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Innovative Solutions for

Your Application Needs

Complete Spectroscopy Catalog & Corporate Profile

SPECTROMETERS | LASERS | TOTAL SOLUTIONS

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What does B&W Tek do?

B&W Tek is an advanced instrumentation company producing optical spectroscopy and laser instrumentation, as well as laboratory, portable and handheld Raman systems. We provide spectroscopy and laser solutions for the pharmaceutical, biomedical, physical, chemical, LED lighting and research communities. Originally established as a producer of green lasers in 1997, we've grown into an industry-leading, total solutions provider; coupling our core technologies with custom design and manufacturing capabilities.

Since the company's establishment, we've emphasized strong vertical integration for better efficiency and faster growth. These values allow us to provide you with higher quality products that still fit into your budget. B&W Tek uses core components that are designed and manufactured in-house to create total solutions for a wide range of applications.

Our core technologies include:

Diffraction Limited, Spectrum Stabilized, and High Power Lasers

UV, Vis, NIR, & Raman Spectrometers

Sampling Accessories & Broadband Light Sources

Who uses B&W Tek products & services?

B&W Tek has always had a strong presence in the photonics industry, and now we are breaking into new areas and applications like never before. Using our innovative engineering resources and fast-growing technology, B&W Tek offers products and services that provide solutions for a variety of industries:

Medical & BioMedical OEM/OED

B&W Tek has a long history of providing components and integrated OEM and OED solutions for the medical & biomedical industry. We have designed and manufactured medical laser systems for applications ranging from equine airway surgery to photodynamic therapy and we continue to be on the cutting edge of high power medical laser technology. B&W Tek's spectrometers and low power lasers are also frequently integrated into biomedical systems such as microplate readers and fluorescence imaging systems.

Pharmaceuticals

Combining a number of our core technologies, we have become the world leader in portable Raman spectroscopy. Raman spectroscopy is a highly selective and powerful tool for both qualitative and quantitative analysis of organic and inorganic compounds. Our CFR 21 Part 11 compliant products reduce production costs within cGMP facilities while simultaneously escalating productivity.

LED Lighting

As part of the booming LED industry, B&W Tek continues to provide solutions for LED manufacturers and end-users alike. Our high speed modular spectrometers are key building blocks in LED binning and sorting machines, while our spectral irradiance meters are used for spectral power and colorimetric analysis of solid state lighting, which is rapidly becoming today's dominant light source.

Semiconductor/Solar

B&W Tek's products are often used in the solar and semiconductor industry for various metrology applications. Our Raman systems are ideal for measuring stresses and strains in silicon wafers, as well as performing quantitative analysis of crystallinity. Our broadband spectrophotometers are ideal for thin-film thickness measurements, and our modular spectrometers are ideal for integration into plasma process monitoring systems for end point detection.

Academic / Government Labs

Our extensive line of lasers, spectrometers and accessories are capable of generating and detecting light for a wide variety of applications, which makes them the ideal choice for scientists looking for versatile equipment for their laboratories. B&W Tek is partnering with universities across the world to help foster the next generation of breakthrough research in areas such as cancer diagnostics, molecular level archeological analysis, and green technology.

Specialty Chemicals

Optical spectroscopy is one of the most commonly used techniques in analytical chemistry, and B&W Tek offers a full range of spectroscopy solutions to suit the needs of this industry. We offer modular spectrometers and excitation sources, complete laboratory Raman and spectrophotometric systems, as well as handheld and field portable instrumentation.

What added benefit does B&W Tek provide?

At B&W Tek, not only do we design, manufacture and assemble all of our own products, we also have the knowledge and expertise needed to guarantee that our products will fit the demands of your application. We feel that providing instrumentation is just part of our commitment towards providing your solution.

Our experienced staff is standing by to offer service, support and their extensive knowledge to help you find the answers you're looking for. Our research and development team consists of over 30 engineers in varying disciplines, each with an advanced degree in their field, and we're eager to share our information and experience with you. We even post our knowledge on our website – so you can access the answers you need whenever and as often as you'd like!

As part of our mission to provide knowledge, as well as products, to our customers, we've established the New Horizons Academic Partnership Program. For over fifteen years, B&W Tek has supported researchers with advanced instrumentation for optical spectroscopy and laser systems. Now, we are looking to extend our research partnerships to academic institutions with special pricing and applications support. We are thrilled to be supporting breakthrough research in every way we can.

What can I expect from B&W Tek?

At B&W Tek, we guarantee superior performance, quality, and solid regulatory compliance standards on each product that leaves our facility. We operate in ISO 13485 & ISO 9001 certified facilities equipped with clean room environments and apply an extensive Overall Quality Control Test (OQCT) to make sure our products and services pass or exceed domestic and international standards and regulations. Our mock FDA Quality Systems Inspections Technique (QSIT) allows us to conduct Installation Qualification (IQ), Operational Qualification (OQ), and Performance Qualification (PQ) checks, as well as software verification and validation. We also apply Six Sigma methodologies to ensure that each product passes all tests at each production process level.

ISO 9001 & ISO 13485 Certified
FDA & CDRH Registration and Compliance
CE Safety Standards
UL Safety Standards
Manufacturing FDA Class II and III Devices
Application of Six Sigma Methodologies

About B&W Tek

What makes B&W Tek different from other providers?

While there are many companies that can provide you with some of the components you need for your application, we are a "one-stop-shop" that provides everything you need in one place. In many of the industries we serve, we're the only one of our kind. At B&W Tek, we pride ourselves on providing not just the pieces of each project, but a total solution. Due to our resources and expertise, we're able to do this for our customers in a number of ways.

With a variety of extensive product families, we're able to take an assortment of ready-to-use, off-the-shelf products and put them together to form a complete setup. There are hundreds of possible options by combining any variety of our lasers, spectrometers, accessories, and even software packages - all of which are designed and built by our own staff.

We're also able to provide total solutions with input from you! By offering various services in industrial design, custom development, end-user training, and regulatory compliance testing and certification, we work with you to make your ideas come to life. We design, engineer, prototype and manufacture an extensive range of instrumentation for a variety of applications, working with you from concept to completion. Though we may not currently make the product that's perfect for your application, we are always open to the challenge of creating new technologies and breaking into new applications.

How will B&W Tek make my ideas a reality?

As part of our mission to provide a total solution, we've developed the OEM Product Development Cycle to ensure that we meet your goals at each milestone. Our project management and engineering team work closely with you to understand not only the product requirements, but your overall business goals. Our extremely flexible and adaptable solutions are the perfect answer for every OEM need.

Phase 1: Evaluation
From the very beginning, B&W Tek works closely with you to obtain a detailed view of your project's requirements. After studying and evaluating the technical feasibility, we then propose a solution that's unique to you.

Phase 2: Development and Prototype
Once you approve our proposal, we will demonstrate and deliver a collection of prototype products for your feedback. In most cases, we provide these to you in less than 3 months!

Phase 3: Pilot Production
From here, B&W Tek works with you to resolve any manufacturing concerns, pursue any possibilities for cost reduction, and scale up for full production. We will provide final qualification of the product design and develop additional testing protocols to address the quality and reliability of your new product.

Phase 4: Full Production
Next, we establish the final manufacturing process and bring your product into full volume production. Our dedicated, high standard quality control team works hard to ensure that every single one of your products meets performance and stability requirements.

Phase 5: Post Production Services
With facilities in the United States, Asia, and Europe, B&W Tek provides a full range of post-production services to empower and support you. We offer customized configurations in order to deliver turn-key solutions to your customers. We also provide customized warranty and service policies to eliminate time consuming or costly repairs and give you the opportunity to access our technology upgrades and product development news first hand.

What types of products does B&W Tek offer?

Lasers

B&W Tek offers a complete line of high performance diode, DPSS and fiber laser modules and systems. Our product lines cover a range of wavelengths from 375nm to 1850nm with power outputs up to 150W. We offer a wide variety of high performance class IIIb & IV laser products in both end-user and OEM configurations, as well as high power medical OEM lasers.

Applications:

- Fluorescence
- Laser Biomodulation
- Laser Printing
- Laser Surgery
- Metrology
- Particle Counting
- Photodynamic Therapy
- Plastic Welding
- Precision Alignment
- Raman Spectroscopy/ Microscopy

Spectrometers

Our line of spectrometers cover UV to NIR and everything in between. Fiber coupled and free space miniature spectrometers are available with a wide selection of sampling accessories. Each spectrometer comes with a USB interface and our own BWSpec™ software. We offer set standard configuration and customizable OEM solutions.

Applications:

- Absorption
- Fluorescence
- Material Identification
- Metrology
- Process Monitoring
- Quality Control
- Raman Spectroscopy/ Microscopy
- Reflection
- Spectral Irradiance
- Wavelength Identification

Accessories

At B&W Tek, we believe in providing all of the elements for your solution; making the journey to find an answer faster and easier. We offer a wide range of accessories for all of our products, including:

- External Batteries
- Fiber Optics
- Integrating Spheres
- Light Sources
- Multiplexers
- Sample Holders
- Sampling Probes

What types of products does B&W Tek offer?

Raman Spectrometers

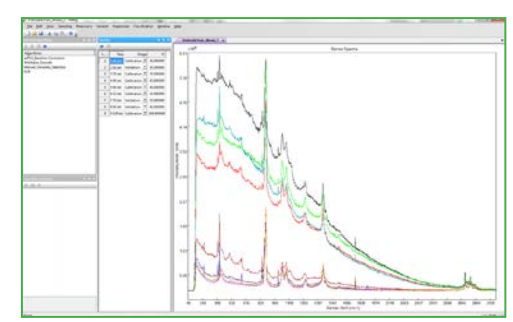
B&W Tek offers a complete line of high performance laboratory, portable, and handheld Raman spectrometers. We are the worldwide leader in Raman systems manufacturing, with over 10,000 spectrometers shipped. We have recently introduced the NanoRam™, a new class of small, handheld instruments for materials identification and verification within cGMP compliant facilities. The NanoRam is a state-of-the-art compact Raman spectrometer and integrated computing system that can support a broad range of applications in multiple industries. Based on our award winning i-Raman® spectrometer, B&W Tek has also released solutions for gemology and polymer analysis. Designed for use by non-specialists, these new capabilities represent our focus on solution-oriented products.

Applications:

- Agriculture
- Bioscience
- Forensic Analysis
- Gemology
- Geology/Mineralogy
- Medical Diagnosis
- Pharmaceuticals
- Polymers/Chemical Processes
- Raman Microscopy

Spectroscopy Software

B&W Tek offers comprehensive software packages that provide solutions for all sorts of application needs. Powerful calculations, easy data management, and user friendly, easy-to-follow work flow are all available at the tips of your fingers.



