for an application. Both Systems and Setups include a spectrometer, the necessary sampling accessories, a light source and software. Some spectrometers are preset with a grating, wavelength range and other bench accessories for specific measurement types such as fluorescence. You still specify other components, such as light sources and sampling accessories.

# Spectrometer Comparison Chart

This table outlines the specifications of our most popular user-configured spectrometers.
Please refer to specific product pages for more detailed information.

| Specifications | USB4000 p. 14 | HR2000+ p. 20 | HR4000 p. 21 | QE65000 p. 26 |
|---|---|---|---|---|
| PHYSICAL | | | | |
| Dimensions (in mm): | 89.1 x 63.3 x 34.4 | 148.6 x 104.8 x 45.1 | 148.6 x 104.8 x 45.1 | 182 x 110 x 47 |
| Weight: | 190 grams | 570 grams | 570 grams | 1050 grams |
| DETECTOR | | | | |
| Detector: | Toshiba TCD1304AP linear CCD array | Sony ILX511 linear silicon CCD array | Toshiba TCD1304AP linear CCD array | Hamamatsu S7031-1006 back-thinned area CCD |
| Detector range: | 200-1100 nm | 200-1100 nm | 200-1100 nm | 200-1100 nm |
| Pixels: | 3648 pixels | 2048 pixels | 3648 pixels | 1024 x 58 (1044 x 64 total) |
| Pixel size: | 8 µm x 200 µm | 14 µm x 200 µm | 8 µm x 200 µm | 24.6 µm square size |
| Pixel well depth: | ~100,000 electrons | ~62,500 electrons | ~100,000 electrons | 300,000 electrons/well<br>~1.5 million electrons/column |
| Sensitivity: | 400 nm: 130 photons/count<br>600 nm: 60 photons/count | 400 nm: 75 photons/count<br>600 nm: 41 photons/count | 400 nm: 130 photons/count<br>600 nm: 60 photons/count | 22 electrons/count for all wavelengths<br>250 nm: 26 photons/count |
| OPTICAL BENCH | | | | |
| Design: | f/4, Asymmetrical crossed Czerny-Turner | f/4, Symmetrical crossed Czerny-Turner | f/4, Symmetrical crossed Czerny-Turner | f/4, Symmetrical crossed Czerny-Turner |
| Focal length (input): | 42 mm | 101.6 mm | 101.6 mm | 101.6 mm |
| Focal length (output): | 68 mm | 101.6 mm | 101.6 mm | 101.6 mm |
| Entrance aperture: | 5, 10, 25, 50, 100, or 200 µm wide slits or fiber | 5, 10, 25, 50, 100 or 200 µm wide slits or fiber | 5, 10, 25, 50, 100 or 200 µm wide slits or fiber | 5, 10, 25, 50, 100 or 200 µm wide slits or fiber |
| Grating options: | 14 gratings, UV through Shortwave NIR | 14 gratings, UV through Shortwave NIR | 14 gratings, UV through Shortwave NIR | 14 gratings, UV through Shortwave NIR |
| HC-1 grating option: | No | No | Yes, HC-1 provides 200-1050 nm range (best efficiency) | Yes, HC1-QE provides 200-950 nm range |
| Detector collection lens: | Yes, L4 | Yes, L2 | Yes, L4 | No |
| OFLV filters: | OFLV-200-850<br>OFLV-350-1000 | No | OFLV-200-1100 | OFLV-QE |
| Order-sorting filters: | Longpass OF-1 filters | Longpass OF-1 filters | Longpass OF-1 filters | Longpass OF-1 filters |
| Fiber optic connector: | SMA 905 to 0.22 numerical aperture single-strand fiber | SMA 905 to 0.22 numerical aperture single-strand fiber | SMA 905 to 0.22 numerical aperture single-strand fiber | SMA 905 to 0.22 numerical aperture single-strand fiber |
| SPECTROSCOPIC | | | | |
| Wavelength range: | Grating dependent | Grating dependent | Grating dependent | Grating dependent |
| Optical resolution: | ~0.3-10.0 nm FWHM | ~0.035-6.8 nm FWHM | ~0.02-8.4 nm FWHM | ~0.14-7.7 nm FWHM |
| Signal-to-noise ratio: | 300:1 (at full signal) | 250:1 (at full signal) | 300:1 (at full signal) | 1000:1 (at full signal) |
| A/D resolution: | 16 bit | 14 bit | 14 bit | 16 bit |
| Dark noise: | 50 RMS counts | 12 RMS counts | 12 RMS counts | 2.5 RMS counts |
| Dynamic range: | 2 x $10^8$ (system); 1300:1 for a single acquisition | 2 x $10^8$ (system); 1300:1 for a single acquisition | 2 x $10^8$ (system); 1300:1 for a single acquisition | 7.5 x $10^9$ (system); 25000:1 for a single acquisition |
| Integration time: | 3.8 ms to 10 seconds | 1 ms to 20 seconds | 3.8 ms to 10 seconds | 8 ms to 15 minutes |
| Stray light: | <0.05% at 600 nm<br><0.10% at 435 nm | <0.05% at 600 nm<br><0.10% at 435 nm | <0.05% at 600 nm<br><0.10% at 435 nm | <0.08% at 600 nm<br><0.4% at 435 nm |
| Corrected linearity: | >99.8% | >99.8% | >99.8% | >99.8% |
| ELECTRONICS | | | | |
| Power consumption: | 250 mA @ 5 VDC | 450 mA @ 5 VDC | 450 mA @ 5 VDC | 500 mA @ 5 VDC no TE cool<br>3 A @ 5 VDC with TE cool |
| Data transfer speed: | Full spectrum to memory every 5 ms with USB 2.0 port,<br>18 ms with USB 1.1 port | Full spectrum to memory every 1 ms with USB 2.0 port,<br>15 ms with USB 1.1 port,<br>200 ms with serial port | Full spectrum to memory every 4 ms with USB 2.0 port,<br>18 ms with USB 1.1 port | Full spectrum to memory every 8 ms with USB 2.0 port,<br>8 ms with USB 1.1 port |
| Inputs/Outputs: | Yes, 8 onboard digital user-programmable GPIOs | Yes, 10 onboard digital user-programmable GPIOs | Yes, 10 onboard digital user-programmable GPIOs | Yes, 10 onboard digital user-programmable GPIOs |
| Analog channels: | No | Yes, one 13-bit analog input and one 9-bit analog output | Yes, one 13-bit analog input and one 9-bit analog output | No |
| Trigger modes: | 4 modes | 4 modes | 4 modes | 4 modes |
| Auto nulling: | Yes | Yes | Yes | Yes |
| Strobe functions: | Yes | Yes | Yes | No |
| Gated delay feature: | Yes | Yes | No | Yes |
| COMPUTER | | | | |
| Operating systems: | Windows 98/Me/2000/XP, Mac OS X and Linux when using the USB port;<br>Any 32-bit Windows OS when using the serial port | Windows 98/Me/2000/XP, Mac OS X and Linux when using the USB port;<br>Any 32-bit Windows OS when using the serial port | Windows 98/Me/2000/XP, Mac OS X and Linux when using the USB port;<br>Any 32-bit Windows OS when using the serial port | Windows 98/Me/2000/XP, Mac OS X and Linux when using the USB port;<br>Any 32-bit Windows OS when using the serial port |
| Computer interfaces: | USB 2.0 @ 480 Mbps (USB 1.1 compatible);<br>RS-232 (2-wire) @ 115.2 K baud | USB 2.0 @ 480 Mbps (USB 1.1 compatible);<br>RS-232 (2-wire) @ 115.2 K baud | USB 2.0 @ 480 Mbps (USB 1.1 compatible);<br>RS-232 (2-wire) @ 115.2 K baud | USB 2.0 @ 480 Mbps;<br>RS-232 (2-wire) @ 115.2 K baud |
| Peripheral interfaces: | SPI (3-Wire);<br>$I^2C$ inter-integrated circuit\ | SPI (3-Wire);<br>$I^2C$ inter-integrated circuit | SPI (3-Wire);<br>$I^2C$ inter-integrated circuit | SPI (3-wire);<br>$I^2C$ inter-integrated circuit |

# USB4000 Plug-and-Play Spectrometer


*In this setup, a USB4000 is configured for fluorescence. A PX-2 Pulsed Xenon Light Source provides the excitation via optical fiber and a CUV-FL-DA Direct-attach Cuvette Holder holds the sample and redirects light energy directly into the USB4000 Spectrometer. A filter, such as one of our LVFs, are often used to block excitation wavelengths.*

| Specifications | |
|---|---|
| PHYSICAL | |
| Dimensions (in mm): | 89.1 x 63.3 x 34.4 |
| Weight: | 190 grams |
| DETECTOR | |
| Detector: | Toshiba TCD1304AP linear CCD array (page 17) |
| Detector range: | 200-1100 nm |
| Pixels: | 3648 pixels |
| Pixel size: | 8 µm x 200 µm |
| Pixel well depth: | ~100,000 electrons |
| Sensitivity: | 130 photons/count at 400 nm;<br>60 photons/count at 600 nm |
| OPTICAL BENCH | |
| Design: | f/4, Asymmetrical crossed Czerny-Turner |
| Focal length: | 42 mm input; 68 mm output |
| Entrance aperture: | 5, 10, 25, 50, 100, or 200 µm wide slit or fiber (page 15) |
| Grating options: | 14 gratings, UV through Shortwave NIR (page 16) |
| Fiber optic connector: | SMA 905 to 0.22 numerical aperture single-strand fiber |
| SPECTROSCOPIC | |
| Wavelength range: | Grating dependent |
| Optical resolution: | ~0.3-10.0 nm FWHM |
| Signal-to-noise ratio: | 300:1 (at full signal) |
| A/D resolution: | 16 bit |
| Dark noise: | 50 RMS counts |
| Dynamic range: | 2 x $10^8$ (system); 1300:1 for a single acquisition |
| Integration time: | 3.8 ms to 10 seconds |
| Stray light: | <0.05% at 600 nm; <0.10% at 435 nm |
| Corrected linearity: | >99.8% |
| ELECTRONICS | |
| Power consumption: | 250 mA @ 5 VDC |
| Data transfer speed: | Full spectrum to memory every 5 ms with USB 2.0 port,<br>18 ms with USB 1.1 port |
| Inputs/Outputs: | Yes, 8 onboard digital user-programmable GPIOs |
| Analog channels: | No |
| Trigger modes: | 4 modes |
| Strobe functions: | Yes |
| COMPUTER | |
| Operating systems: | Windows 98/Me/2000/XP, Mac OS X and Linux with<br>USB port; Any 32-bit Windows OS with serial port |
| Computer interfaces: | USB 2.0 @ 480 Mbps; RS-232 (2-wire) @ 115.2 K baud |
| Peripheral interfaces: | SPI (3-wire); $I^2C$ inter-integrated circuit |

**We've sold over 85,000 spectrometer channels for thousands of applications, and we've used that experience to make the most flexible, versatile and cost-effective spectrometer ever built.**

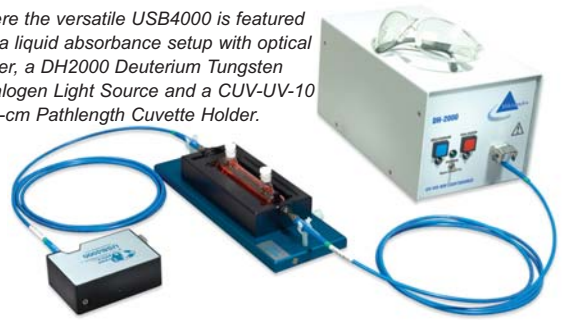
## World's Most Popular Spectrometer Just Got Better

We redesigned the USB4000 -- the most popular spectrometer in the world -- to include an advanced detector and powerful high-speed electronics. The USB4000 features a 16-bit A/D, four triggering options, a dark-level correction during temperature changes, and a 22-pin connector with eight user-programmable GPIOs. What's more, the USB4000 interfaces to computers with Linux, Mac or Windows operating systems. The modular USB4000 is responsive from 200-1100 nm and can be configured with various Ocean Optics optical bench accessories, light sources and sampling optics to create application-specific systems for thousands of absorbance, reflection and emission applications.

## Electronic Advancements

The USB4000 Spectrometer is distinguished by its enhanced electronics: 16-bit A/D resolution with auto nulling feature (an enhanced electrical dark-signal correction); EEPROM storage of calibration coefficients for simple spectrometer start-up; 8 programmable GPIO signals for controlling peripheral devices; and an electronic shutter for spectrometer integration times as fast as 3.8 milliseconds -- a handy feature to prevent detector saturation. In addition, the USB4000 has signal-to-noise of 300:1 and optical resolution (FWHM) ranging from 0.03-8.4 nm (depending on your grating and entrance aperture selection).

*Here the versatile USB4000 is featured in a liquid absorbance setup with optical fiber, a DH2000 Deuterium Tungsten Halogen Light Source and a CUV-UV-10 10-cm Pathlength Cuvette Holder.*



## Streamlined Start-up Software & Hot Swapping

The USB4000 interfaces to a computer via USB 2.0. Data unique to each spectrometer is programmed into a memory chip on the USB4000; SpectraSuite Spectroscopy Operating Software reads these values for easy setup and hot swapping among computers, whether they run on Linux, Mac or Windows operating systems. When connected to a computer via USB, the USB4000 draws its power from the computer. With its small-footprint design, plug-and-play convenience, advanced electronics and powerful detector, the USB4000 has succeed the USB2000 as the most frequently specified fiber optic spectrometer in the world.