BWSpec™ is the foundation for all B&W Tek software platforms and comes standard with every spectrometer that we sell. Built on the proven BWSpec platform, BWID™ is optimized for identification and verification of materials. For industrial Raman applications that require federal compliance, BWID™-Pharma supports all requirements of FDA 21 CFR Part 11 Compliance. BWIQ™ chemometrics software is a multivariate analysis package that can analyze spectral data and discover internal relationships between spectra and response data or spectra and sample classes.

Innovative Solutions for
Modular Spectroscopy

How Does a Spectrometer Work?

Over the past 20 years, miniature fiber optic spectrometers have evolved from a novelty to the spectrometer of choice for many modern spectroscopists. People are realizing the advanced utility and flexibility provided by their small size and compatibility with a plethora of sampling accessories.

The basic function of a spectrometer is to take in light, break it into its spectral components, digitize the signal as a function of wavelength, and read it out and display it through a computer. The first step in this process is to direct light through a fiber optic cable into the spectrometer through a narrow aperture known as an entrance slit. The slit vinyettes the light as it enters the spectrometer. In most spectrometers, the divergent light is then collimated by a concave mirror and directed onto a grating. The grating then disperses the spectral components of the light at slightly varying angles, which is then focused by a second concave mirror and imaged onto the detector. Alternatively, a concave holographic grating can be used to perform all three of these functions simultaneously. This alternative has various advantages and disadvantages, which will be discussed in more detail later on.

Once the light is imaged onto the detector the photons are then converted into electrons which are digitized and readout through a USB (or serial port) to a computer. The software then interpolates the signal based on the number of pixels in the detector and the linear dispersion of the diffraction grating to create a calibration that enables the data to be plotted as a function of wavelength over the given spectral range. This data can then be used and manipulated for countless spectroscopic applications, some of which will be discussed here later on.

In the following sections we will explain the inner-workings of a spectrometer and how all of the components work together to achieve a desired outcome, so that no matter what your application is, you'll know what to look for. We'll first discuss each component individually so that you have a full understanding of their function in the workings of a spectrometer, then we'll discuss the variety of configurations that are possible with those components, and why each of them has a different function. We'll even touch on some of the accessories used to make your application as successful as they can possibly be.

Part 1: The Slit

Overview

A spectrometer is an imaging system which maps a plurality of monochromatic images of the entrance slit onto the detector plane. This slit is critical to the spectrometer's performance and determines the amount of light (photon flux) that enters the optical bench. It is a driving force when determining the spectral resolution; other factors are grating groove frequency and detector pixel size.

The optical resolution and throughput of a spectrometer will ultimately be determined by the installed slit. Light entering the optical bench of a spectrometer via a fiber or lens is focused onto the pre-mounted and aligned slit. The slit controls the angle of the light which enters the optical bench.

Slit widths come in a number of different sizes from 5μm to as large as 800μm with a 1mm (standard) to 2mm height. Selecting the right slit for your application is very important since they are aligned and permanently mounted into a spectrometer and should only be changed by a trained technician.

The most common slits used in spectrometers are 10, 25, 50, 100, 200 μm, etc. For systems where optical fibers are used for input light coupling, a fiber bundle matched with the shape of the entrance slit (stacked fiber) may help increase the coupling efficiency and system throughput.

Technical Details

The function of the entrance slit is to define a clear-cut object for the optical bench. The size (width (W_s) and height (H_s)) of the entrance slit is one of the main factors that affect the throughput of the spectrograph. The image width of the entrance slit is a key factor in determining the spectral resolution of the spectrometer when it is greater than the pixel width of the detector array. Both the throughput and resolution of the system should be balanced by selecting a proper entrance slit width.

The image width of the entrance slit (W_i) can be estimated as,

$$W_i = (M^2 \cdot W_s^2 + W_o^2)^{1/2},$$

Equation 1-1

where M is the magnification of the optical bench set by the ratio of the focal length of the focusing mirror / lens to the collimating mirror / lens, W_s is the width of the entrance slit, and W_o is the image broadening caused by the optical bench. Under the condition that the resolution requirement is satisfied, the slit width should be as wide as possible to improve the throughput of the spectrograph.

For a standard Czerzy-Turner optical bench, W_o is approximately a few tens of microns, so reducing the width of the entrance slit below this value won't significantly improve the resolution of the system. Axial transmissive optical benches can significantly reduce W_o, thus achieving a finer spectral resolution. Another limit on spectral resolution is set by the pixel width (W_p) of the array detector. Reducing W_i below W_p will not increase resolution of the spectrometer.

Part 2: The Grating

Overview

The diffraction grating of a spectrometer determines the wavelength range and partially determines the optical resolution that the spectrometer will achieve. Choosing the correct grating is a key factor in optimizing your spectrometer for the best spectral results in your application. Gratings will influence your optical resolution and the maximum efficiency for a specific wavelength range. The grating can be described in two parts: the groove frequency and the blaze angle, which are further explained in this section.

There are two types of diffraction gratings: ruled gratings and holographic gratings. Ruled gratings are created by etching a large number of parallel grooves onto the surface of a substrate, then coating it with a highly reflective material. Holographic gratings, on the other hand, are created by interfering two UV beams to create a sinusoidal index of refraction variation in a piece of optical glass. This process results in a much more uniform spectral response, but a much lower overall efficiency.

While ruled gratings are the simplest and least expensive gratings to manufacture, they exhibit much more stray light. This is due to surface imperfections and other errors in the groove period. Thus, for spectroscopic applications (such as UV spectroscopy) where the detector response is poorer and the optics are suffering more loss, holographic gratings are generally selected to improve the stray light performance of the spectrometer. Another advantage of holographic gratings is that they are easily formed on concave surfaces, allowing them to function as both the dispersive element and focusing optic at the same time.

Groove Frequency

The amount of dispersion is determined by the amount of grooves per mm ruled into the grating. This is commonly referred to as groove density, or groove frequency. The groove frequency of the grating determines the spectrometer's wavelength coverage and is also a major factor in the spectral resolution. The wavelength coverage of a spectrometer is inversely proportional to the dispersion of the grating due to its fixed geometry. However, the greater the dispersion, the greater the resolving power of the spectrometer. Inversely, decreasing the groove frequency decreases the dispersion and increases wavelength coverage at the cost of spectral resolution.

For example, if you were to choose a Quest™ X spectrometer with a 900g/mm, it would give you a wavelength range of 370 nm, with an optical resolution as low as 0.5nm. Comparably, if you were to choose a Quest™ X with a 600g/mm grating, it would instead give you up to 700nm of wavelength coverage with an optical resolution as low as 1.0nm. As this example shows, you are able to increase your wavelength coverage at the sacrifice of optical resolution.

When the required wavelength coverage is broad, i.e. $\lambda_{max} > 2\lambda_{min}$, optical signals in wavelengths from different diffraction orders may end up at the same spatial position on the detector plane, which will become evident once we take a look at the grating equation. In this case, a linear variable filter (LVF) is required to eliminate any unwanted higher order contributions, or perform "order sorting".

For fixed grating spectrometers, it can be shown that the angular dispersion from the grating is described by

$$\frac{d\beta}{d\lambda} = \frac{m}{10^6\, d \cos\beta},$$

Equation 2-1

where β is the diffraction angle, d is the groove period (which is equal to the inverse of the groove density), m is the diffraction order, and λ is the wavelength of light, as shown in Figure 2-1.

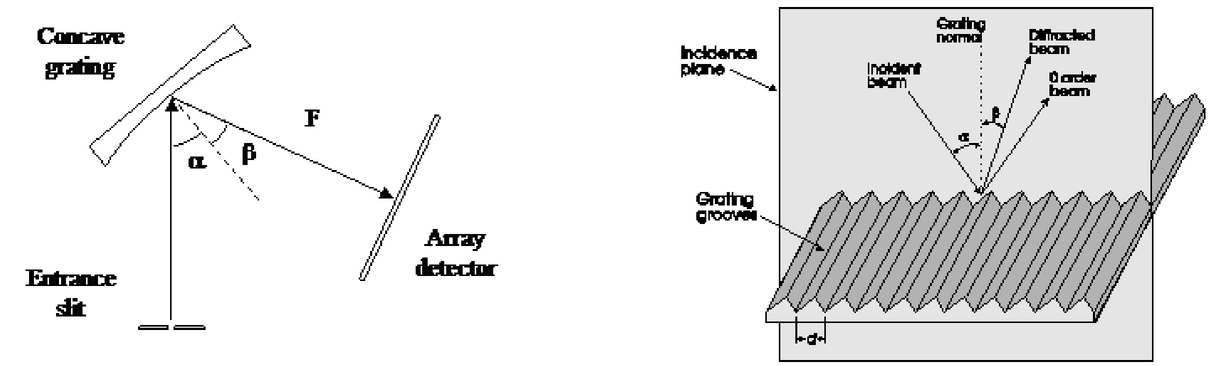


Figure 2-1 Geometric Representation of Diffraction from Both a Concave and a Flat Grating

By taking into account the focal length (*F*) of the focusing mirror and by assuming the small angle approximation, equation 2-1 can be rewritten as

$$\frac{d\lambda}{dL} = \frac{10^6\, d \cos\beta}{m\, F},$$

Equation 2-2

which gives the linear dispersion in terms of nm/mm. From the linear dispersion, the maximum spectral range ($\lambda_{max} - \lambda_{min}$) can be calculated based upon the detector length (L_D), which can be calculated by multiplying the total number of pixels on the detector (*n*) by the pixel width (W_p) resulting in the expression

$$(\lambda_{max} - \lambda_{min}) = L_D \frac{d\lambda}{dL} = L_D \frac{10^6\, d \cos\beta}{m\, F}.$$

Equation 2-3

Based on equation 2-3, it is clear that the maximum spectral range of a spectrometer is determined by the detector length (L_D), the groove density (*1/d*) and the focal length (*F*).

The minimum wavelength difference that can be resolved by the diffraction grating is given by

$$d\lambda = \frac{d}{m\, L_g} = \frac{1}{m\, N},$$

Equation 2-4

where N is the total number of grooves on the diffraction grating. This is consistent with transform limit theory which states that the smallest resolvable unit of any transform is inversely proportional to the number of samples. Generally, the resolving power of the grating is much higher than the overall resolving power of the spectrometer, showing that the dispersion is only one of many factors in determining the overall spectral resolution.

It should also be noted that the longest wavelength that will be diffracted by a grating is *2d*, which places an upper limit on the spectral range of the grating. For near-infrared (NIR) applications, this long wavelength limitation may restrict the maximum groove density allowed for your spectrometer.

Blaze Angle

As a grating diffracts incident polychromatic light, it does not do so with uniform efficiency. The overall shape of the diffraction curve is determined mainly by the groove facet angle, otherwise known as the blaze angle. Using this property, it is possible to calculate which blaze angle will correspond to which peak efficiency; this is called the blaze wavelength. This concept is illustrated in Figure 2-1, which compares three different 150g/mm gratings blazed at 500nm, 1250nm & 2000nm.