**USB4000:** $2,199
**SPECTRASUITE:** $199

# USB4000 Optical Bench Options

What makes the USB4000 Spectrometer so special are the options that allow you to configure the bench for your application. Our Applications Scientists can help you choose the optimum components, or you can follow this guide to choose an entrance aperture size, detector accessories, filters, a grating and more. The diagram below shows how light moves through the asymmetrical crossed Czerny-Turner optical bench, which has no moving parts that can wear or break; all components specified are fixed in place at the time of manufacture.

## Components of the USB4000 Optical Bench

**1 SMA 905 Connector**
Light from a fiber enters the optical bench through the SMA 905 Connector. The SMA 905 bulkhead provides a precise locus for the end of the optical fiber, fixed slit, absorbance filter and fiber clad mode aperture.

**2 Fixed Entrance Slit:** specify slit size
Light passes through the installed slit, which acts as the entrance aperture. Slits come in various widths from 5 µm to 200 µm. The slit is fixed in the SMA 905 bulkhead to sit against the end of a fiber.

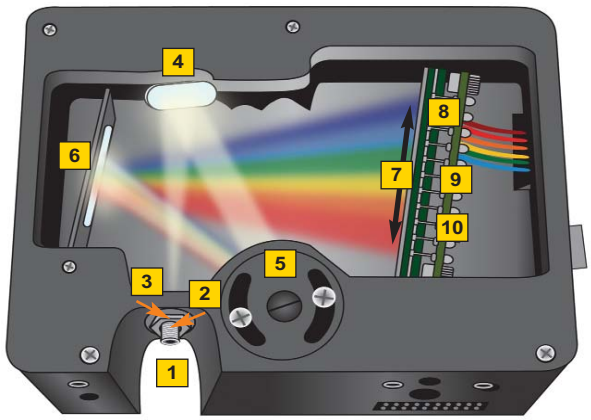
**3 Longpass Absorbing Filter:** optional
If selected, an absorbance filter is installed between the slit and the clad mode aperture in the SMA 905 bulkhead. The filter is used to block second- and third-order effects or to balance color.

**4 Collimating Mirror:** specify standard or SAG+
The collimating mirror is matched to the 0.22 numerical aperture of our optical fiber. Light reflects from this mirror, as a collimated beam, toward the grating. You can opt to install a standard mirror or a UV absorbing SAG+ mirror.

**5 Grating & Wavelength Range:** specify grating & starting wavelength
We install the grating on a platform that we then rotate to select the starting wavelength you've specified. Then we permanently fix the grating in place to eliminate mechanical shifts or drift.

**6 Focusing Mirror:** specify standard or SAG+
This mirror focuses first-order spectra on the detector plane. Both the collimating and focusing mirrors are made in-house to guarantee the highest reflectance and the lowest stray light possible. You can opt to install a standard or SAG+ mirror.

**7 L4 Detector Collection Lens:** optional
This cylindrical lens, made in-house to ensure aberration-free performance, is fixed to the detector to focus the light from the tall slit onto the shorter detector elements. It increases light-collection efficiency.




**8 Detector**
We offer a 3648-element Toshiba TCD1304AP linear CCD array detector. Each pixel responds to the wavelength of light that strikes it. Electronics bring the complete spectrum to the software.

**9 OFLV Variable Longpass Order-sorting Filter:** optional
Our proprietary filters precisely block second- and third-order light from reaching specific detector elements.

**10 UV4 Detector Upgrade:** optional
When selected, the detector's standard BK7 window is replaced with a quartz window to enhance the performance of the spectrometer for applications <340 nm.

## 1 SMA 905 Connector

A precision SMA 905 Connector aligns to the spectrometer's entrance slit and ensures concentricity of the fiber. For an upgrade fee that includes the cost of the custom connector and labor, we will replace the standard SMA 905 Connector with a different connector of your choice. We also offer connector adapters, such as an SMA-to-ST Adapter and an SMA-to-FC Adapter. Please call for details on connectors and adapters.

## 2 Fixed Entrance Slit

Another option available with a USB4000 user-configured spectrometer is the size of the entrance aperture. Entrance slits are rectangular apertures, 1-mm tall and various widths from 5 µm to 200 µm, with the width determining the amount of light entering the bench. A slit is permanent; it only can be changed by our technicians. You can opt against having a slit, in which case the diameter of the fiber connected to the spectrometer determines the size of the entrance aperture.

| Slit | Description | Pixel Resolution | Price |
|---|---|---|---|
| SLIT-5 | 5-µm wide x 1-mm high | ~5.3 pixels | $150 |
| SLIT-10 | 10-µm wide x 1-mm high | ~5.7 pixels | $150 |
| SLIT-25 | 25-µm wide x 1-mm high | ~7.5 pixels | $150 |
| SLIT-50 | 50-µm wide x 1-mm high | ~11.6 pixels | $150 |
| SLIT-100 | 100-µm wide x 1-mm high | ~21 pixels | $150 |
| SLIT-200 | 200-µm wide x 1-mm high | ~42 pixels | $150 |

*A slit is installed on the inside edge of the bulkhead of an SMA 905 Connector.*

# USB4000 Optical Bench Options

## 3 Longpass Absorbing Filter

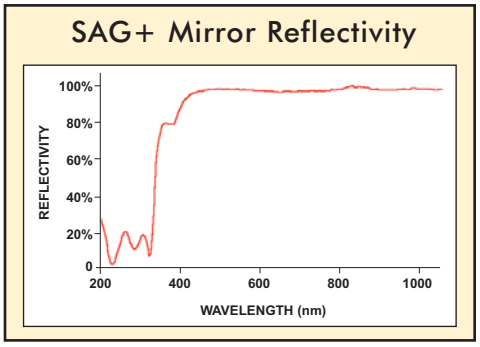
We offer longpass absorbing or blocking filters; each filter has a transmission band and a blocking band to restrict radiation to a certain wavelength region for eliminating second- and third-order effects. These filters are installed permanently between the slit and the clad mode aperture in the bulkhead of the SMA 905 Connector.

| Item | Description | Price |
|---|---|---|
| OF1-WG305 | Longpass filter; transmits light >305 nm | $50 |
| OF1-GG375 | Longpass filter; transmits light >375 nm | $50 |
| OF1-GG475 | Longpass filter; transmits light >475 nm | $50 |
| OF1-OG515 | Longpass filter; transmits light >515 nm | $50 |
| OF1-OG550 | Longpass filter; transmits light >550 nm | $50 |
| OF1-OG590 | Longpass filter; transmits light >590 nm | $50 |

## 4 & 6 Collimating & Focusing Mirrors

You can replace standard aluminum-coated reflective mirrors with our proprietary, UV-absorbing SAG+ Mirrors, which increase reflectance in the VIS-NIR and, in turn, increase the sensitivity of the spectrometer. SAG+ Mirrors are often specified for fluorescence. These mirrors also absorb nearly all UV light, which reduces the effects of excitation scattering in fluorescence measurements. Unlike typical silver-coated mirrors, the SAG+ mirrors won't oxidize. They have excellent reflectivity -- more than 95% across the VIS-NIR.

SAG+UPG: $250




## 5 Choosing a Grating & Wavelength Range

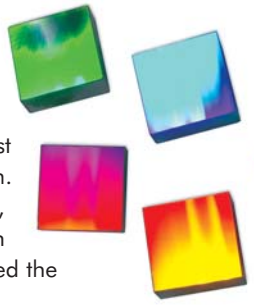
### Wide Selection Allows Flexibility

You choose from among 14 gratings for each spectrometer. With each grating, you consider its groove density (which helps determine the resolution), its spectral range (which helps determine the wavelength range) and its blaze wavelength (which helps determine the most efficient range).

### Performance & Stability

Instead of the gratings rotating as they do in instruments such as scanning monochromators, our gratings are permanently fixed in place at the time of manufacture to ensure long-term performance and stability. (See page 18 for Grating Efficiency Curves.) A grating must be specified for each spectrometer. We offer ruled and holographic diffraction gratings. Both are polymer replicas of master gratings. There are trade-offs between these gratings: holographic gratings produce less stray light while ruled gratings are more reflective, resulting in higher sensitivity.

### Grating Selection Chart



- The **Groove Density** ($mm^{-1}$) of a grating determines its dispersion, while the angle of the groove determines the most efficient region of the spectrum. The greater the groove density, the better the optical resolution possible, but the more truncated the spectral range.
- The **Spectral Range** is the dispersion of the grating across the linear array. The spectral range (bandwidth) is a function of the groove density and does not change. When you choose a starting wavelength for a spectrometer, you add its spectral range to the starting wavelength to determine the wavelength range.
- For ruled gratings, the **Blaze Wavelength** is the peak wavelength in an efficiency curve. For holographic gratings, it is the most efficient wavelength region.
- The **Best Efficiency** region is the range where efficiency is >30%. In some cases, gratings have a greater spectral range than is efficiently diffracted. For example, Grating #1 has a 650 nm spectral range, but is most efficient from 200-575 nm. In this case, wavelengths >575 nm will have lower intensity due to the the grating's reduced efficiency.

| Grating Number | Intended Use | Groove Density | Spectral Range | Blaze Wavelength | Best Efficiency (>30%) |
|---|---|---|---|---|---|
| 1 | UV | 600 | 650 nm | 300 nm | 200-575 nm |
| 2 | UV-VIS | 600 | 650 nm | 400 nm | 250-800 nm |
| 3 | VIS-Color | 600 | 650 nm | 500 nm | 350-850 nm |
| 4 | NIR | 600 | 625 nm | 750 nm | 530-1100 nm |
| 5 | UV-VIS | 1200 | 300 nm | Holographic UV | 200-400 nm |
| 6 | NIR | 1200 | 200-270 nm | 750 nm | 500-1100 nm |
| 7 | UV-VIS | 2400 | 100-140 nm | Holographic UV | 200-500 nm |
| 8 | UV | 3600 | 50-75 nm | Holographic UV | 290-340 nm |
| 9 | VIS-NIR | 1200 | 200-270 nm | Holographic VIS | 400-800 nm |
| 10 | UV-VIS | 1800 | 100-190 nm | Holographic UV | 200-635 nm |
| 11 | UV-VIS | 1800 | 120-160 nm | Holographic VIS | 320-720 nm |
| 12 | UV-VIS | 2400 | 50-120 nm | Holographic VIS | 250-575 nm |
| 13 | UV-VIS-NIR | 300 | 1700 nm | 500 nm | 300-1100 nm |
| 14 | NIR | 600 | 625 nm | 1000 nm | 650-1100 nm |

# USB4000 Optical Bench Options

## 7 L4 Detector Collection Lens

This cylindrical lens, made in-house to ensure aberration-free performance, is fixed to the detector's window to focus the light from the tall slit onto the shorter detector elements. It increases light-collection efficiency and reduces stray light. It also is useful in a configuration with a large-diameter fiber for low light-level applications. At right is a detector with the L4 lens.

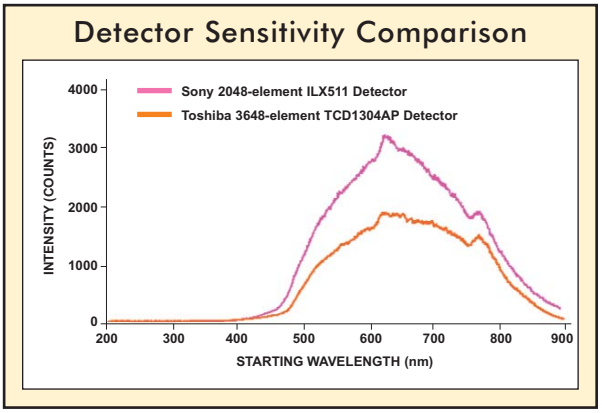
**L4 Detector Collection Lens: $150**

*Toshiba TCD1304AP Detector with L4 Detector Collection Lens (above) and without (below).*

## 8 Detector: 3648-element Linear CCD Array

In each USB4000, we install the Toshiba TCD1304AP linear CCD array detector. In the USB2000, the USB4000's predecessor, we used the Sony ILX511 detector. Both are linear silicon CCD arrays, with an effective range of 200-1100 nm, and with the same dynamic range (1300:1).

There are some differences between the Toshiba detector and the Sony detector. For example, since the Toshiba's pixels are only 8 µm wide instead of 14 µm wide, the sensitivity for a Toshiba pixel seems to be ~60% (8 µm/14 µm) that of a Sony pixel (see graph at right). However, on a per-unit area basis, the sensitivity is about the same since the Toshiba has 3648 pixels compared with the Sony's 2048; the total signal is the same. Because the Toshiba detector has an electronic shutter, you can almost never have too much light; the shutter prevents the detector from saturating.




## 9 Detector with OFLV Filter

Our OFLV Variable Longpass Order-sorting Filters are applied to the detector's window to eliminate second- and third-order effects. We use patented coating technology to apply the filter onto the substrate. In fact, we are the only miniature spectrometer manufacturer to offer "clean" first-order spectra.

## 10 Detector with UV4 Detector Window Upgrade

When you specify a detector with the UV4 Detector Window Upgrade, we replace the detector's standard BK7 window with a quartz window to enhance the spectrometer's performance from 200-340 nm.

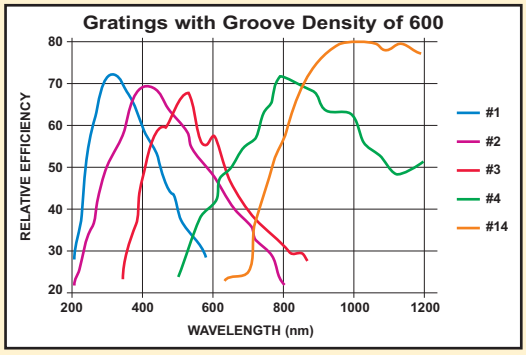
| Toshiba TCD1304AP Specifications | |
|---|---|
| Detector: | Toshiba TCD1304AP linear CCD array |
| Detector range: | 200-1100 nm |
| Pixels: | 3648 pixels |
| Pixel size: | 8 µm x 200 µm |
| Pixel well depth: | ~100,000 electrons |
| Sensitivity: | 400 nm: 130 photons/count, 600 nm: 60 photons/count |
| Maximum pixel rate: | Rate at which pixels are digitized is 1 MHz |

| Detector | Description | Price |
|---|---|---|
| DET4-VIS | Toshiba TCD1304AP Detector installed into a USB4000 User-Configured Spectrometer; best for systems with wavelength ranges above 400 nm | Free |
| DET4-UV | Toshiba TCD1304AP Detector with UV4 Detector Window Upgrade installed into a USB4000 User-Configured Spectrometer; best for systems with wavelength ranges in the UV | $150 |
| DET4-350-1000 | Toshiba TCD1304AP Detector with OFLV-350-1000 Variable Longpass Order-sorting Filter installed into a USB4000 User-Configured Spectrometer; best when using Grating #2, #3 or #4 | $150 |
| DET4-200-850 | Toshiba TCD1304AP Detector with UV4 Detector Window Upgrade and OFLV-200-850 Variable Longpass Order-sorting Filter installed into a USB4000 Spectrometer; best when using Grating #1 or #2 | $300 |

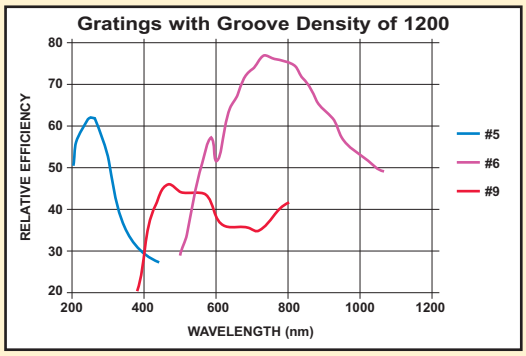
# USB4000 Optical Bench Options

## Grating Efficiency Curves

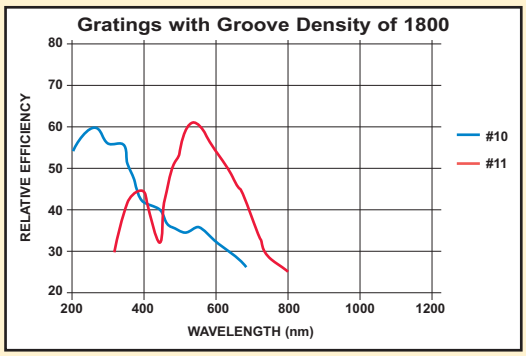
Below are the Grating Efficiency Curves for gratings with groove densities of 600, 1200, 1800 and 2400 mm$^{-1}$. See curves for all of our gratings at OceanOptics.com/Technical/GratingCharts.asp.



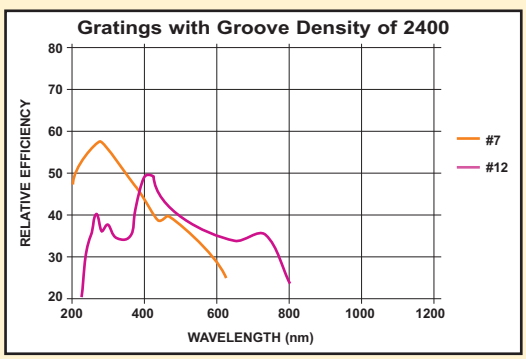

*Efficiency Curves for Gratings 1, 2, 3, 4 and 14.*




*Efficiency Curves for Gratings 5, 6 and 9.*



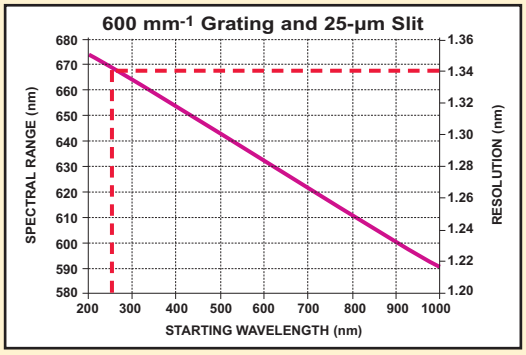

*Efficiency Curves for Gratings 10 and 11.*



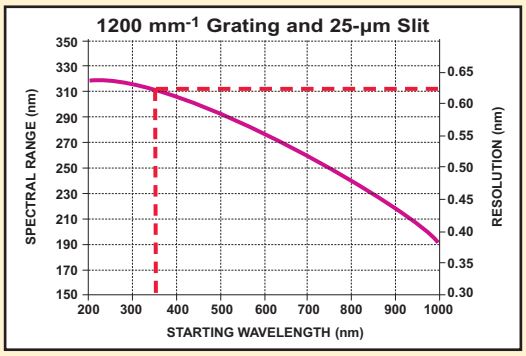

*Efficiency Curves for Gratings 7 and 12.*

## Predicted Ranges & Resolution

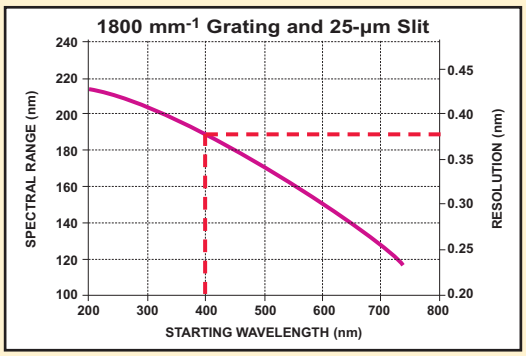
Here are a series of graphs to demonstrate the range and optical resolution (FWHM) of your USB4000 Spectrometer with a 25 µm slit. See our website for additional graphs of ranges and resolutions for every slit size.



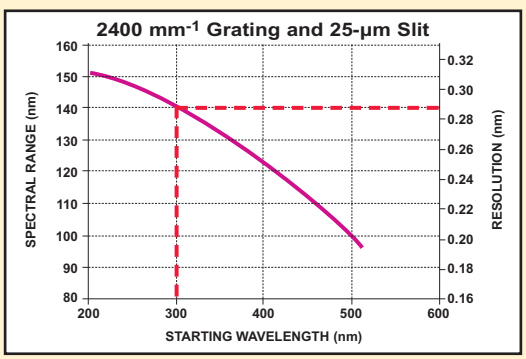

***Example:*** *If the starting wavelength is 250 nm, then the range is ~667 nm, providing a 250-917 nm wavelength range and 1.34 nm resolution.*




***Example:*** *If the starting wavelength is 350 nm, then the range is ~310 nm, providing a 350-660 nm wavelength range and 0.63 nm resolution.*




***Example:*** *If the starting wavelength is 400 nm, then the range is ~190 nm, providing a 400-590 nm wavelength range and 0.38 nm resolution.*




***Example:*** *If the starting wavelength is 300 nm, then the range is ~140 nm, providing a 300-440 nm wavelength range and 0.29 nm resolution.*

# USB4000 Direct-attach Accessories

## USB-DT Deuterium Tungsten Light Source

The USB-DT Deuterium Tungsten Light Source is our most versatile combination UV-VIS lamp. Use the USB-DT as a stand-alone unit with any spectrometer, stack it with a USB4000 Spectrometer, or combine it with a "breakout box" accessory and an "HR"-series or QE65000 Spectrometer for software control of lamp functions. This compact source is about the size of a deck of cards, provides stable, broadband output from 200-2000 nm, and requires a simple 5-volt wall transformer to operate. See page 124 for details.

**USB-DT: $1,499**

*USB-DT*

*USB-ISS-UV-VIS*

## USB-ISS-UV-VIS Integrated Sampling System for Cuvettes

The USB-ISS-UV-VIS is a direct-attach sample holder and deuterium tungsten light source (200-1100 nm) for measuring absorbance. This sampling system allows you to control both the intensity of the tungsten bulb and the shutter via software. The USB-ISS-UV-VIS requires an external power supply (included). See page 92 for more.

**USB-ISS-UV-VIS: $1,499**

*USB-ISS-VIS*

## USB-ISS-VIS Integrated Sampling System for Cuvettes

The USB-ISS-VIS is a direct-attach sample holder and violet LED-boosted tungsten light source (390-900 nm) combination for measuring relative absorbance. The light source boosts signal in the blue and provides over 10,000 hours of use. See page 92 for full specifications.

**USB-ISS-VIS: $499**

*USB-ISS-T*

## USB-ISS-T Integrated Sampling System for Test Tubes

The USB-ISS-T is a direct-attach sample holder and violet LED-boosted tungsten light source (390-900 nm) combination for measuring absorbance in 12-mm outer diameter test tubes. The sampling optics combine a diffuse source with a collimated input to the spectrometer to eliminate optical artifacts in the test tubes. See page 92 for specifications.

**USB-ISS-T: $499**

*USB-LS-450*

## USB-LS-450 Pulsed Blue LED Module

The USB-LS-450 is an LED module designed for fluorescence measurements in the lab or field, or as part of an Oxygen Sensor system. In addition, the USB-LS-450 has a port for attaching a 100 ohm RTD temperature sensor and onboard memory for storing temperature and oxygen calibration coefficients. See page 131 for details.

**USB-LS-450: $549**

*USB-FHS*

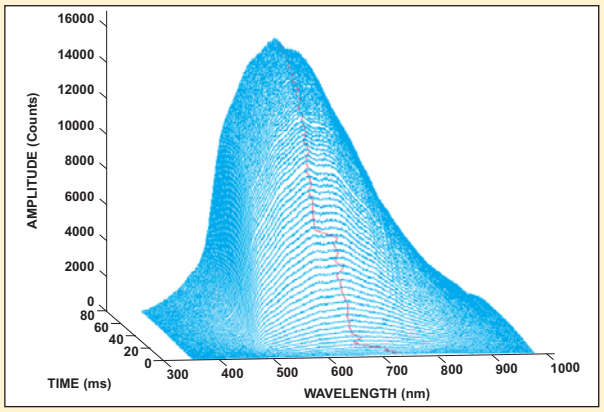
## USB-FHS Filter Holder System

The USB-FHS is a filter holder and violet LED-boosted tungsten light source for measuring filters and other samples up to 18-mm thick. The USB-FHS is optimized for 390-900 nm and attaches to the USB4000 via a mounting plate.

**USB-FHS: $499**

# HR2000+ High-speed Spectrometer

## Monitoring LS-1 Start-up Condition




*This power-up data for our LS-1 Tungsten Halogen Light Source was taken by an HR2000+ at 2-millisecond intervals. The graph shows the tremendous amount of data generated with the HR2000+'s acquisition rate speed of 1000 spectra per second.*

*In this setup, a DH2000 Deuterium Light Source provides light via optical fiber to a CUV-10 Cuvette Holder for 10-cm sample cells. A second optical fiber collects the light and sends it to the HR2000+.*

| Specifications | |
|---|---|
| PHYSICAL | |
| Dimensions: | 148.6 mm x 104.8 mm x 45.1 mm |
| Weight: | 570 g |
| DETECTOR | |
| Detector: | Sony ILX511 linear silicon CCD array (page 24) |
| Detector range: | 200-1100 nm |
| Pixels: | 2048 pixels, pixel size of 14 µm x 200 µm |
| Sensitivity: | 75 photons/count at 400 nm;<br>41 photons/count at 600 nm |
| OPTICAL BENCH | |
| Design: | f/4, Symmetrical crossed Czerny-Turner |
| Focal length: | 101.6 mm input, 101.6 mm output |
| Entrance aperture: | 5, 10, 25, 50, 100 or 200 µm wide slits (page 22) or fiber |
| Grating options: | 14 gratings, UV through Shortwave NIR (page 23) |
| Fiber optic connector: | SMA 905 to 0.22 numerical aperture single-strand fiber |
| SPECTROSCOPIC | |
| Wavelength range: | Grating dependent |
| Optical resolution: | ~0.035-6.8 nm FWHM |
| Signal-to-noise ratio: | 250:1 (at full signal) |
| Dark noise: | 12 RMS counts |
| Dynamic range: | 2 x $10^8$ (system); 1300:1 for a single acquisition |
| Integration time: | 1 ms to 20 seconds |
| ELECTRONICS | |
| Power consumption: | 450 mA @ 5 VDC |
| Data transfer speed: | Full spectrum to memory every 1 ms with USB 2.0 port,<br>15 ms with USB 1.1 port, 200 ms with serial port |
| Inputs/Outputs: | Yes, 10 onboard digital user-programmable GPIOs* |
| Analog channels: | One 13-bit analog input, one 9-bit analog output |
| COMPUTER | |
| Operating systems: | Windows 98/Me/2000/XP, Mac OS X and Linux with<br>USB port; any 32-bit Windows OS with serial port |
| Computer interfaces: | USB 2.0 @ 480 Mbps; RS-232 (2-wire) @ 115.2 K baud |
| Peripheral interfaces: | SPI (3-Wire), $I^2C$ inter-integrated circuit |

** Programming the GPIOs requires SpectraSuite, OmniDriver or one of our other device drivers. See pages 80-82 for details.*

### Dynamic Electronics Enhances Control

The HR2000+ Spectrometer integrates a powerful analog-to-digital (A/D) converter, programmable electronics and a high-resolution optical bench. This innovative combination produces our fastest spectrometer yet and provides resolution to 0.035 nm (FWHM).