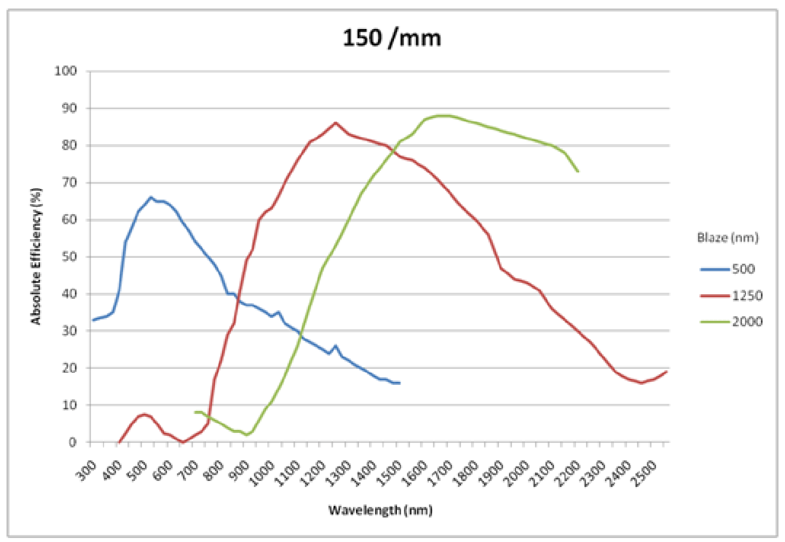


Figure 2-2 Comparison of Grating Efficiency As a Function of Blaze Wavelenth

Gratings can be blazed to provide high diffraction efficiency (>85%) at a specific wavelength, i.e. a blaze wavelength (λ_B). As a rule of thumb, the grating efficiency will decrease by 50% at $0.6\times\lambda_B$ and $1.8\times\lambda_B$. This sets a limit on the spectral coverage of the spectrometer. Generally, the blaze wavelength of the diffraction grating is biased toward the weak side of the spectral range to improve the overall signal to noise ratio (SNR) of the spectrometer.

Part 3: The Detector

Overview

We've discussed the importance that the entrance slit and the diffraction grating have in forming a spectral image of the incident light in the image plane. In traditional spectrometer (monochrometer) designs, a second slit is placed in the image plane, known as the exit slit. The exit slit is typically the same size as the entrance slit since the entrance slit width is one of the limiting factors on the spectrometer's resolution (as was shown in Part 1). In this configuration a single element detector is placed behind the exit slit and the grating is rotated to scan the spectral image across the slit, and therefore measure the intensity of the light as a function of wavelength.

In modern spectrometers, CCD and linear detector arrays have facilitated the development of "fixed grating" spectrometers. As the incident light strikes the individual pixels across the CCD, each pixel represents a portion of the spectrum that the electronics can then translate and display with a given intensity using software. This advancement has allowed for spectrometers to be constructed without the need for moving parts, and therefore greatly reduce the size and power consumption. The use of compact multi-element detectors has allowed for a new class of low cost, compact spectrometers to be developed: commonly referred to as "miniature spectrometers."

Detector Types

While photodetectors can be characterized in many different ways, the most important differentiator is the detector material. The two most common semiconductor materials used in miniature spectrometers are Si and InGaAs. It is critical to choose the proper detector material when designing a spectrometer because the bandgap energy (E_{gap}) of the semiconductor determines the upper wavelength limit (λ_{max}) that can be detected by the following relationship

$$\lambda_{max} = \frac{hc}{E_{gap}},$$

Equation 3-1

where *h* is Plank's constant and *c* is the speed of light. The product of Plank's constant and the speed of light can be expressed as 1240 eV•nm or 1.24 eV•µm to simplify the conversion from energy to wavelength. For example, the bandgap energy of Si is 1.11eV which corresponds to a maximum wavelength of 1117.117nm.

InGaAs, on the other hand, is an alloy created by mixing InAs and GaAs, which have a bandgap of 0.36eV and 1.43eV respectively. Therefore, depending on the ratio of In and Ga the bandgap energy can be tuned in between those two values. However, due to a variety of factors, not all ratios of In and Ga are easily fabricated, therefore 1.7µm (or 0.73eV) has become the standard configuration for InGaAs detector arrays. It is also possible to use extended InGaAs arrays which can detect out to 2.2µm or 2.6µm, but these detectors are much more expensive and are much nosier than traditional InGaAs detectors.

The lower detection limit of a material is slightly harder to quantify because it is determined by the absorbance characteristics of the semiconductor material, and as a result can vary widely with the thickness of the detector. Another common method of lowering the detection limit of the detector is to place a fluorescent coating on the window of the detector, which will absorb the higher energy photons and reemit lower energy photons which are then detectable by the sensor. Figure 3-1 below shows a comparison of the detectivity (D*) as a function of wavelength for both Si (CCD) and InGaAs.

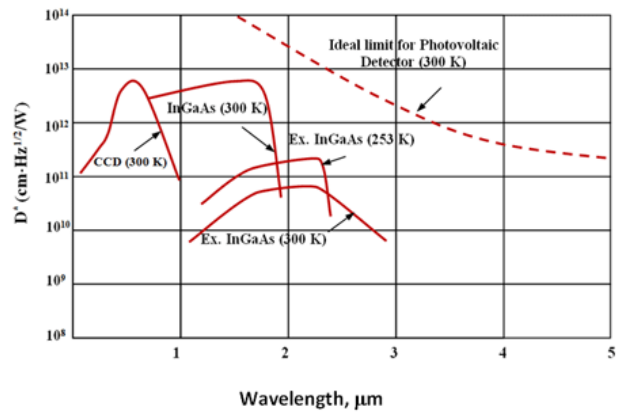


Figure 3-1 Approximate D* Values As a Function of Wavelength for Some Typical Detectors

CCDs, BT-CCDs, and PDAs

While currently InGaAs detector arrays are only available in one configuration, Si multi-element detectors are readily available in three different subcategories: charge coupled devices (CCDs) back-thinned charge coupled devices (BT-CCDs), and photodiode arrays (PDAs).

CCD technology allows for small pixel size (~14μm) detectors to be constructed because it eliminates the need for direct readout circuitry from each individual pixel. This is accomplished by transferring the charge from one pixel to another, allowing for all of the information along the array to be read out from a single pixel. CCDs can be constructed very inexpensively which makes them an ideal choice for most miniature spectrometers, but they do have two drawbacks. First, the gate structure on the front of the CCD can cause the incident light to scatter and therefore not be absorbed. Second, CCDs need to have a relatively large P-Si substrate to facilitate low cost production limiting the efficiency of the detector (especially at shorter wavelengths) due to absorption through the P layer.

To mitigate both of these issues in spectroscopy applications where very high sensitivity is needed, BT-CCDs are ideal. BT-CCDs are made by etching the P-Si substrate of the CCD to a thickness of approximately 10μm. This process greatly reduces the amount of absorption and increases the overall efficiency of the detector. This process also allows the detector to be illuminated from the back side (P-Si region) which eliminates the effects from the gate structure on the surface of the detector. Figure 3-2 shows a typical comparison of the quantum efficiency between a traditional front illuminated CCD and a back illuminated BT-CCD.

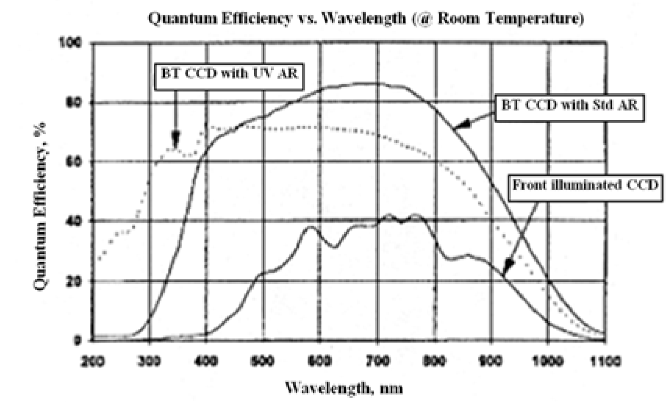


Figure 3-2 Typical Quantum Efficiency of Front-illuminated CCD and Back-thinned CCD

While there are distinct advantages to the use of BT-CCDs in spectroscopy, there are also two major drawbacks that should be noted. First, this process greatly increases the cost of production, and second (since the detector is so thin) there can be an etaloning effect caused from reflections off the front and back surfaces of the detector. The etaloning phenomena associated with BT-CCDs can be mitigated by a process known as deep depletion, but once again this adds additional cost to the production process.

PDA detectors are more traditional linear detectors which consist of a set of individual photodiodes that are arranged in a linear fashion using CMOS technology. These detectors, while not having the small pixel size and high sensitivity, have several advantages over CCD and BT-CCD detectors. First, the lack of charge transfer eliminates the need for a gate structure on the front surface of the detector and greatly increases the readout speed. The second advantage of PDA detectors is that the well depth is much higher than the well depth of a CCD; a typical PDA detector well depth is ~156,000,000e- as compared to ~65,000e- for a standard CCD. The larger well depth of PDA detectors causes them to have a very large dynamic range (~50,000:1) as well as an extremely linear response. These properties make PDAs ideal for applications where it is necessary to detect small changes in large signals, such as LED monitoring.

Detector Noise

The main noise sources found in an array detector include readout noise, shot noise, dark noise, and fixed pattern noise.

Readout noise is caused by electronic noise in the detector output stage and related circuitry, which largely dictates the detection limit of the spectrometer.

Shot noise is associated with the statistical variation in the number of photons incident on the detector, which follows a Poisson distribution. Therefore, shot noise is proportional to the square root of the incident photon flux.

Dark noise is associated with the statistical changes in the number of electrons generated in a dark state. A photo detector exhibits a small output even when no incident light is present. This is known as the dark current or dark output. Dark current is caused by thermally generated electron movements and is strongly dependent on ambient temperatures. Similar to shot noise, dark noise also follows a Poisson distribution; as a result, dark noise is proportional to the square root of the dark current.

The fixed pattern noise is the variation in photo-response between neighboring pixels. This variation results mainly from variations in the quantum efficiency among pixels caused by non-uniformities in the aperture area and film thickness that arise during fabrication.

The total noise of an array detector is the root square sum of these four noise sources.

TE Cooling

Cooling an array detector with a built-in thermoelectric cooler (TEC) is an effective way to reduce dark noise as well as to enhance the dynamic range and detection limit. For Si detectors, dark current doubles when the temperature increases by approximately 5 to 7 °C and halves when the temperature decreases by approximately 5 to 7°C. Figure 3-3 shows the dark noise for an un-cooled and cooled CCD detector at an integration time of 60 seconds. When operating at room temperature, the dark noise nearly saturates the un-cooled CCD. When the CCD is cooled down to only 10°C by the TEC, the dark current is reduced by about four times and the dark noise is reduced by about two times. This makes the CCD capable of operating at a longer integration time to detect weak optical signals. When a CCD based spectrometer is involved in non-demanding high light level applications such as LED measurement, the dark noise reduction due to TE cooling is minimal because of the relatively short integration time used.

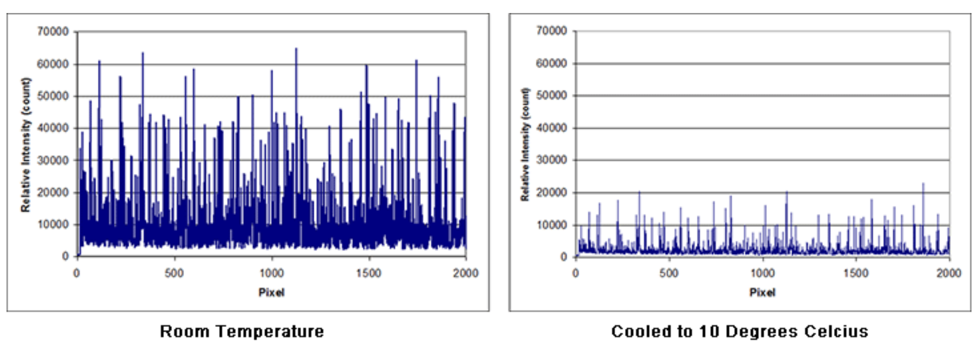


Figure 3-3 Dark Current for Cooled and Un-cooled CCD Detector (Integration Time = 60s)

As a rule of thumb, when the integration time of a CCD spectrometer is set to less than 200ms, the detector is operating in a read noise limited state. Therefore, there is no significant noise reduction due to the TE cooling; however the temperature regulation under these conditions will be beneficial for long term baseline stability.

Part 4: The Optical Bench

Overview

As stated in Part 1: The Slit, a spectrometer is an imaging system which maps a plurality of monochromatic images of the entrance slit onto the detector plane. In the past 3 sections, we discussed the three key configurable components of the spectrometer: the slit, the grating, and the detector. In this section, we will discuss how these different components work together with different optical components to form a complete system. This system is typically referred to as the spectrograph, or optical bench. While there are many different possible optical bench configurations, the three most common types are the crossed Czerny-Turner, unfolded Czerny-Turner, and concave holographic spectrographs (shown in Figures 4-1, 4-2, and 4-3 respectively).

Czerny-Turner

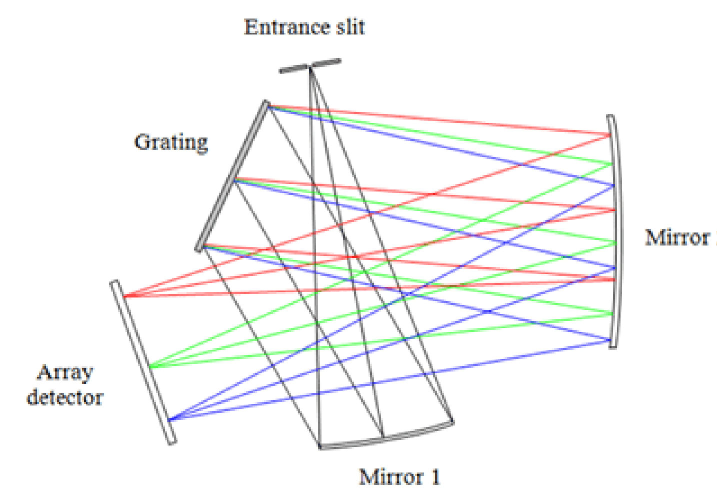


Figure 4-1 Crossed Czerny-Turner Spectrograph

The crossed Czerny-Turner configuration consists of two concave mirrors and one plano diffraction grating, as illustrated in figure 4-1. The focal length of mirror 1 is selected such that it collimates the light emitted from the entrance slit and directs the collimated beam of light onto the diffraction grating. Once the light has been diffracted and separated into its chromatic components, mirror 2 is then used to focus the dispersed light from the grating onto the detector plane.

The crossed Czerny-Turner configuration offers a compact and flexible spectrograph design. For a diffraction grating with a given angular dispersion value, the focal length of the two mirrors can be designed to provide various linear dispersion values. This determines the spectral coverage for a given detector, sensing length and resolution of the system. By optimizing the geometry of the configuration, the crossed Czerny-Turner spectrograph may provide a flattened spectral field and good coma correction. However, due to its off-axis geometry, the Czerny-Turner optical bench exhibits a large image aberration, which may broaden the image width of the entrance slit by a few tens of microns. Thus, the Czerny-Turner optical bench is mainly used for low to medium resolution spectrometers. Although this design is not intended for two dimensional imaging, using aspheric mirrors (such as toroidal mirrors) instead of spherical mirrors can provide a certain degree of correction to the spherical aberration and astigmatism.

To minimize image aberrations, the Czerny-Turner optical bench is generally designed with an f-number (*f/#*) of >3, which in turn places a limit on its throughput. The f-number of an optical system expresses the diameter of the entrance pupil in terms of its effective focal length. The f-number is defined as *f/# = f/D*, where *f* is the focal length of the collection optic and *D* is the diameter of the element. The f-number is used to characterize the light gathering power of the optical system. The relation of the f-number with another important optical concept, Numerical Aperture (*NA*), is that: *f/# = 1/(2•NA)*, where the numerical aperture of an optical system is a dimensionless number that characterizes the range of angles over which the system can accept or emit light.

The relatively large *f/#* of Czerny-Turner optical benches, in comparison to a typical multimode fiber (*NA ≈ 0.22*), can cause a fairly high level of stray light in the optical bench. One simple and cost-effective way to mitigate this issue is by unfolding the optical bench as shown in Figure 4-2. This allows for the insertion of "beam blocks" into the optical path, greatly reducing the stray light and, as a result, the optical noise in the system. This issue is not as damaging in the visible and NIR regions where there is an abundance of signal and higher quantum efficiencies, but it can be a problem for dealing with medium to low light level UV applications. This makes the unfolded Czerny-Turner spectrograph ideal for UV applications that require a compact form factor.

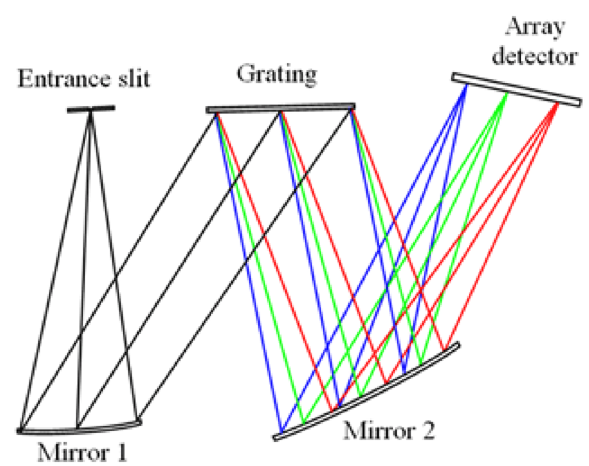


Figure 4-2 Unfolded Czerny-Turner Spectrograph

Concave Holographic

The third most common optical bench is based on an aberration corrected concave holographic grating (CHG). Here, the concave grating is used both as the dispersive and focusing element, which in turn means that the number of optical elements is reduced. This increases throughput and efficiency of the spectrograph, thus making it higher in throughput and more rugged. The holographic grating technology permits correction of all image aberrations present in spherical, mirror based Czerny-Turner spectrometers at one wavelength, with good mitigation over a wide wavelength range.

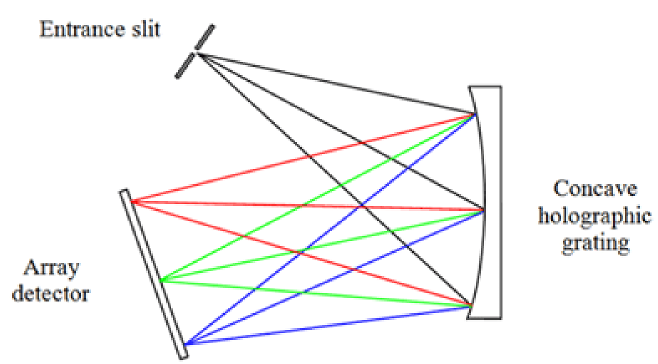


Figure 4-3 Concave-Holographic Spectrograph

In comparison with a ruled grating, the holographic grating presents up to over a 10x reduction in stray light, which helps to minimize the interferences due to unwanted light. A ruled diffraction grating is produced by a ruling engine that cuts grooves into the coating layer on the grating substrate (typically glass coated with a thin reflective layer) using a diamond tipped tool.

A holographic diffraction grating is produced using a photolithographic technique that utilizes a holographic interference pattern. Ruled diffraction gratings, by the nature of the manufacturing process, cannot be produced without defects, which may include periodic errors, spacing errors and surface irregularities. All of these contribute to increased stray light and ghosting (false spectral lines caused by periodic errors). The optical technique used to manufacture holographic diffraction gratings does not produce periodic errors, spacing errors or surface irregularities. This means that holographic gratings have significantly reduced stray light (typically 5-10x lower stray light compared to ruled gratings) and removed ghosts completely.

Ruled gratings are generally selected when working with low groove density, e.g., less than 1200 g/mm. When high groove density, low stray light, and/or concave gratings are required, holographic gratings are the better choice. It is important to keep in mind that the maximum diffraction efficiency of concave holographic gratings is typically ~35% in comparison to plano ruled gratings, which can have peak efficiencies of ~80%.

Part 5: Spectral Resolution

Introduction

One of the most important characteristics of a spectrometer is the spectral (or optical) resolution. The spectral resolution of a system determines the maximum number of spectral peaks that the spectrometer can resolve. For example, if a spectrometer with a wavelength range of 200nm had a spectral resolution of 1nm, the system would be capable of resolving a maximum of 200 individual wavelengths (peaks) across a spectrum.

In dispersive array spectrometers, there are 3 main factors that determine the spectral resolution of a spectrometer: the slit, the diffraction grating, and the detector. The slit determines the minimum image size that the optical bench can form in the detector plane. The diffraction grating determines the total wavelength range of the spectrometer. The detector determines the maximum number and size of discreet points in which the spectrum can be digitized.

Measuring Spectral Resolution

It is important to understand that the observed signal (S_o) is not solely dependent on the spectral resolution (R) of the spectrometer but it is also dependent on the linewidth of the signal (S_r). As a result, the observed resolution is the convolution of the two sources,

$$S_o(\lambda) = S_r(\lambda) * R(\lambda).$$

Equation 5-1

When the signal linewidth is significantly greater than the spectral resolution, the effect can be ignored and one can assume that the measured resolution is the same as the signal resolution. Conversely, when the signal linewidth is significantly narrower than the spectrometer resolution, the observed spectrum will be limited solely by the spectrometer resolution.