### 1,000 Full Spectra/Second

The HR2000+ utilizes an onboard, 2-MHz A/D converter, which allows you to capture and transfer one full spectrum into memory every millisecond when the spectrometer is interfaced to a PC via the USB port.

### Programmable Microcontroller

The HR2000+ has an onboard programmable microcontroller that provides flexibility in controlling the spectrometer and accessories. Through a new 30-pin connector, you can implement all operating parameters in the software, such as controlling external light sources, creating processes and routines and retrieving data from external devices. The HR2000+ gives you access to 10 user-programmable digital I/Os for interfacing to other equipment; one analog input and one analog output; and a pulse generator for triggering other devices. (Programming the I/Os requires SpectraSuite Spectroscopy Operating Software.)

### "HR" Optical Bench

The HR2000+ is responsive from 200-1100 nm, but its specific range, resolution and sensitivity depend on your "HR" Optical Bench options. You select the grating, wavelength range, mirror coating, detector window and entrance aperture size. Choose from hundreds of accessories to create application-specific systems.


### High-resolution Applications

The HR2000+ is ideal for applications where fast reactions need to be monitored and high resolution is necessary, such as protein dynamics. For solution chemistry or color measurements, the USB4000 is more likely to fill your requirements.

### Plug-and-Play Operation

The HR2000+ interfaces to a PC, PLC or other embedded controllers via USB 2.0 or serial port. When connected to a PC via the USB port, the HR2000+ does not require an external power supply -- the spectrometer draws its power from the PC. When operating via the serial port, the HR2000+ requires a power supply (not included). Data unique to each spectrometer are programmed into a memory chip on the HR2000+; software reads these values for easy setup and hot swapping among PCs.

**HR2000+: $3,499**

# HR4000 High-resolution Spectrometer

## 0.02 nm Optical Resolution (FWHM) Possible

The HR4000 Spectrometer is our next-generation high-resolution spectrometer. The HR4000 has a 3648-element CCD-array detector from Toshiba that enables optical resolution as precise as 0.02 nm (FWHM). The HR4000 is responsive from 200-1100 nm, but the specific range and resolution depend on your grating and entrance slit choices (see pages 22-24 for options). This novel combination of optics and electronics is ideal for applications such as characterizing lasers, measuring gas absorbance, and determining atomic emission lines.

## Electronic Shutter Prevents Saturation

Integration Time is a setting in our software that is specified by the user. It's analogous to the shutter speed of a camera: the value specified for the integration time is the amount of time the detector "looks" at the incoming photons. Because the Toshiba detector has an electronic shutter, you can specify, via software, minimum integration times as short as 3.8 milliseconds, which allow you to measure transient events like laser pulses. Also, the ability to integrate the spectrometer for short durations eliminates saturation problems that can occur in high light-level applications such as laser analysis.

*One popular application for the HR4000 is laser analysis. A typical setup may look something like this: a laser's beam is directed into the FOIS-1 Integrating Sphere. An optical fiber collects the light and sends it to the HR4000.*

## Onboard Microcontroller

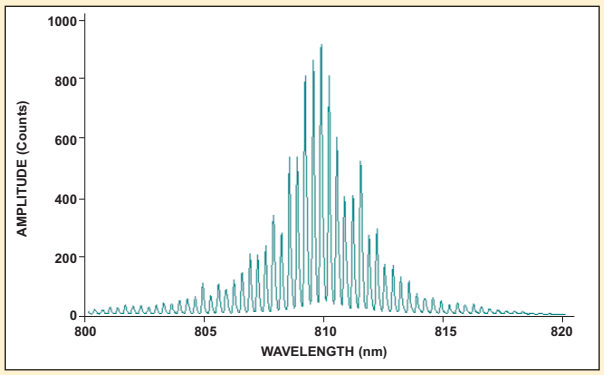
The HR4000's onboard microcontroller provides you with considerable flexibility in controlling the spectrometer and accessories. Through a 30-pin connector, you can implement all operating parameters in the software: control light sources, create processes, and retrieve information on external objects. You have access to 10 user-programmable digital inputs/outputs for interfacing to other equipment; one analog input and one analog output; and a pulse generator for triggering other devices. (Programming the GPIOs requires SpectraSuite, OmniDriver or one of our other device drivers. See pages 80-82 for details.)

## Plug-and-Play USB Operation

The HR4000 interfaces to a PC, PLC or other embedded controllers via USB 2.0 or RS-232 serial port. When using the serial port, the HR4000 requires a single 5-volt power supply (not included). Data unique to each spectrometer are programmed into a memory chip on the HR4000; our spectrometer operating software reads these values for easy setup and hot swapping among PCs.

**HR4000: $3,999**

## Sample Spectrum of Laser




*We acquired this spectrum of a 810-nm Multimode Diode Laser with an HR4000, Grating H11 and a 5-µm slit.*

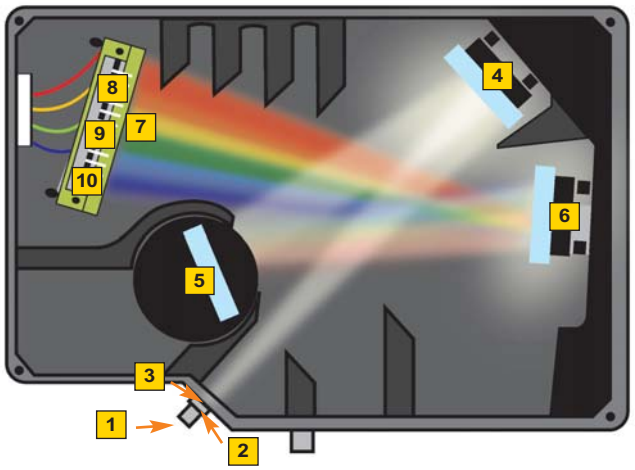
| Specifications | |
|---|---|
| PHYSICAL | |
| Dimensions: | 148.6 mm x 104.8 mm x 45.1 mm |
| Weight: | 570 g |
| DETECTOR | |
| Detector: | Toshiba TCD1304AP linear CCD array (page 24) |
| Detector range: | 200-1100 nm |
| Pixels: | 3648 pixels, pixel size of 8 µm x 200 µm |
| Pixel well depth: | ~100,000 electrons |
| Sensitivity: | 130 photons/count at 400 nm; 60 photons/count at 600 nm |
| OPTICAL BENCH | |
| Design: | f/4, Symmetrical crossed Czerny-Turner |
| Focal length: | 101.6 mm input, 101.6 mm output |
| Entrance aperture: | 5, 10, 25, 50, 100 or 200 µm wide slits (page 22) or fiber |
| Grating options: | 14 gratings, UV through Shortwave NIR (page 23) |
| Order-sorting filters: | longpass OF-1 filters and OFLV-200-1100 (page 24) |
| Fiber optic connector: | SMA 905 to 0.22 numerical aperture single-strand fiber |
| SPECTROSCOPIC | |
| Wavelength range: | Grating dependent |
| Optical resolution: | ~0.02-8.4 nm FWHM |
| Signal-to-noise ratio: | 300:1 (at full signal) |
| Dark noise: | 12 RMS counts |
| Dynamic range: | 2 x $10^8$ (system); 1300:1 for a single acquisition |
| Integration time: | 3.8 ms to 10 seconds |
| ELECTRONICS | |
| Power consumption: | 450 mA @ 5 VDC |
| Data transfer speed: | Full spectrum to memory every 4 ms with USB 2.0 port, 18 ms with USB 1.1 port |
| Inputs/Outputs: | Yes, 10 onboard digital user-programmable GPIOs |
| Analog channels: | One 13-bit analog input, One 9-bit analog output |
| COMPUTER | |
| Operating systems: | Windows 98/Me/2000/XP, Mac OS X and Linux with USB port; any 32-bit Windows OS using serial port* |
| Computer interfaces: | USB 2.0 @ 480 Mbps; RS-232 (2-wire) @ 115.2 K baud |
| Peripheral interfaces: | SPI (3-Wire), $I^2C$ inter-integrated circuit |

** You cannot use SpectraSuite if you're interfacing an HR4000 to a PC via RS-232. A Command Set is included for writing your own software.*

# Options for the "HR" Optical Bench

Below is a diagram of the "HR" Optical Bench used in HR2000+ and HR4000 High-resolution Spectrometers. It shows how light moves through the symmetrical crossed Czerny-Turner design of the bench. All components in the bench are fixed in place during manufacturing. Not only do you have detector choices with the "HR" bench, you also have a whole host of other options when configuring your High-resolution Spectrometer. You can choose various entrance aperture sizes, detector accessories, filters, gratings and more to optimize your spectrometer.

## Components of the "HR" Optical Bench




**1 SMA 905 Connector**
Light from a fiber enters the optical bench through the SMA 905 Connector. The SMA 905 bulkhead provides a precise locus for the end of the optical fiber, fixed slit, absorbance filter and fiber clad mode aperture.

**2 Fixed Entrance Slit: specify slit size**
Light passes through the installed slit, which acts as the entrance aperture. Slits are available in widths from 5 µm to 200 µm. Each is permanently fixed to the SMA 905 bulkhead. (Without a slit, a fiber acts as the entrance aperture.)

**3 Longpass Absorbance Filter: optional**
If selected, an absorbance filter is installed between the slit and the clad mode aperture in the SMA 905 bulkhead. The filter is used to block second- and third-order effects or to balance color.

**4 Collimating Mirror: specify standard or SAG+**
The collimating mirror is matched to the 0.22 numerical aperture of our optical fiber. Light reflects from this mirror, as a collimated beam, toward the grating. You can opt to install a standard mirror or a UV absorbing SAG+ mirror.

**5 Grating & Wavelength Range: specify grating & starting wavelength**
We install the grating on a platform that we then rotate to select the starting wavelength you've specified. Then we permanently fix the grating in place to eliminate mechanical shifts or drift.

**6 Focusing Mirror: specify standard or SAG+**
This mirror focuses first-order spectra on the detector plane. Both the collimating and focusing mirrors are made in-house to guarantee the highest reflectance and the lowest stray light possible. You can opt for a standard mirror or SAG+ mirror.

**7 L2 and L4 Detector Collection Lenses: optional**
This cylindrical lens, made in-house to ensure aberration-free performance, is fixed to the detector to focus the light from the tall slit onto the shorter detector elements. It increases light-collection efficiency.

**8 Detector: specify Sony or Toshiba detector**
We offer two detectors for the "HR" Bench; both are linear CCD arrays. Each pixel responds to the wavelength of light that strikes it. Electronics bring the complete spectrum to the software.

**9 OFLV Variable Longpass Order-sorting Filter: optional**
Our proprietary filters precisely block second- and third-order light from reaching specific detector elements.

**10 UV2 and UV4 Detector Upgrades: optional**
When selected, the detector's standard BK7 window is replaced with a quartz window to enhance the performance of the spectrometer for applications <340 nm.

## 1 SMA 905 Connector

A precision SMA 905 Connector aligns to the spectrometer's entrance slit and ensures concentricity of the fiber. For an upgrade fee that includes the cost of the custom connector and labor, we will replace the standard SMA 905 Connector with a different connector of your choice. We also offer connector adapters, such as an SMA-to-ST Adapter and an SMA-to-FC Adapter. Please call for details on connectors and adapters.

## 2 Fixed Entrance Slit

Another option available with "HR" User-configured Spectrometers is selecting the size of the entrance aperture. Entrance slits are rectangular apertures, 1-mm tall and various widths from 5 µm to 200 µm, with the width determining the amount of light entering the bench. A slit is fixed in place. Note that the smallest slit achieves the best optical resolution.