For most applications it is safe to assume that you are working in one of these limiting cases, but for certain applications such as high resolution Raman spectroscopy, this convolution cannot be ignored. For example, if a spectrometer has a spectral resolution of ~3cm^{-1} and uses a laser with a linewidth of ~4cm^{-1}, the observed signal will have a linewidth of ~5cm^{-1} since the spectral resolutions are so close to each other (assuming a Gaussian distribution).

For this reason, when attempting to measure the spectral resolution of a spectrometer it is important to assure that the measured signal is significantly narrow to assure that the measurement is resolution limited. This is typically accomplished by using a low pressure emission lamp, such as an Hg vapor or Ar, since the linewidth of such sources is typically much narrower than the spectral resolution of a dispersive array spectrometer. If narrower resolution is required, a single mode laser can be used.

After the data is collected from the low pressure lamp, the spectral resolution is measured at the full width half maximum (FWHM) of the peak of interest.

Calculating Spectral Resolution:

When calculating the spectral resolution ($\delta\lambda$) of a spectrometer, there are four values you will need to know: the slit width (W_s), the spectral range of the spectrometer ($\Delta\lambda$), the pixel width (W_p), and the number of pixels in the detector (n). It is also important to remember that spectral resolution is defined as the FWHM. One very common mistake when calculating spectral resolution is to overlook the fact that in order to determine the FWHM of a peak, a minimum of three pixels is required, therefore the spectral resolution (assuming the $W_s = W_p$) is equal to three times the pixel resolution ($\Delta\lambda/n$). This relationship can be expanded on to create a value known as resolution factor (RF), which is determined by the relationship between the slit width and the pixel width. As would be expected, when $W_s \approx W_p$ the resolution factor is 3. When $W_s \approx 2W_p$ the resolution factor drops to 2.5, and continues to drop until $W_s > 4W_p$ when the resolution factor levels out to 1.5.

All of this information can be summarized by the following equation,

$$\delta\lambda = \frac{RF \cdot \Delta\lambda \cdot W_s}{n \cdot W_p}.$$

Equation 5-2

For example, if a spectrometer uses a 25µm slit, a 14µm 2048 pixel detector and a wavelength range from 350nm – 1050nm, the calculated resolution will be 1.53nm.

Part 6: Choosing a Fiber Optic

Overview

When configuring a spectrometer for a given experiment, one of the commonly overlooked considerations is in choosing the best fiber optic cable. Although there are many different factors to consider for this choice, this section will focus on the following two key factors: core diameter and absorption.

First, we will briefly review what a fiber optic cable is and how it is used to direct light into a spectrometer. Then, we will discuss the two characteristics stated above and why they are important for determining the throughput of the fiber optic.

Technical Details

A fiber optic can be thought of as a "light pipe". If you consider how the pipes in a home direct water from one location to another by guiding it through twists and turns to the desired location, you can recognize that fiber optics guide light waves in a similar fashion. Instead of directing light to a bathroom or kitchen, though, we are interested in guiding the light into a spectrometer or other optical detection system. This is achieved by a process known as total internal reflection.

In order to understand how total internal reflection is achieved, we must first look at the optical property known as refraction. Refraction arises because the speed of light varies based on the material it is traveling through. As a result, when light transitions from one medium to another, the angle at which the light is traveling is retarded relative to the interface.

The refracting power of a material is defined as

$$n = \frac{c}{v},$$

Equation 6-1

where n is the index of refraction, v is the speed of light in the medium of interest, and c is the speed of light in a vacuum. For example, the index of refraction of air is 1.000293, which shows that the speed of light in air is almost exactly the same as it is in a vacuum, whereas the index of refraction of water is 1.333, showing that light travels 25% slower in water than in a vacuum.

The relationship between the index of refraction and the angle at which light travels is defined by Snell's law

$$n_1 \sin\theta_1 = n_2 \sin\theta_2.$$

Equation 6-2

From this equation, we can see that the refracted angle (θ_2) is dependent on the ratio of the indices of the two materials (n_1/n_2) as well as the incident angle (θ_1). As a result, by controlling the ratio of the indices, one can engineer the refracted angle such that all of the light is reflected back from the interface. This is known as total internal reflection and is the method that allows for light to be contained and guided inside of a fiber optic.

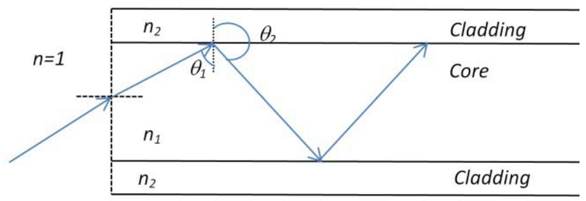


Figure 6-1 Total Internal Reflection in a Fiber Optic

Figure 6-1 illustrates how a fiber optic is designed to facilitate total internal reflection by using two different types of glass, a lower index cladding, and a higher index core in order to trap the light within the core of the fiber and guide it through the fiber optic. This ability to collect light from one place and direct it to another is the reason fiber optic cables are the ideal solution for coupling light into a spectrometer.

Core Diameter

Since all of the light in a fiber optic is collected in the core, the diameter of the core directly correlates to the amount of light that can be transmitted. Based on this principle, it would seem intuitive that a larger core diameter will improve the sensitivity and signal-to-noise ratio of a spectrometer. While this is true to a certain extent, there are other limiting factors that need to be considered when selecting the right fiber optic.

The first thing to consider is the pixel height of the detector. As shown in previous sections, the optical bench of a spectrometer is designed to form an image of the slit onto the detector plane. If the detector pixels are only 200µm in height and you select a 400µm core fiber, 50% of the light incident on the detector is wasted. In this case, there appears to be no advantage gained from having a larger core, but there is a way to get around this issue by adding a cylindrical lens into the optical bench in front of the detector.

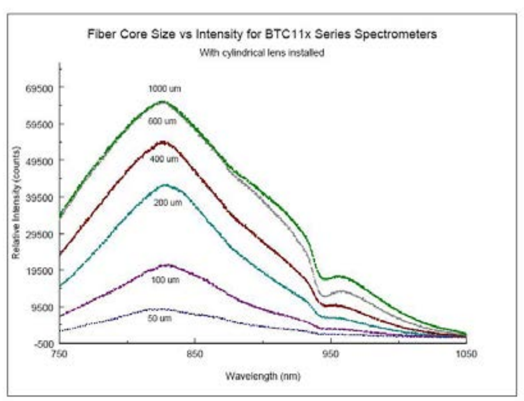


Figure 6-2 Signal Intensity for Various Core Diameters with a Cylindrical Lens Installed

The cylindrical lens focuses the image of the slit in the axis that is orthogonal to the array without distorting the image along the axis that is parallel to the array in the detector plane. This allows for the light from the entire core to be directed onto the pixel, greatly increasing the sensitivity of the overall setup. Figure 6-2 shows that this approach works quite well up to a 600µm core fiber.

Absorption

Another important factor to consider is the absorption properties of the fiber optic. If the light is absorbed by the fiber, it will never be detected by the spectrometer.

During the traditional manufacturing process for fiber-optics, OH^- ions are inadvertently doped into the glass by the plasma torches used to soften the bulb so that it can be drawn into fibers. The presence of these ions creates very strong absorption bands (known as water peaks) in the NIR, which can greatly interfere with the ability to make broad band measurements through this region. In order to avoid this when using fiber optics for NIR spectroscopy, fiber optics need to be manufactured using special low OH^- plasma torches.

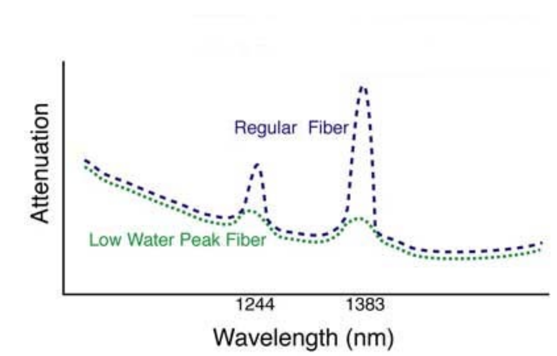


Figure 6-3 Comparison of Standard and Low OH- Fiber Optics in the NIR

Inversely, there are also severe absorption properties in the UV spectrum. This property arises from a photo-chemical effect known as solarization, which worsens over time with extended UV exposure especially below 290nm.

For these reasons, it is extremely important to pay close attention when selecting a fiber for a specific application. When operating in the NIR spectra, make sure to choose low OH- fiber optics (also commonly called NIR fiber optics). When working in the visible and near UV spectral region, standard fiber optics commonly referred to as UV fiber optics are acceptable. When working in the deep UV (<290nm), solarization resistant fibers generally referred to as SRUV fibers are required.

Part 7: Fiber Optic Bundles

Overview

For many spectroscopic applications, proper sampling requires more than just a simple fiber optic patch cord. In cases that require you to measure various samples simultaneously or those that require improved signal to noise ratio (as in the case of weak signals), the use of fiber optic bundles are required. In this section, we will discuss the advantages and disadvantages of some common fiber optic bundle configurations.

Fiber Optic Bundles

A fiber optic bundle is defined as any fiber optic assembly that contains more than one fiber optic in a single cable. The most common example of a fiber optic bundle is known as a bifurcated fiber assembly. The goal of using a bifurcated fiber assembly is either to split a signal or to combine signals. Figure 7-1 shows an example of a typical bifurcated fiber assembly.

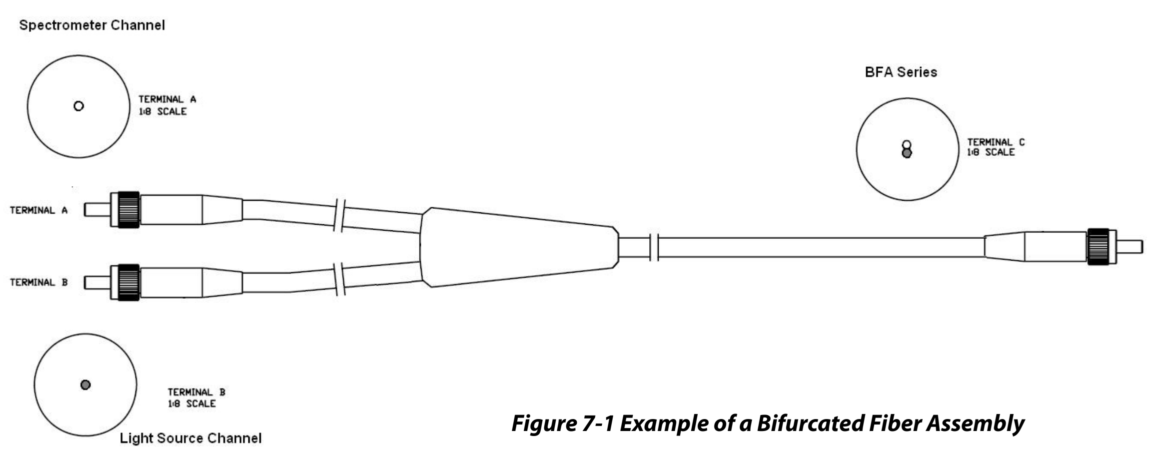


Figure 7-1 Example of a Bifurcated Fiber Assembly

Some of the most common applications for bifurcated fiber assemblies are those that require you to direct light from a sample into two different spectrometers. This is generally used to extend the spectral coverage of the measurement, either to maintain higher resolution or to cover an extended range. For example, if someone is looking to make a broadband measurement from 350 – 1700nm, they need to use both an InGaAs and a Si detector array. By using a bifurcated fiber assembly with one UV fiber and one NIR fiber to direct light into each spectrometer, they can make a simultaneous measurement. Figure 7-2 shows an example spectrum of this type of measurement.