*A slit is installed on the inside edge of the bulkhead of an SMA 905 Connector.*

| Slit | Description | HR2000+ Pixel Resolution | HR4000 Pixel Resolution | Price |
|---|---|---|---|---|
| SLIT-5 | 5-µm wide x 1-mm high | 1.5 pixels | 2.0 pixels | $150 |
| SLIT-10 | 10-µm wide x 1-mm high | 2.0 pixels | 3.7 pixels | $150 |
| SLIT-25 | 25-µm wide x 1-mm high | 2.5 pixels | 4.4 pixels | $150 |
| SLIT-50 | 50-µm wide x 1-mm high | 4.2 pixels | 7.4 pixels | $150 |
| SLIT-100 | 100-µm wide x 1-mm high | 8.0 pixels | 14.0 pixels | $150 |
| SLIT-200 | 200-µm wide x 1-mm high | 15.3 pixels | 26.8 pixels | $150 |

# Options for the "HR" Optical Bench

## 3 Longpass Absorbing Filters

We offer longpass absorbing or blocking filters; each filter has a transmission band and a blocking band to restrict radiation to a certain wavelength region for eliminating second- and third-order effects. These filters are installed permanently between the slit and the clad mode aperture in the bulkhead of the SMA 905 Connector.

| Item | Description | Price |
|---|---|---|
| OF1-WG305 | Longpass filter; transmits light >305 nm | $50 |
| OF1-GG375 | Longpass filter; transmits light >375 nm | $50 |
| OF1-GG475 | Longpass filter; transmits light >475 nm | $50 |
| OF1-OG515 | Longpass filter; transmits light >515 nm | $50 |
| OF1-OG550 | Longpass filter; transmits light >550 nm | $50 |
| OF1-OG590 | Longpass filter; transmits light >590 nm | $50 |

## 4 & 6 Collimating & Focusing Mirrors

Another bench option is to replace the standard aluminum-coated reflective mirrors with our proprietary, UV-absorbing SAG+ Mirrors, which increase reflectance in the VIS-NIR and, in turn, increase the sensitivity of the spectrometer. SAG+ Mirrors are often specified for fluorescence. These mirrors also absorb nearly all UV light, which reduces the effects of excitation scattering in fluorescence measurements. Unlike most silver-coated mirrors, the SAG+ mirrors won't oxidize. See page 16 for a spectral graph illustrating SAG+ reflectivity.

SAG+UPG-HR: $250

## 5 Choosing a Grating & Wavelength Range

### Wide Selection Allows Flexibility

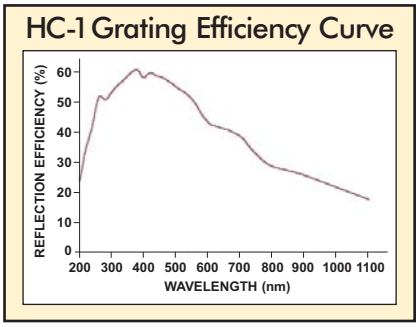
You choose from among 14 gratings for each spectrometer. With each grating, you consider its groove density (which helps determine the resolution), its spectral range (which helps determine the wavelength range) and its blaze wavelength (which helps determine the most efficient range). Our gratings are permanently fixed in place at the time of manufacture to ensure long-term performance and stability. We offer ruled and holographic diffraction gratings. Both are polymer replicas of master gratings. There are trade-offs between these gratings: holographic gratings produce less stray light while ruled gratings are more reflective, resulting in higher sensitivity.

| Grating Number | Intended Use | Groove Density | Spectral Range | Blaze Wavelength | Best Efficiency (>30%) |
|---|---|---|---|---|---|
| HC1* | UV-NIR | 300 | 200-1100 nm | variable | 200-1100 nm |
| H1 | UV | 600 | 425-445 nm | 300 nm | 200-575 nm |
| H2 | UV-VIS | 600 | 415-445 nm | 400 nm | 250-800 nm |
| H3 | VIS-Color | 600 | 410-440 nm | 500 nm | 350-850 nm |
| H4 | NIR | 600 | 410-430 nm | 750 nm | 530-1100 nm |
| H5 | UV-VIS | 1200 | 205-220 nm | holographic: UV | 200-400 nm |
| H6 | NIR | 1200 | 140-195 nm | 750 nm | 500-1100 nm |
| H7 | UV-VIS | 2400 | 72-102 nm | holographic: UV | 200-500 nm |
| H9 | VIS-NIR | 1200 | 165-205 nm | holographic: VIS | 400-800 nm |
| H10 | UV-VIS | 1800 | 95-140 nm | holographic: UV | 200-635 nm |
| H11 | UV-VIS | 1800 | 75-135 nm | holographic: VIS | 320-800 nm |
| H12 | UV-VIS | 2400 | 60-100 nm | holographic: VIS | 250-575 nm |
| H13 | UV-VIS-NIR | 300 | 900 nm | 500 nm | 300-1100 nm |
| H14 | NIR | 600 | 410-420 nm | 1000 nm | 650-1100 nm |

### Grating Selection Chart

- The **Groove Density** ($mm^{-1}$) of a grating determines its dispersion, while the angle of the groove determines the most efficient region of the spectrum. The greater the groove density, the better the optical resolution possible, but the more truncated the spectral range.
- The **Spectral Range** is the dispersion of the grating across the linear array. The spectral range (bandwidth) is a function of the groove density and does not change. When you choose a starting wavelength for a spectrometer, you add its spectral range to the starting wavelength to determine the wavelength range.
- For ruled gratings, the **Blaze Wavelength** is the peak wavelength in an efficiency curve. For holographic gratings, it is the most efficient wavelength region.
- The **Best Efficiency** region is the range where efficiency is >30%. In some cases, gratings have a greater spectral range than is efficiently diffracted. For example, Grating #1 has a 650 nm spectral range, but is most efficient from 200-575 nm. In this case, wavelengths >575 nm will have lower intensity due to the the grating's reduced efficiency.

Grating Efficiency Curves for the "HR" bench are the same as those for the USB (see page 18) except for the HC-1 Grating; its curve is shown here. All gratings are free with the purchase of a spectrometer, except for the HC-1, which is $600.



# Options for the "HR" Optical Bench

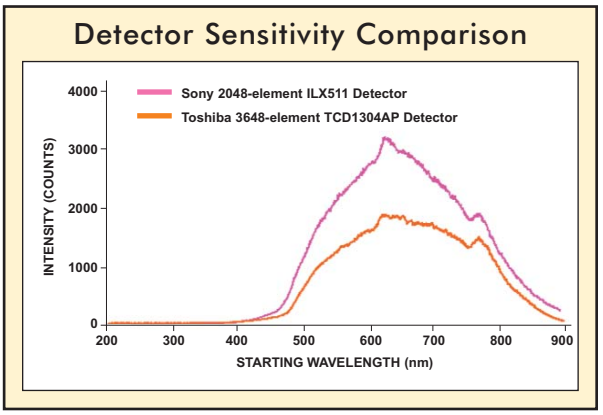
## 7 L2 or L4 Detector Collection Lens

The cylindrical L2 and L4 Detector Collection Lenses -- made in-house to ensure aberration-free performance -- are fixed to a detector's window to focus the light from the tall slit onto the shorter detector elements. They increase light-collection efficiency and reduce stray light. They are also useful with a large-diameter fiber for low light-level applications. Use the L2 with the Sony detector and the L4 with the Toshiba detector.

**L2 or L4 Detector Collection Lens: $150**

## 8 Detector: 2048-element or 3648-element Linear CCD Array

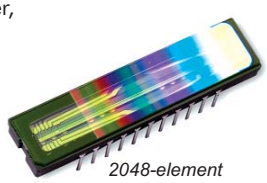
The HR2000+ utilizes the Sony ILX511 linear silicon CCD array detector. Our next-generation HR4000 High-resolution Spectrometer utilizes the Toshiba TCD1304AP linear CCD array detector, which has some electronic advances over the Sony, such as a user-programmable microcontroller. Both are linear silicon CCD arrays, with an effective range of 200-1100 nm, and with the same dynamic range (1300:1).




There are some differences between the detectors. For example, the Toshiba detector achieves better optical resolution (see the facing page for details). Also, since the Toshiba's pixels are only 8 µm wide instead of 14 µm wide, the sensitivity for a Toshiba pixel seems to be ~60% (8 µm/14 µm) that of a Sony pixel (see graph at right). However, on a per-unit area basis, the sensitivity is about the same since the Toshiba has 3648 pixels compared with the Sony's 2048; the total signal is the same. Because the Toshiba detector has an electronic shutter, you can almost never have too much light; the shutter prevents the detector from saturating, making possible analysis of transient events such as laser pulses.

**Specifications**

| | Sony ILX511 linear silicon CCD array | Toshiba TCD1304AP linear CCD array |
|---|---|---|
| Detector range: | 200-1100 nm | 200-1100 nm |
| Pixels: | 2048 pixels | 3648 pixels |
| Pixel size: | 14 µm x 200 µm | 8 µm x 200 µm |
| Pixel well depth: | ~62,500 electrons | ~100,000 electrons |
| Maximum pixel rate: | Rate at which pixels are digitized is 2 MHz | Rate at which pixels are digitized is 1 MHz |



*2048-element Sony Detector*

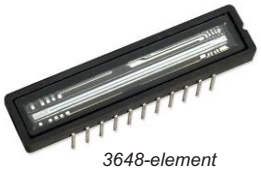
*3648-element Toshiba Detector with L4 Collection Lens*

## 9 Detector with OFLV Filter:

Our OFLV Variable Longpass Order-sorting Filters are applied to the detector's window to eliminate second- and third-order effects. We use patented coating technology to apply the filter onto the substrate. In fact, we are the only miniature spectrometer manufacturer to offer "clean" first-order spectra.

## 10 Detector with UV2 or UV4 Detector Window Upgrade

When you specify a detector with a UV2 or UV4 Detector Window Upgrade, we replace the detector's standard BK7 window with a quartz window to enhance the spectrometer's performance from 200-340 nm.



*3648-element Toshiba Detector*

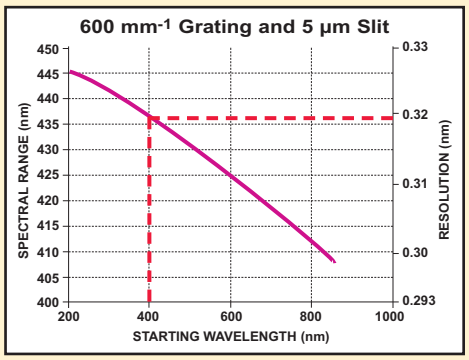
| Item | Description | Spectrometer | Price |
|---|---|---|---|
| DET4-VIS | Toshiba TCD1304AP Detector installed into a HR4000 User-Configured Spectrometer; best for systems with wavelength ranges above 400 nm | HR4000 | Free |
| DET4-UV | Toshiba TCD1304AP Detector with UV4 Detector Window Upgrade installed into a HR4000 User Configured Spectrometer; best for systems with wavelength ranges in the UV | HR4000 | $150 |
| DET4-200-1100 | Toshiba TCD1304AP Detector with OFLV-200-1100 Variable Longpass Order-sorting Filter and UV4 Detector Window Upgrade installed into a HR4000 User-configured Spectrometer; used with HC1 Grating ($600) | HR4000 | $400 |
| DET2-VIS | Sony ILX511 Detector installed into an HR2000+ User-Configured Spectrometer; best for systems with wavelength ranges above 400 nm | HR2000+ | Free |
| DET2-UV | Sony ILX511 Detector with UV2 Detector Window Upgrade installed into an HR2000+ User-Configured Spectrometer; best for systems with wavelength ranges in the UV | HR2000+ | $150 |

# Options for the "HR" Optical Bench

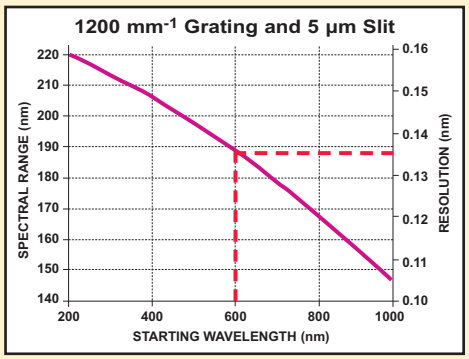
## Predicted Ranges & Resolution

These graphs demonstrate the range and resolution of your "HR" Bench Spectrometer with a 5 µm slit. See our website for additional graphs of ranges and resolutions for every slit size.

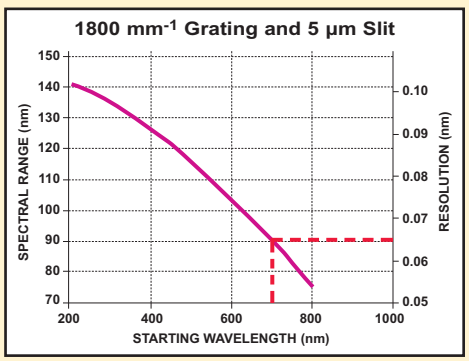
### "HR" Bench with Sony Detector: HR2000+



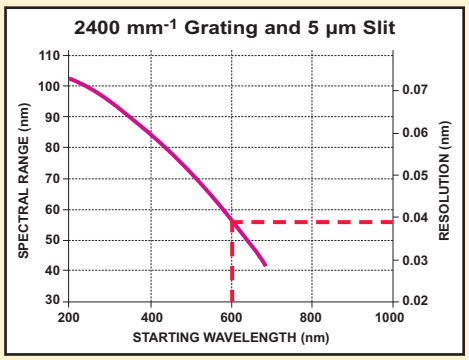

***Example:*** *If the starting wavelength is 400 nm, then the range is ~437 nm, providing a 400-837 nm wavelength range and 0.32 nm resolution.*




***Example:*** *If the starting wavelength is 600 nm, then the range is ~188 nm, providing a 600-788 nm wavelength range and 0.137 nm resolution.*

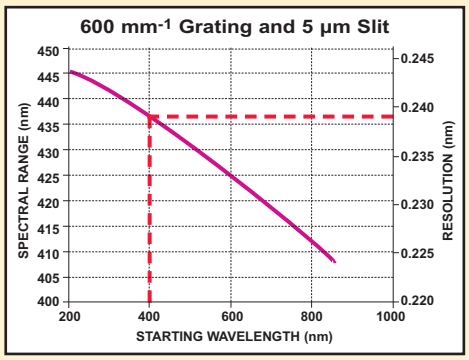



***Example:*** *If the starting wavelength is 700 nm, then the range is ~90 nm, providing a 700-790 nm wavelength range and 0.065 nm resolution.*

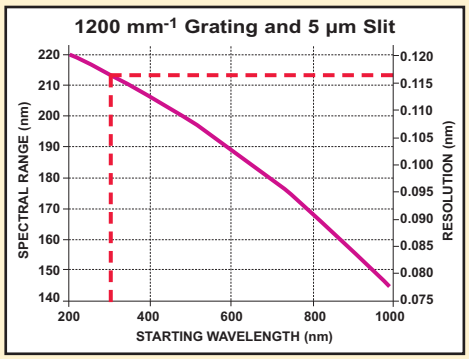



***Example:*** *If the starting wavelength is 600 nm, then the range is ~56 nm, providing a 600-656 nm wavelength range and 0.039 nm resolution.*

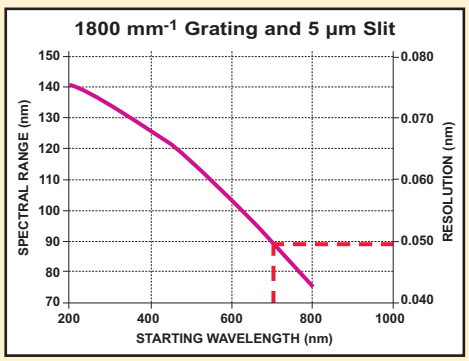
### "HR" Bench with Toshiba Detector: HR4000



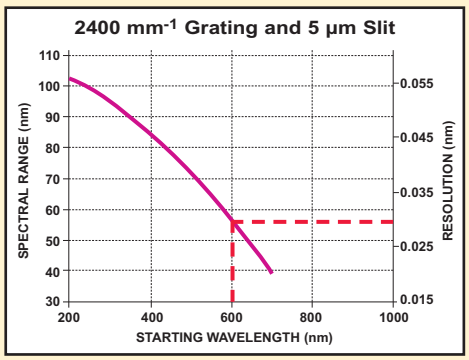

***Example:*** *If the starting wavelength is 400 nm, then the range is ~437 nm, providing a 400-837 nm wavelength range and 0.239 nm resolution.*




***Example:*** *If the starting wavelength is 300 nm, then the range is ~215 nm, providing a 300-515 nm wavelength range and 0.117 nm resolution.*

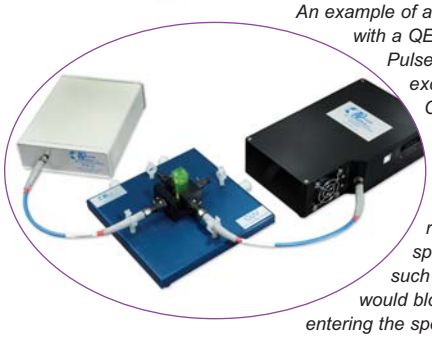



***Example:*** *If the starting wavelength is 700 nm, then the range is ~90 nm, providing a 700-790 nm wavelength range and 0.05 nm resolution.*




***Example:*** *If the starting wavelength is 600 nm, then the range is ~56 nm, providing a 600-656 nm wavelength range and 0.029 nm resolution.*

# QE65000 Scientific-grade Spectrometer



*An example of a fluorescence setup with a QE65000 uses the PX-2 Pulsed Xenon Lamp as an excitation source and the CUV-ALL Cuvette Holder for samples. An optical fiber delivers excitation light to the sample holder and read light to the spectrometer. A filter, such as one of our LVFs, would block excitation light from entering the spectrometer*

| Specifications | |
|---|---|
| PHYSICAL | |
| Dimensions (in mm): | 182 x 110 x 47 |
| Weight: | 1.18 kg (without power supply) |
| DETECTOR | |
| Detector: | Hamamatsu S7031-1006 back-thinned FFT-CCD |
| Detector range: | 200-1100 nm |
| Pixels: | 1024 x 58 (1044 x 64 total); 24.6 µm square size |
| Pixel well depth: | 300,000 electrons/well ~1.5 mill. electrons/column |
| Sensitivity: | 400 nm: 22 electrons/count, 250 nm: 26 photons/count |
| OPTICAL BENCH | |
| Design: | f/4, Symmetrical crossed Czerny-Turner |
| Focal length: | 101.6 mm input, 101.6 mm output |
| Entrance aperture: | 5, 10, 25, 50, 100, or 200 µm wide slits (page 27) |
| Grating options: | 14 gratings, UV through Shortwave NIR (page 28) |
| Fiber optic connector: | SMA 905 to 0.22 numerical aperture single-strand fiber |
| SPECTROSCOPIC | |
| Wavelength range: | Grating dependent |
| Optical resolution: | ~0.14-7.7 nm FWHM |
| Signal-to-noise ratio: | 1000:1 (at full signal) |
| Dark noise: | 2.5 RMS counts |
| Dynamic range: | 25000:1 a single acquisition; 7.5 x $10^9$ (system) |
| Integration time: | 8 milliseconds to 15 minutes |
| Stray light: | <0.08% at 600 nm, <0.4% at 435 nm |
| ELECTRONICS | |
| Power consumption: | 500 mA @ 5 VDC no TE cool;<br>3 A @ 5 VDC with TE cool |
| Data transfer speed: | Full spectrum to memory every 4 ms with USB 2.0 port, 8 ms with USB 1.1 port |
| Inputs/Outputs: | 10 onboard digital user-programmable GPIOs |
| TEMPERATURE & THERMOELECTRIC (TE) COOLING | |
| Temperature limits: | 0 °C to 50 °C for spectrometer, no condensation |
| Temperature range: | 13 °C maximum range between the high and low |
| Set point: | Software controlled |
| Lowest set point: | 40 °C below ambient, to -15 °C |
| Stability: | ±0.1 °C of set temperature in <2 minutes |
| COMPUTER | |
| Operating systems: | Windows 98/Me/2000/XP, Mac OS X and Linux when using the USB port; 32-bit Windows OS when using the serial port |
| Computer interfaces: | USB 2.0 @ 480 Mbps; RS-232 (2-wire) @ 115K baud |
| Peripheral interfaces: | SPI (3-wire); $I^2C$ inter-integrated circuit |

## New Scientific-grade Spectrometer

The QE65000 Spectrometer is a unique combination of detector and optical bench technologies that provides users with high spectral response and high optical resolution in one scientific-grade spectrometer package.

## Quantum Efficiency to 90%

The Hamamatsu FFT-CCD detector used in the QE65000 provides 90% quantum efficiency (defined as how efficiently a photon is converted to a photo-electron). Most of our other detectors are linear CCDs but with this "2D" area detector, we can bin a vertical row of pixels, which offers significant improvement in the signal-to-noise ratio and signal processing speed of the detector compared with a linear CCD, where signals are digitally added by an external circuit.

## Increased System Sensitivity

In our spectrometers with linear CCDs, the slit's width, not its height, regulates the amount of light entering the bench because linear CCDs cannot efficiently collect the light from the entire height of the slit. But in the QE65000, the 2D area detector can better take advantage of the height of the slit and the additional light, greatly improving system sensitivity.

## Back-thinned: Great for the UV

Because the detector in the QE65000 is back-thinned (or back-illuminated), it has great native response in the UV and does not require the additional coatings that we typically apply to other detectors for UV applications.

## Demanding Low Light-level Applications

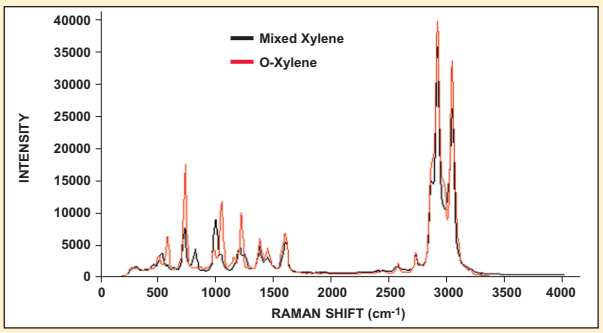
The QE65000 Spectrometer is a great option for low-light level applications such as fluorescence, Raman spectroscopy, DNA sequencing, astronomy and thin-film reflectivity. The TE-cooled (down to -15 °C) detector features low noise and low dark signal, which enables low-light-level detection and long integration times from 8 milliseconds to 15 minutes.

## Onboard Programming

The QE65000 also has an onboard programmable micro-controller for controlling the spectrometer and accessories. You have access to 10 user-programmable digital inputs/outputs and a pulse generator for triggering other devices.

**QE65000: $9,999**

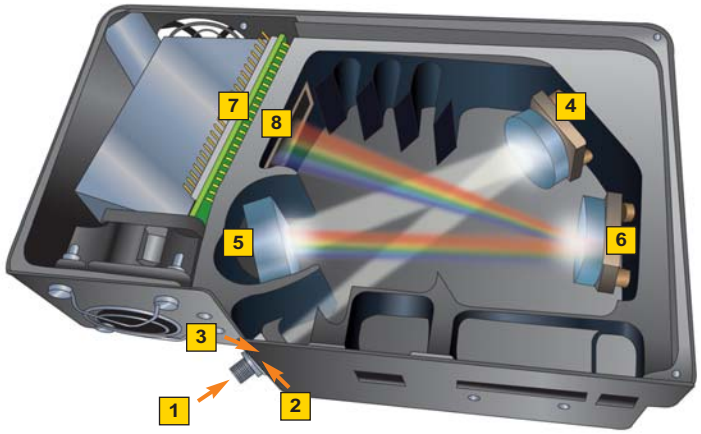
### Comparing Xylenes




*To acquire Raman spectra for xylene, we used a QE65000 with a 10 µm slit and Grating H14, plus a 532 nm laser and probe.*

# Options for the "QE" Optical Bench

## Components of the "QE" Optical Bench




**1 SMA 905 Connector**
Light from a fiber enters the optical bench through the SMA 905 Connector. The SMA 905 bulkhead provides a precise locus for the end of the optical fiber, fixed slit, absorbance filter and fiber clad mode aperture.

**2 Fixed Entrance Slit: specify slit size**
Light passes through the installed slit, which acts as the entrance aperture. Slits are available in widths from 5 µm to 200 µm. Each is permanently fixed to the SMA 905 bulkhead. (Without a slit, a fiber acts as the entrance aperture.)

**3 Longpass Absorbing Filter: optional**
If selected, an OF-1 absorbance filter is installed between the slit and the clad mode aperture in the SMA 905 bulkhead. The filter is used to block second- and third-order effects.

**4 Collimating Mirror: specify standard or SAG+**
The collimating mirror is matched to the 0.22 numerical aperture of our optical fiber. Light reflects from this mirror, as a collimated beam, toward the grating. Opt to install a standard mirror or a SAG+UPG-HR mirror.

**5 Grating: specify grating**
We install the grating on a platform that we then rotate to select the starting wavelength you've specified. Then we permanently fix the grating in place to eliminate mechanical shifts or drift.

**6 Focusing Mirror: specify standard or SAG+**
This mirror focuses first-order spectra on the detector plane and sends higher orders to light traps built into the optical bench. Both the collimating and focusing mirrors are made in-house to guarantee the highest reflectance and the lowest stray light possible. Opt for a standard mirror or a UV-absorbing SAG+UPG-HR mirror.

**7 Detector with TE cooling**
The TE-cooled, back-thinned, "2D" detector provides great signal processing speed, improved signal-to-noise ratio and great native response in the UV. It generates virtually no dark noise, allowing for long integration times.

**8 OFLV Filters: optional**
Our proprietary filters precisely block second- and third-order light from reaching specific detector elements.

## 1 SMA 905 Connector

A precision SMA 905 Connector aligns to the spectrometer's entrance slit and ensures concentricity of the fiber. For an upgrade fee that includes the cost of a another connector and labor, we will replace the standard SMA 905 Connector with a different connector of your choice.

## 2 Fixed Entrance Slit

One option available with the user-configured QE65000 Spectrometer is the size of the entrance aperture, with the width determining the amount of light entering the bench. A slit is fixed in place; it only can be changed by our technicians.

| Slit | Description | Pixel Resolution | Price |
|---|---|---|---|
| SLIT-5 | 5-µm wide x 1-mm high | ~2.0 pixels | $150 |
| SLIT-10 | 10-µm wide x 1-mm high | ~2.2 pixels | $150 |
| SLIT-25 | 25-µm wide x 1-mm high | ~2.6 pixels | $150 |
| SLIT-50 | 50-µm wide x 1-mm high | ~3.3 pixels | $150 |
| SLIT-100 | 100-µm wide x 1-mm high | ~4.7 pixels | $150 |
| SLIT-200 | 200-µm wide x 1-mm high | ~8.9 pixels | $150 |

## 3 Longpass Absorbing Filters

We offer longpass absorbing or blocking filters; each filter has a transmission band and a blocking band to restrict radiation to a certain wavelength region for eliminating second- and third-order effects. These filters are installed permanently between the slit and the clad mode aperture in the bulkhead of the SMA 905 Connector.

| Item | Description | Price |
|---|---|---|
| OF1-WG305 | Longpass filter; transmits light >305 nm | $50 |
| OF1-GG375 | Longpass filter; transmits light >375 nm | $50 |
| OF1-GG475 | Longpass filter; transmits light >475 nm | $50 |
| OF1-OG515 | Longpass filter; transmits light >515 nm | $50 |
| OF1-OG550 | Longpass filter; transmits light >550 nm | $50 |
| OF1-OG590 | Longpass filter; transmits light >590 nm | $50 |

## 4 & 6 Collimating & Focusing Mirrors

Another bench option is to replace the standard aluminum-coated reflective mirrors with our proprietary, UV-absorbing SAG+ Mirrors, which increase reflectance in the VIS-NIR and, in turn, increase the sensitivity of the spectrometer. SAG+ Mirrors are often specified for fluorescence. These mirrors also absorb nearly all UV light, which reduces the effects of excitation scattering in fluorescence measurements. Unlike most silver-coated mirrors, the SAG+ mirrors won't oxidize. See page 16 for a spectral graph illustrating SAG+ reflectivity.