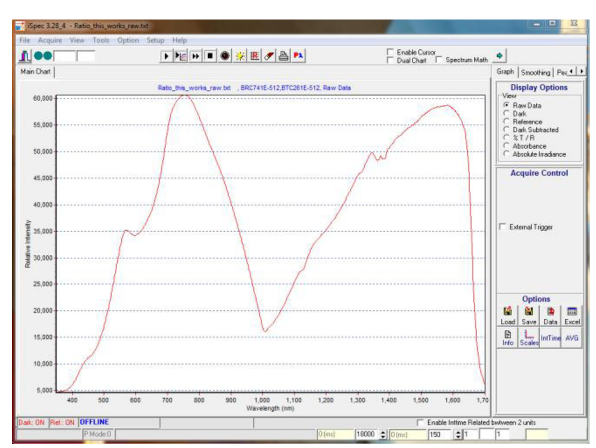


Figure 7-2 Spectrum of a Tungsten Halogen Lamp from 350 – 1700nm

A bifurcated fiber can also be used to couple the signal from multiple samples into the same spectrometer. When using a bifurcated fiber in this fashion, only one sample can emit light at a time, or special care should be taken to make sure the signals do not have spectral overlap.

The same basic principal and applications can be scaled up to trifurcated and quadfurcated fiber assemblies as well. An example of a trifurcated fiber assembly is shown in Figure 7-3 below.

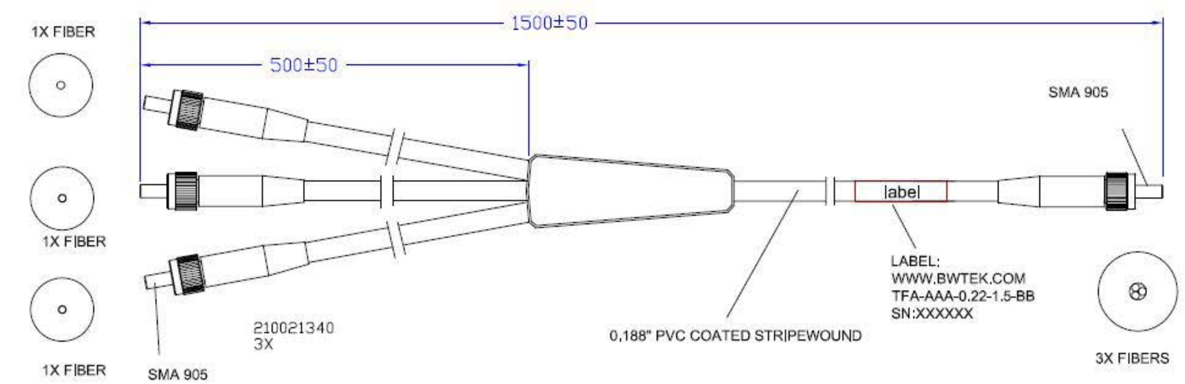


Figure 7-3 Trifurcated Fiber Assembly

Another common bundled fiber optic assembly is called a "round to slit" configuration. This configuration consists of multiple small core fibers (typically 100µm) that are put into one fiber assembly with fibers bundled tightly in a circular fashion on one end, and stacked linearly on top of each other on the other end. The end with fibers stacked linearly on top of one another form a pattern to match the entrance slit of the spectrometer, as shown in Figure 7-4 below.

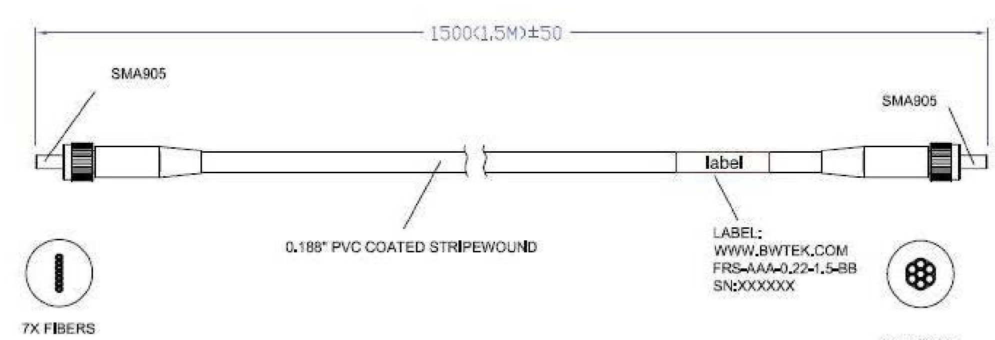


Figure 7-4 "Round to Slit" Fiber Optic Bundle

This configuration allows for much higher throughput into the spectrometer, as opposed to simply using a larger core fiber. As shown in Figure 7-5 below, when a large core fiber is placed in front of the entrance slit of a spectrometer, the majority of the light is vinyetted and doesn't make it into the spectrometer. By contrast, when the smaller fibers are stacked along the entrance slit, significantly more light enters into the spectrometer, allowing for much higher sensitivity and signal to noise. As a result, the slit can remain relatively narrow and maintain resolution without sacrificing throughput.

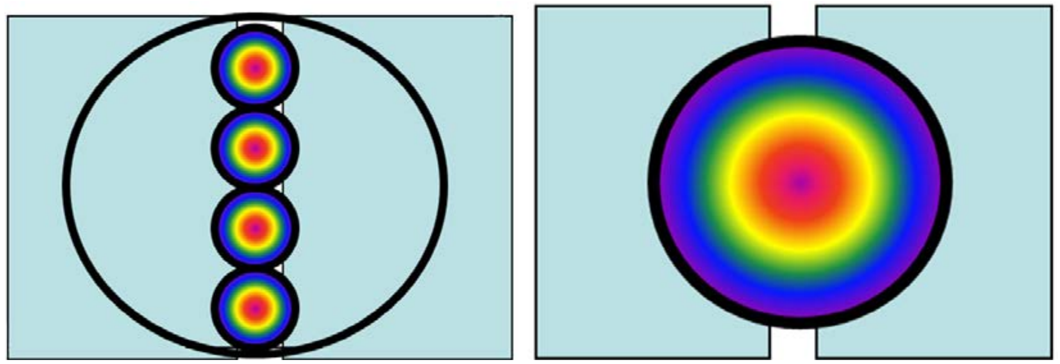


Figure 7-5 Comparison of Stacked Fiber to Single Large Core Fiber

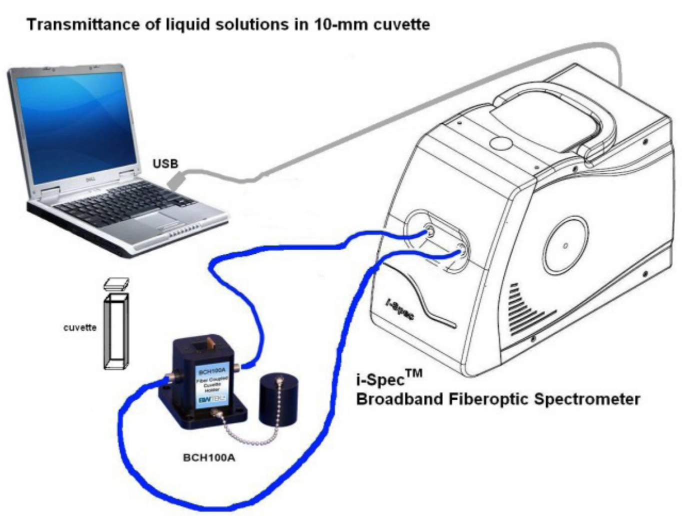


Figure 7-6 Example Transmittance Setup Utilizing a "Round to Slit" Fiber Bundle

When using a fiber optic assembly with a slit configuration, it is important to remember two important details. First, in order to get any benefit from the fiber stacking, a cylindrical lens must be used to prevent the vast majority of the light to be imaged above and below the detector. Second, it is important to properly align the fiber stack to the entrance slit, which can be done by shining light into the round end of the assembly and monitoring the signal as the fiber is rotated in the SMA905 connection port. When peak signal is achieved, the fiber can then be screwed down to lock the position. One very common application using this kind of fiber optic assembly is NIR transmission spectroscopy, where there are very few photons and photon energy is extremely low. An example of a transmittance setup is shown in Figure 7-6.

By combining various combinations of single, round, and stacked configurations with regular, bifurcated, trifurcated, and quadfurcated fiber assemblies, there are countless options available to suit any application. In the next section, we will discuss how to combine fiber bundles with other various opto-mechanical components to create more specific applications.

Part 8: Fiber Optic Probes

Overview

Now that we understand the basics of fiber optic cables and bundles and how they can be used to collect and direct light, we will explore how fiber optics can be packaged and combined with different opto-mechanical components to construct fiber optic probes. Fiber optic probes are the ideal solution for analyzing large or awkwardly shaped samples, monitoring real-time kinetic reactions, sampling in vivo, and any other application where it is difficult to bring the sample to the spectrometer. The flexibility and user-friendliness of fiber optic probes has made them one of the most widespread tools in modern spectroscopy. In this section, we will briefly discuss four of the most common fiber optic probes: reflectance probes, dark-field reflection probes, transflectance dip probes, and Raman probes.

Reflectance Probes

The most basic fiber optic probe is a reflectance probe, which in its simplest form consists of a bifurcated fiber where the distal (bundled) end is placed in a metal sheath instead of a SMA connector, as shown in figure 8-1. This setup allows for one of the bifurcated ends to be connected to a light source, such as a fiber coupled tungsten halogen lamp, while the other is connected to a spectrometer. In this setup, the light from the lamp will travel through the 1st bifurcated end to the distal end of the probe and reflect off of the sample. The reflected light from the sample will then travel from the distal end to the 2nd bifurcated end and into the spectrometer for analysis.