SAG+UPG-HR: $250

# Options for the "QE" Optical Bench

## 5 Choosing a Grating & Wavelength Range

You choose from among 14 gratings for each spectrometer. With each grating, you consider its groove density (which helps determine the resolution), its spectral range (which helps determine the wavelength range) and its blaze wavelength (which helps determine the most efficient range).

- The **Groove Density** ($mm^{-1}$) of a grating determines its dispersion, while the angle of the groove determines the most efficient region of the spectrum. The greater the groove density, the better the optical resolution possible, but the more truncated the spectral range.
- The **Spectral Range** is the dispersion of the grating across the linear array. The spectral range (bandwidth) is a function of the groove density and does not change. When you choose a starting wavelength for a spectrometer, you add its spectral range to the starting wavelength to determine the wavelength range.
- For ruled gratings, the **Blaze Wavelength** is the peak wavelength in an efficiency curve. For holographic gratings, it is the most efficient wavelength region.
- The **Best Efficiency** region is the range where efficiency is >30%. In some cases, gratings have a greater spectral range than is efficiently diffracted. For example, Grating #1 has a 650 nm spectral range, but is most efficient from 200-575 nm so wavelengths >575 nm will have lower intensity.

Grating Efficiency Curves are on the next page. (The HC-1 curve is on page 23.) All gratings are free with the purchase of a spectrometer, except for the HC1-QE, which is $600.

| Grating Number | Intended Use | Groove Density | Spectral Range | Blaze Wavelength | Best Efficiency (>30%) |
|---|---|---|---|---|---|
| HC1-QE | UV-NIR | 300 | 200-950 nm | variable | 200-950 nm |
| H1 | UV | 600 | 373-390 nm | 300 nm | 200-575 nm |
| H2 | UV-VIS | 600 | 365-390 nm | 400 nm | 250-800 nm |
| H3 | VIS-Color | 600 | 360-386 nm | 500 nm | 350-850 nm |
| H4 | NIR | 600 | 360-377 nm | 750 nm | 530-1100 nm |
| H5 | UV-VIS | 1200 | 180-193 nm | holographic: UV | 200-400 nm |
| H6 | NIR | 1200 | 123-170 nm | 750 nm | 500-1100 nm |
| H7 | UV-VIS | 2400 | 63-90 nm | holographic: UV | 200-500 nm |
| H9 | VIS-NIR | 1200 | 145-180 nm | holographic: VIS | 400-800 nm |
| H10 | UV-VIS | 1800 | 83-123 nm | holographic: UV | 200-635 nm |
| H11 | UV-VIS | 1800 | 66-120 nm | holographic: VIS | 320-800 nm |
| H12 | UV-VIS | 2400 | 52-88 nm | holographic: VIS | 250-575 nm |
| H13 | UV-VIS-NIR | 300 | 790 nm | 500 nm | 300-1100 nm |
| H14 | NIR | 600 | 360-370 nm | 1000 nm | 650-1100 nm |

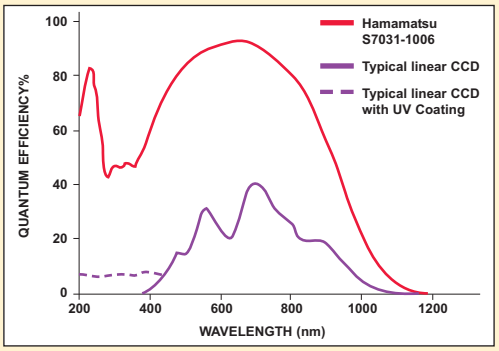
## 7 Back-thinned Area Detector

The QE65000's Hamamatsu S7031-1006 FFT-CCD area detector provides 90% quantum efficiency (defined as how efficiently a photon is converted to a photoelectron). The TE-cooled detector features low noise and low dark signal, which enables low-light-level detection and long integration times, thus achieving a wide dynamic range.


The S7031 is a 2D array, which allows us to bin pixels in a vertical column to acquire light from the entire height of the spectrometer's slit image. This improves light collection and signal-to-noise significantly. Because the detector is back-thinned (or back-illuminated), it has great native response in the UV and does not require the UV detector upgrade that we apply to other detectors.

In our spectrometers with linear CCDs, the slit's width, not its height, regulates the amount of light entering the bench because linear CCDs cannot efficiently collect the light from the entire height of the slit. But in the QE65000, the 2D area detector can better take advantage of the height of the entrance slit and the additional light, greatly improving system sensitivity.

### Detector Quantum Efficiency




| Detector Specifications | |
|---|---|
| Detector: | Hamamatsu S7031-1006 area CCD |
| Detector range: | 200-1100 nm |
| Pixels: | 1024 x 58 (1044 x 64 total); 24.6 µm square size |
| Pixel area: | active area: 24.576 mm x 1.392 mm |
| Pixel well depth: | 300,000 electrons/well;<br>~1.5 million electrons/column sum well |
| Sensitivity: | 400 nm: 22 electrons/count;<br>250 nm: 26 photons/count |
| Dark current: | 4000 $e^-$/pixel/sec @ 25 °C; 200 $e^-$/pixel/sec @ 0 °C |

## 8 Detector with OFLV Filter

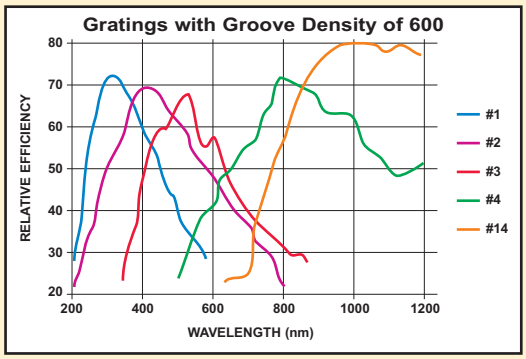
The OFLV-QE is one of our Variable Longpass Order-sorting Filters used to eliminate second-order effects and is used with an HC-1 Grating in a 200-950 nm wavelength range system in a QE65000. We use patented coating technology to apply the filter onto the substrate of the detector's window.

**OFLV-QE: $250**

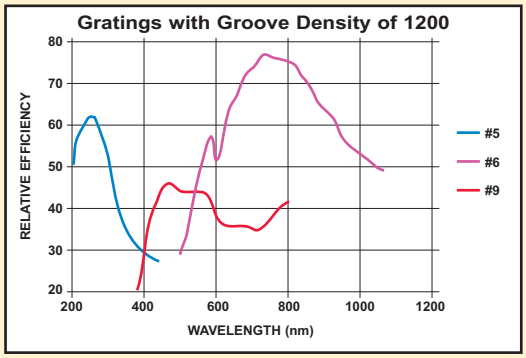
# Options for the "QE" Optical Bench

## Grating Efficiency Curves

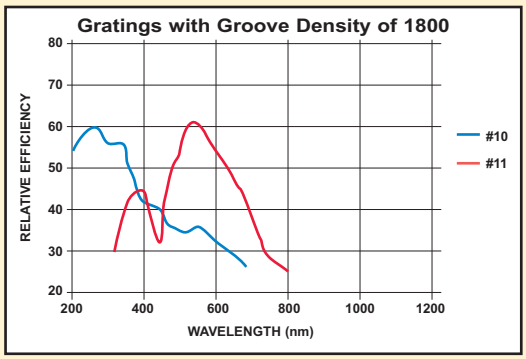
Below are the Grating Efficiency Curves for gratings with groove densities of 600, 1200, 1800 and 2400 $mm^{-1}$. See curves for all of our gratings at our website.



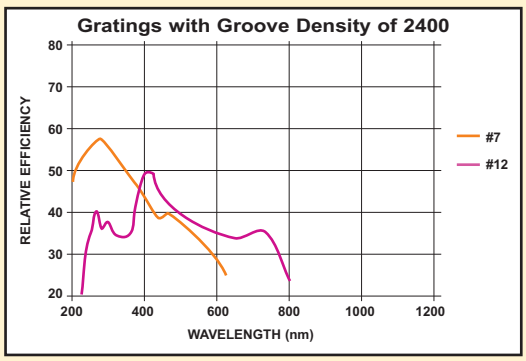

*Efficiency Curves for Gratings 1, 2, 3, 4 and 14.*




*Efficiency Curves for Gratings 5, 6 and 9.*



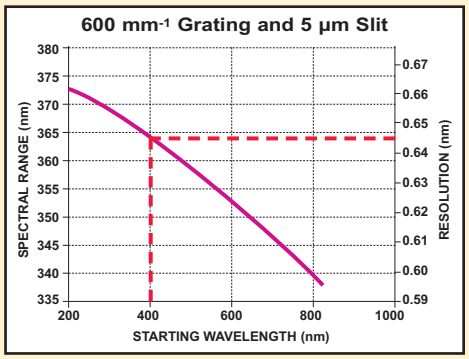

*Efficiency Curves for Gratings 10 and 11.*



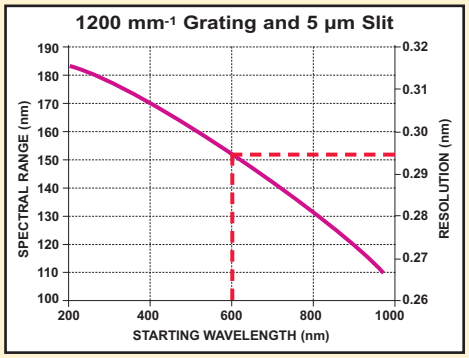

*Efficiency Curves for Gratings 7 and 12.*

## Predicted Ranges & Resolution

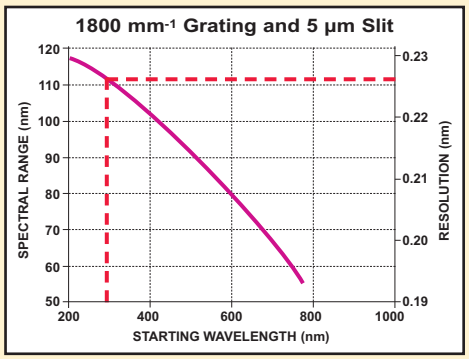
These graphs demonstrate the range and resolution of your "QE" Bench Spectrometer with a 5 µm slit. See our website for more graphs of ranges and resolutions for every slit size.



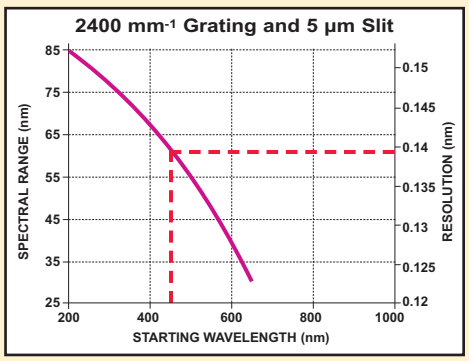

***Example:*** *If the starting wavelength is 400 nm, then the range is ~364 nm, providing a 400-764 nm wavelength range and 0.645 nm resolution.*




***Example:*** *If the starting wavelength is 600 nm, then the range is ~152 nm, providing a 600-752 nm wavelength range and 0.295 nm resolution.*




***Example:*** *If the starting wavelength is 300 nm, then the range is ~112 nm, providing a 300-412 nm wavelength range and 0.226 nm resolution.*




***Example:*** *If the starting wavelength is 450 nm, then the range is ~62 nm, providing a 450-512 nm wavelength range and 0.139 nm resolution.*

# NIR-series Near-infrared Spectrometers

## 3 Wavelength-Range Options

Our NIR-series Near-infrared Spectrometers provide full spectral analysis in real time and meet a wide variety of measurement needs. Three different NIR systems provide you with multiple wavelength ranges for measuring sugar, alcohol, moisture, fats and more. These small-footprint, plug-and-play systems provide a full spectrum in one millisecond, and offer optical resolution as low as 3.0 nm FWHM.

## InGaAs Detector Cooled for Optimum Signal-to-Noise and Sensitivity

The NIR-series Spectrometers each feature a Hamamatsu InGaAs linear-array detector with onboard thermoelectric cooling. A thermistor monitors the array's temperature and a thermoelectric device can cool each array to 30 °C below ambient, keeping the array stable to within ±0.1 °C. You can set and monitor the detector's temperature via software.

## NIR512 Spectrometer: 900-1700 nm

The NIR-512 Spectrometer features a 512-element InGaAs linear-array detector. With the NIR-512, the only diffractive grating available is Grating N1, and it provides a 900-1700 nm wavelength range, producing an optical resolution of <5.0 nm FWHM.