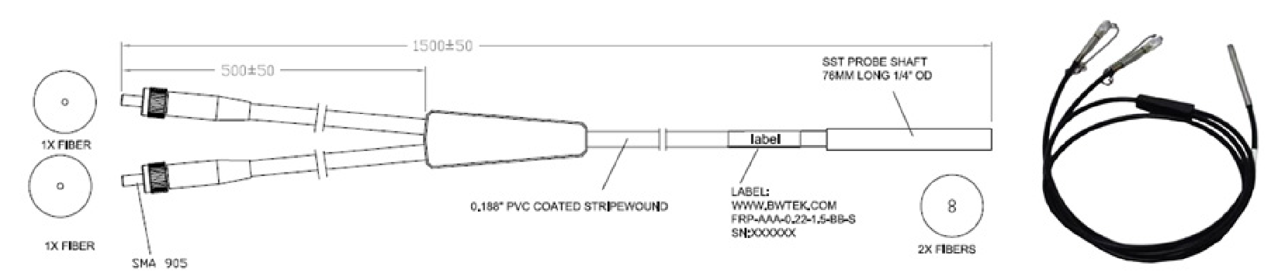


Figure 8-1 Fiber Optic Reflectance Probe

It is important to note that before reflection data can be collected by the spectrometer, the system must be calibrated by taking a reference scan. This reference scan is taken by placing a white light reflectance standard, such as PTFE, at the same geometry from the probe as will be used in the actual measurement. This will allow the spectrometer to measure the ratio between a "perfect" white light reflector and the sample of interest in order to determine which wavelengths of light are reflected and which are absorbed.

When measuring reflection, there are two standard geometries that are employed: 0° and 45° normal to the sample. When measuring at 0°, the probe will pick up the specular (mirror like) component of the reflected light as well as the diffuse component, but when measuring at 45°, the majority of the specular light is not collected by the probe. This is an important consideration for applications such as colorimetry and NIR spectroscopy, where the specular component can distort the spectrum and skew the results.

A slightly more complex approach to the design of reflectance probes is to employ a round-to-slit fiber optic bundle. As described in the previous section, this is one common approach to overcoming the issue of weak photon energy in the NIR. In many reflection probes designed to work in the NIR, this method is applied by stacking 6 fibers on the bifurcated end attached to the spectrometer and employing a 6-around-1 configuration on the distal end. The 6 outer fibers are going to the slit configuration on the spectrometer and the center fiber connects to the light source in the other bifurcated end, as shown in figure 8-2 below.

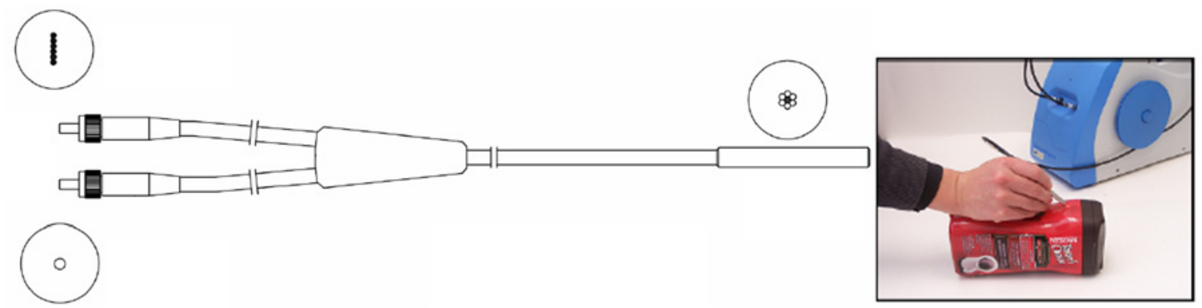


Figure 8-2 Fiber Optic Reflection Probe with Slit-to-Bundle Configuration

Reflectance probes can also be scaled up to trifurcated and quadfurcated designs in order to increase the spectral range over which the reflection data is collected.

Dark Field Reflectance Probes

Specular reflection does not contain any useful information for NIR spectroscopy, but it can typically be removed by measuring the sample at a 45° angle. However, if the sample cannot be measured at a 45° angle, such as when working in a field or production setting, dark-field illumination (a method borrowed from microscopy) can be used. The dark-field probe works by illuminating the sample with an annulus of 7 fibers. The diffusely reflected light is then collected by a bundle of 7 fibers in the center of the probe which directs the light to the spectrometer in a slit configuration, as shown in figure 8-3 below. The specular components of the light are further reduced by the use of a lens at the distal end of the probe to redirect the light away from the center fiber bundle.

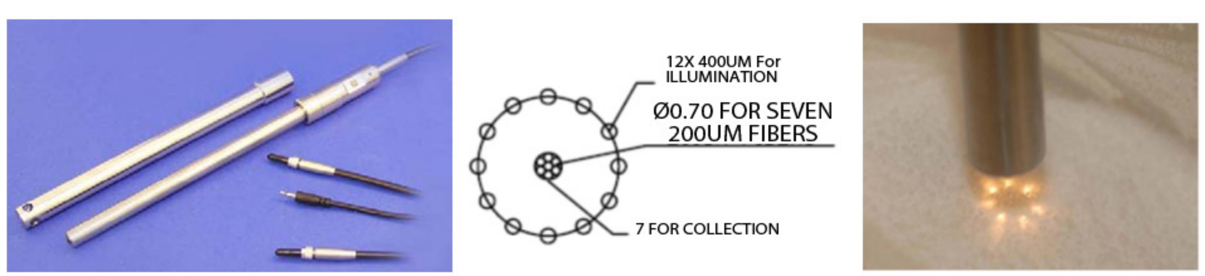


Figure 8-3 Dark-field Fiber Optic Probe

Transflectance Dip Probes

While reflection probes can be used to measure liquids, they are primarily designed for the measurement of solids. When measuring liquid samples, a dip probe is generally the probe of choice since it can be submerged into the sample, allowing for kinetic data to be collected. The design of a fiber dip probe is very similar to that of a reflection probe, though special effort is taken to guarantee that it is liquid tight and inert. The key functional difference is the presence of a cavity which, when immersed, fills with the liquid sample. This cavity contains an optically transparent window placed at the distal end of the fiber and a small mirror placed at the bottom of the cavity to reflect the transmitted light back through the sample and into the collection fiber as shown below in figure 8-4. This setup is commonly referred to as a transflectance, due to the fact that this method combines transmission and reflection, doubling the optical path length.

It is important to note that transflectance measurements can also be made using a dark-field reflectance probe configuration. Figure 8-3 shows an adaptor which can be placed over the dark-field probe to enable transflectance measurements in liquids and slurries.

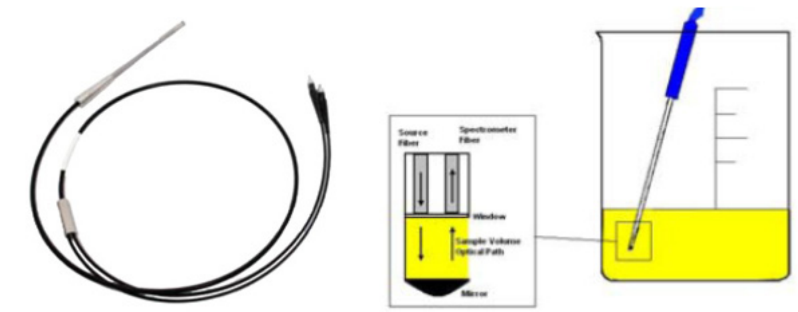


Figure 8-4 Fiber Optic Transflectance Dip Probe

Raman Probes

The last probe that we will discuss in this section is called a Raman probe, which is used to measure the inelastic scattering of light off of a sample. Raman scattering is a nonlinear effect resulting in the shift in wavelength from a known monochromatic source. This shift is equal to the vibrational frequency of the molecular bonds in the material. As a result, a Raman probe must be capable of directing and focusing the monochromatic excitation source (typically a laser) to the sample, collecting the scattered light and then directing it to the spectrometer. Figure 8-5 shows a typical design for a Raman probe.

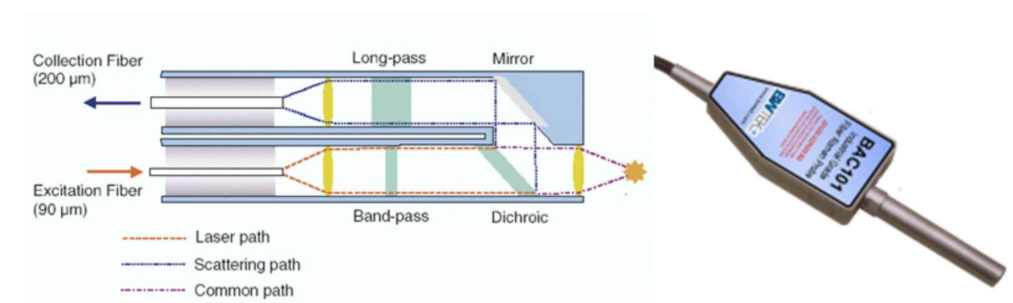


Figure 8-5 Typical Design of a Raman Probe

Since a pure signal is extremely important to Raman spectroscopy, a narrow band-pass filter is placed in the optical path of the excitation source before it reaches the sample. It is also important to note that since the Raman effect is extremely weak, the signal must be collected at a 0° angle normal to the sample. As discussed earlier, this causes interference from specular reflections, which in this case is referred to as Rayleigh scattering. Therefore, it is essential to filter the collected signal through the use of a long pass filter before it is directed to the spectrometer.

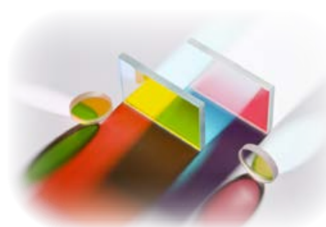
The Raman probe is a perfect example of how fiber optics can be combined with other optical components to enable simple and flexible measurement of even the most complicated spectroscopy.

Applications of Modular Spectroscopy

Reflectance:

- Reflectance is determined by first measuring a white reflectance standard and then measuring the surface of the material of interest in order to calculate the ratio between the two. Reflectance is one of the fundamental spectral properties of a material, and is one of the simplest measurements to make using a spectrometer.
- There are two primary components in a reflected spectrum: specular and diffuse. Each contains different information about the material. Depending on the component of interest, reflectance can be measured using a variety of accessories. Integrating spheres and fiber optic reflectance probes measure both diffuse and/or specular components, whereas a simple collimating lense can be used if you are only interested in the specular components.
- Reflectance can be used to characterize color (both specular & diffuse), coated & un-coated optical components, thin-film thickness, semiconductors, precious metals, and countless other materials.

Transmission:

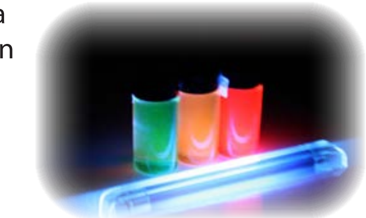


- Transmission, which is also one of the most fundamental spectral properties of a material, has a very similar definition to reflectance. Transmission is defined as the ratio of the spectrum of incident light normal to the surface of the material and the spectrum of the light that is transmitted out of the other side of the material.
- Transmission measurements can be taken on solid, liquid and gas phase materials. Typically for solid materials, these measurements are made using two collimating lenses. For more challenging samples like liquids and gases, fiber coupled cuvette holders, flow cells, or immersion probes are used.
- Transmittance data is typically used for the characterization of optical components.