## NIR256-2.1 Spectrometer: 1200-2100 nm or 900-2100 nm

The NIR256-2.1 Spectrometer uses a 256-element InGaAs linear-array detector. With the NIR256 you have two grating options. With Grating N1, you have a 1200-2100 nm wavelength range. Grating N2 provides a 900-2100 nm wavelength range.

## NIR256-2.5 Spectrometer: 900-2500 nm

The NIR256-2.5 Spectrometer extends farther into the NIR, acquiring real-time spectra up to 2.5 µm. With the NIR256-2.5, you select Grating N2, which provides a wavelength range of 900-2500 nm.

## Plug-and-Play USB Operation

All of the NIR-series Spectrometers interface to PCs via USB 2.0. When operating the spectrometer via the USB port, you have access to the spectrometer's EEPROM, where wavelength calibration coefficients and other data unique to your spectrometer are stored. SpectraSuite Spectroscopy Operating Software reads these values for easy setup and swapping among PCs. A 16-bit A/D converter is mounted with the spectrometer in the same housing. A 5 VDC wall transformer (included) is required. These systems also have a serial port for interfacing to PCs, PLCs and other devices that support the RS-232 protocol.

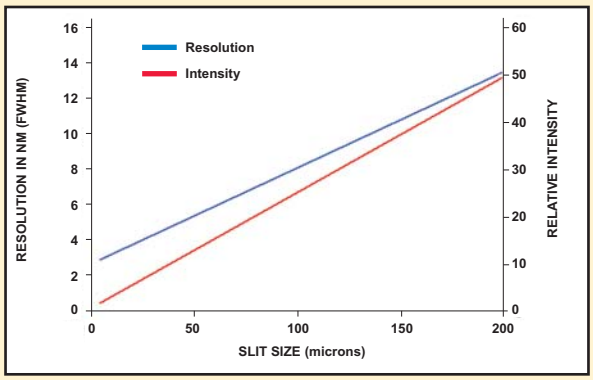
NIR-512: $14,995
NIR256-2.1: $19,999
NIR256-2.5: $21,995
SpectraSuite: $199

| Specifications | NIR-512 | NIR256-2.1 | NIR256-2.5 |
|---|---|---|---|
| PHYSICAL | | | |
| Dimensions (in mm): | 153.4 x 105.2 x 76.2 | 153.4 x 105.2 x 76.2 | 153.4 x 105.2 x 76.2 |
| Weight: | 190 grams | 190 grams | 190 grams |
| DETECTOR | | | |
| Detector: | Hamamatsu G9204-512 InGaAs linear array | Hamamatsu G9206-256 InGaAs linear array | Hamamatsu G9208-256 InGaAs linear array |
| Detector range: | 850-1700 nm | 900-2100 nm | 900-2550 nm |
| Pixels: | 512 | 256 | 256 |
| Pixel size: | 25 µm x 500 µm | 50 µm x 250 µm | 50 µm x 250 µm |
| Pixel well depth: | 187,000,000 electrons | 187,000,000 electrons | 187,000,000 electrons |
| Defective pixels: | None | 2% | 5% |
| OPTICAL BENCH | | | |
| Focal length: | f/4, 40 mm | f/4, 40 mm | f/4, 40 mm |
| Entrance aperture: | 10, 25, 50, 100 or 200 µm wide slits or fiber | 10, 25, 50, 100 or 200 µm wide slits or fiber | 10, 25, 50, 100 or 200 µm wide slits or fiber |
| Grating options: | Grating N1 | Grating N1 and N2 | Grating N2 |
| Fiber optic connector: | SMA 905 to 0.22 numerical aperture single strand fiber | SMA 905 to 0.22 numerical aperture single strand fiber | SMA 905 to 0.22 numerical aperture single strand fiber |
| SPECTROSCOPIC | | | |
| Wavelength range: | 900-1700 nm with Grating N1 | 900-2100 nm with Grating N2; 1200-2100 nm with Grating N1 | 900-2500 nm with Grating N2 |
| Responsivity peak: | 1.6 µm | 1.95 µm | 2.3 µm |
| Optical resolution: | With grating N1, 4.2-14.0 nm FWHM, slit dependent | With grating N1, 4.5-14.0 nm FWHM, slit dependent; with grating N2, 7.5-25.0 nm FWHM, slit dependent | With grating N2 7.5-25.0 nm FWHM, slit dependent |
| Signal-to-noise ratio: | 4000:1 | 4000:1 | 4000:1 |
| A/D resolution: | 16 bit | 16 bit | 16 bit |
| Dark noise: | 12 RMS counts | 12 RMS counts | 12 RMS counts |
| Dynamic range: | 5 x $10^6$ (system); 5000:1 for a single acquisition | 5 x $10^6$ (system); 5000:1 for a single acquisition | 5 x $10^6$ (system); 4000:1 for a single acquisition |
| Integration time: | 1 ms to 3 seconds* | 1 ms to 1 second* | 1 to 30 milliseconds* |
| Corrected linearity: | >99.8% | >99.8% | >99.8% |
| Max. dark current: | 60 pA @ 20 °C | 120 pA @ -15 °C | 2000 pA @ 15 °C |
| ELECTRONICS | | | |
| Power consumption: | 2 A @ 5 VDC | 3 A @ 5 VDC | 2 A @ 5 VDC |
| Data transfer speed: | Full spectrum to memory every 10 ms with USB port | Full spectrum to memory every 10 ms with USB port | Full spectrum to memory every 10 ms with USB port |
| Trigger modes: | 3 modes | 3 modes | 3 modes |
| Strobe functions: | Yes | Yes | Yes |
| COMPUTER | | | |
| Operating systems: | Windows 98/Me/ 2000/XP, Mac OS X & Linux with USB port; Any 32-bit Windows OS with serial port | Windows 98/Me/ 2000/XP, Mac OS X & Linux with USB port; Any 32-bit Windows OS with serial port | Windows 98/Me/ 2000/XP, Mac OS X & Linux with USB port; Any 32-bit Windows OS with serial port |
| Computer interfaces: | USB 2.0 @ 480 Mbps; RS-232 (2-wire) @ 115.2 K baud | USB 2.0 @ 480 Mbps; RS-232 (2-wire) @ 115.2 K baud | USB 2.0 @ 480 Mbps; RS-232 (2-wire) @ 115.2 K baud |
| Peripheral interfaces: | $I^2C$ inter-integrated circuit; SPI (3-wire) | $I^2C$ inter-integrated circuit; SPI (3-wire) | $I^2C$ inter-integrated circuit; SPI (3-wire) |

** Hardware allows integration times up to 32 seconds, but the detectors' dark characteristics do not support it.*

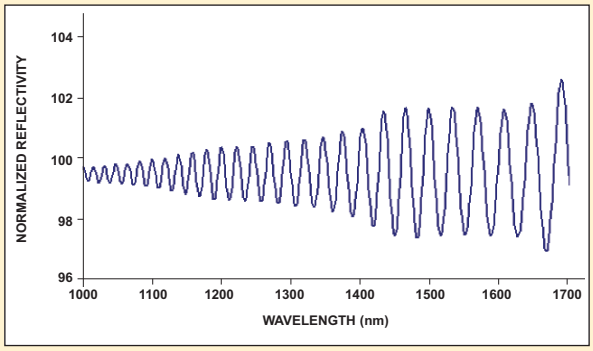
# NIR-series Near-infrared Spectrometers

## NIR-512 Resolution & Intensity vs. Slit Size

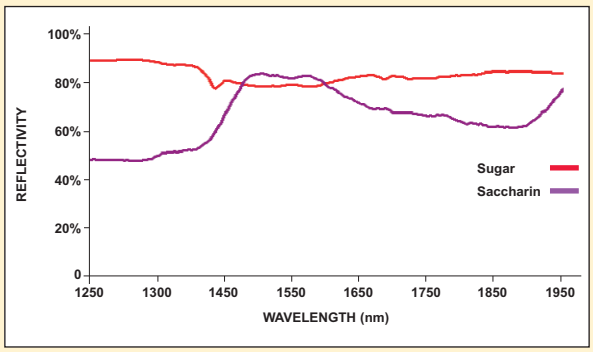



*Use this chart to help determine the best entrance aperture slit size for your application. Note that the smaller-sized slits provide excellent resolution, but lower levels of throughput to the detector.*

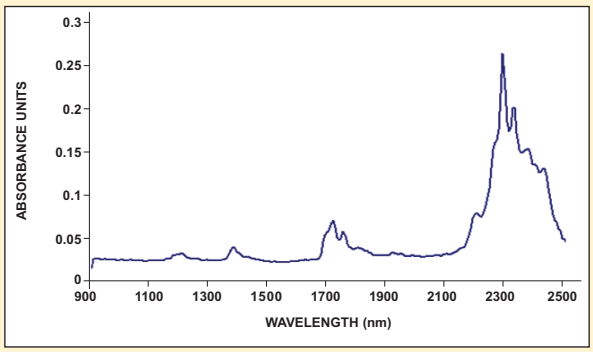
## NIR-512: Silicon Wafer Reflectivity




## NIR256-2.1 Reflectance of Sugar




## NIR256-2.5 Heptane Absorbance




### NIR-series Applications

- Sugar analysis
- Alcohol analysis in brewing
- Moisture analysis
- Nitrogen detection in soils
- Pulpwood QC
- Analysis of lubricants
- Laser characterization
- Fat, oil and lipid determination

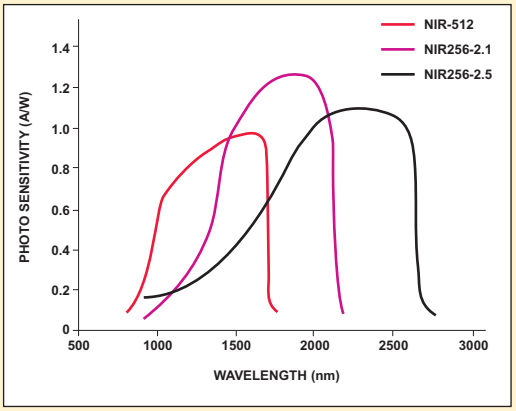
# Options for the "NIR" Optical Bench

## Detectors

In the "NIR" Spectrometers, we offer three different InGaAs linear array detectors, one 512-element array and two 256-element arrays. The Hamamatsu detectors used in the "NIR" Optical Bench are InGaAs photodiode linear arrays with each pixel connected to a charge amplifier array consists of CMOS transistors. These detectors deliver high sensitivity and stable operation in the near infrared.

The detectors all include onboard thermoelectric cooling. A thermistor monitors the array's temperature and a thermoelectric device can cool the arrays to 30 °C below ambient, keeping the array stable to within ±0.1 °C. In addition, you can set and monitor the detector's temperature via software.

### Spectral Response Curves




*This graph compares the spectral response of the three NIR detectors at an operating temperature of 25 °C.*

## Fixed Entrance Slits

An option available with user-configured "NIR" spectrometers is selecting the size of the entrance aperture. Entrance slits are rectangular apertures, 1-mm tall and various widths from 10 µm to 200 µm, with the width determining the amount of light entering the optical bench. A slit is fixed in place; it only can be changed by our technicians. You can opt against having a slit, in which case the diameter of the fiber connected to the spectrometer determines the size of the entrance aperture.

*A slit is installed on the inside edge of the bulkhead of an SMA 905 Connector.*

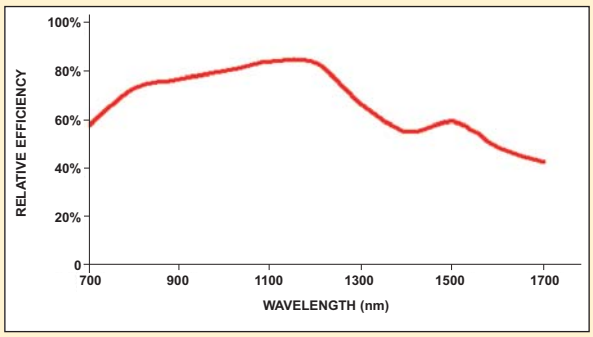
| Slit | Description | NIR-512 Pixel Resolution | NIR256-2.1 Pixel Resolution | NIR256-2.5 Pixel Resolution | Price |
|---|---|---|---|---|---|
| SLIT-10 | 10-µm wide x 1-mm high | ~2.4 pixels | ~1.2 | ~1.2 | $150 |
| SLIT-25 | 25-µm wide x 1-mm high | ~2.4 pixels | ~1.2 | ~1.2 | $150 |
| SLIT-50 | 50-µm wide x 1-mm high | ~2.9 pixels | ~1.5 | ~1.5 | $150 |
| SLIT-100 | 100-µm wide x 1-mm high | ~4.4 pixels | ~2.2 | ~2.2 | $150 |
| SLIT-200 | 200-µm wide x 1-mm high | ~7.9 pixels | ~4.0 | ~4.0 | $150 |

## Grating Selection Chart & Grating Efficiency Graphs

Here are the Grating Selection Chart and the Grating Efficiency Curves for the two gratings available with the "NIR" optical bench.

| Grating Number | Intended Use | Groove Density | Spectral Range | Blaze Wavelength | Best Efficiency |
|---|---|---|---|---|---|
| N1 | NIR-512 or NIR256-2.1 | 300 | 900 nm | 1000 nm | 700-2100 nm |
| N2 | NIR256-2.1 or NIR256-2.5 | 150 | 1600 nm | 1600 nm | 700-2500 nm |

### N1 Grating Efficiency




### N2 Grating Efficiency