Absorption:

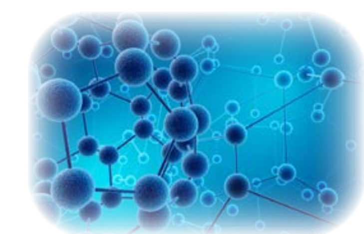
- Absorption is the log of transmission, but is the preferred method for most molecular spectroscopic analyses of materials. Absorption can be measured at any wavelength but is typically employed in the UV (200 - 400nm) and NIR (900 - 2200nm) ranges.
- Typical absorption set-ups are similar to transmission set-ups utilizing cuvette holders, flow cells, and immersion probes.
- Absorption allows for information to be gathered about the fundamental structure of a molecule and can be used for both qualitative and quantitative analyses.

Fluorescence:



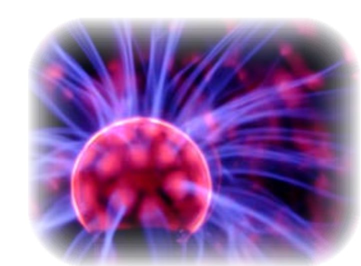
- In fluorescence spectroscopy, a molecule is analyzed by exciting the species with a high energy photon (traditionally in the UV). This causes the electrons to transition from a ground state to a higher energy state. When the electron returns to the ground state, it emits a photon with lower energy which is equal to the energy level of which it was excited to. Therefore, by measuring the spectrum of the emitted light, you can investigate the different electronic and vibrational states of the molecule.
- Fluorescence spectroscopy can also be used to identify non-fluorescent compounds by tagging it with another molecule with known fluorescent properties and an affinity for the compound of interest.
- Typical fluorescence setups will employ a UV excitation source such as a pulsed xenon lamp or a UV laser directed onto a sample with a dichroic mirror to redirect the emitted light into a spectrometer. A right-angle (3-port) cuvette holder can also be used for liquid or powder samples.

Raman:



- Raman spectroscopy, a molecular spectroscopy which is observed as inelastically scattered light, allows for the interrogation and identification of vibrational (phonon) states of molecules. As a result, Raman spectroscopy provides an invaluable analytical tool for molecular finger printing as well as monitoring changes in molecular bond structure (e.g. state changes and stresses & strains).
- In comparison to other vibrational spectroscopy methods, such as FT-IR and NIR, Raman has several major advantages. These advantages stem from the fact that the Raman effect manifests itself in the light scattered off of a sample as opposed to the light absorbed by a sample. Similar to FT-IR, Raman spectroscopy is highly selective which allows Raman to identify and differentiate molecules and chemical species that are very similar.
- Since Raman spectroscopy is such a weak process, it is imperative that you use a TE Cooled spectrometer and a high quality laser.

Emission:



- Emission measurements are the simplest spectroscopic technique, and may be the most commonly used in history. When measuring emission, any variety of accessories can be utilized since in most cases you are not restricted by the size of the sample. Most of the time, a standard fiber optic patch cable is perfectly acceptable for the measurement.
- Examples of these types of measurements include elemental emission spectroscopy, spectral irradiance measurements, laser characterization, plasma endpoint detection, and countless others.

Quest™ *U*

High Performance Low Stray Light CCD Spectrometer

The Quest™ *U* is a linear CCD array spectrometer optimized for UV performance using a low straylight optical bench. It features a 2048 element detector, built-in 16-bit digitizer, USB 2.0 interface with a >2.0 MHz readout speed, and external trigger. The Quest™ *U* is also temperature compensated, which greatly reduces the thermal drift to ~15 counts/°C. This decreases baseline drift and sustains the dynamic range.

The Quest™ *U* is available in two standard spectral configurations; 200nm - 400nm and 200nm - 850nm. Custom configurations and RS232 communication interface are available for OEM applications.

Applications:

- **UV, Vis, and NIR: Spectroscopy / Spectroradiometry / Spectrophotometry**
- **Wavelength Identification**
- **Absorbance**
- **Reflectance**
- **OEM Optical Instrumentation**

Features:

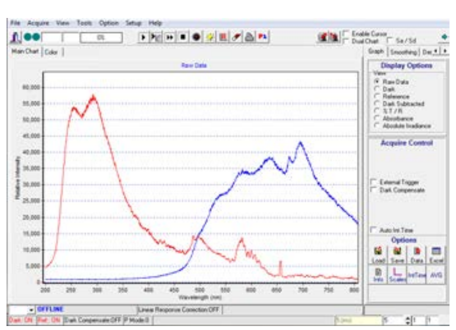
- Thermal Drift ~15 Counts/°C (Typical)
- Low Stray UV Light
- UV and UV/NIR Standard
- < 0.4nm Spectral Resolution
- 16-bit Digitizer
- 1ms Minimum Integration Time
- >2.0 MHz Readout Speed
- Plug-and-play USB 2.0

Accessories:

- Fiber Patch Cords
- Light Sources
- Cuvette Holders
- Inline Filter Holders
- Fiber Optic Probes

Software:

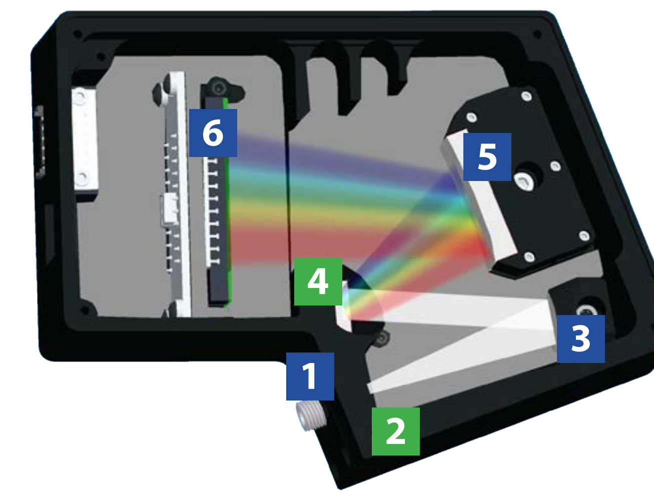
BWSpec™ is a spectral data acquisition software with a wide range of tools that are designed to perform complex measurements and calculations at the click of a button. It allows the user to choose between multiple data formats and offers optimization of scanning parameters, such as integration time. In addition to powerful data acquisition and data processing, other features include automatic dark removal, spectrum smoothing, and manual/auto baseline correction.



Specifications:

Power Input	USB @ < 0.35 Amps
Detector Type	Response Enhanced Linear CCD Array
Detector Pixel Format	2048 x 1 Elements @ 14µm x 200µm Per Element
Spectrograph f/#	3.6
Spectrograph Optical Layout	Czerny-Turner
Dynamic Range	275 (Typical)
Digitizer Resolution	16-bit or 65,535:1
Readout Speed	>2.0 MHz
Data Transfer Speed	Up to 660 Spectra Per Second Via USB 2.0
Integration Time	1 - 65,535ms
Thermal Drift	~29 Counts/°C (Max)
Aux Port	External Trigger, Digital IOs
Operating Temperature	5°C - 35°C
Operational Relative Humidity	85% Noncondensing
Weight	~ 0.8 lbs (0.37 kg)
Dimensions	4.9in x 3.6in x 1.4in (124mm x 91mm x 35mm)
Computer Interface	USB 2.0 / 1.1 and Enhanced RS232
Operating Systems	Windows: XP, Vista, 7

Technical Details



Standard

Fiber Coupler

1 Secures Fiber to Ensure Repeatable Results

By coupling a fiber optic to the SMA 905 adaptor, light will be guided to the slit and optically matched, ensuring reproducibility. For free space sampling, a diffuser or lens assembly can be connected directly to the SMA 905 adaptor.

Configurable

Entrance Slit

2 Determines Photon Flux and Spectral Resolution

Light entering into a spectrometer's optical bench is vinyetted by a pre-mounted and aligned slit. This ultimately determines the spectral resolution and throughput of the spectrometer after grating selection. We offer a variety of slit widths to match your specific application needs: from 10µm - 200µm wide, with custom slits available.

Slit Option	Dimensions	Approx. Resolution 200-400nm
10µm	10µm wide x 1mm high	~0.4nm
25µm	25µm wide x 1mm high	~0.6nm
50µm	50µm wide x 1mm high	~1.0nm
100µm	100µm wide x 1mm high	~1.6nm
200µm	200µm wide x 1mm high	~3.0nm
Custom Slit Widths Available		

Standard

Collimating Mirror

3 Collimates and Redirects Light Towards Grating

Both mirrors are *f/#* matched focusing mirrors coated with $AlMg_2$, which produces approximately 95% reflectance when working in the UV-Vis spectrum. Aluminum (Al) provides reflectance and magnesium (Mg_2) protects the aluminum from oxidation.

Configurable

Diffraction Grating

4 Diffracts Light, Separating Spectral Components

The groove frequency of the grating determines two key aspects of the spectrometer's performance: the wavelength coverage and the spectral resolution. When the groove frequency is increased, the instrument will achieve higher resolution, but the wavelength coverage will decrease. Inversely, decreasing the groove frequency increases wavelength coverage at the cost of spectral resolution.

The blaze angle or blaze wavelength of the grating is also a key parameter in optimizing the spectrometer's performance. The blaze angle determines the maximum efficiency that the grating will have in a specific wavelength region.

Best Efficiency	Spectral Coverage (nm)	Grating
UV	200 - 400	1800/250
UV - NIR	200 - 850	600/250
Custom Configurations Available		

Standard

Focusing Mirror

5 Refocuses Dispersed Light onto Detector

Both mirrors are *f/#* matched focusing mirrors coated with $AlMg_2$, which produces approximately 95% reflectance when working in the UV-Vis spectrum. Aluminum (Al) provides reflectance and magnesium (Mg_2) protects the aluminum from oxidation.

Standard

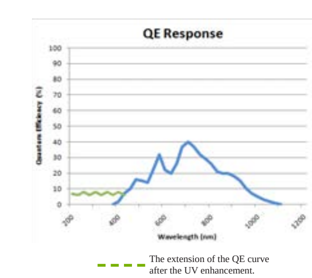
Array Detector

6 Measures Entire Spectrum Simultaneously

The Quest™ *U* features a 2048 x 1 linear CCD array detector with a 14µm pixel width and > 2000 active pixels. As the incident light strikes the individual pixels across the CCD, each pixel represents a portion of the spectrum that the electronics can then translate and display with a given intensity using BWSpec™ software.

The quantum efficiency (QE) and noise level of the array detector greatly influences the spectrometer's sensitivity, dynamic range and signal-to-noise ratio. The spectral acquisition speed of the spectrometer is mainly determined by the detector response over a wavelength region.

Specifications	
Wavelength Range	200nm - 850nm
Pixels	2048
Pixel Size	14µm x 200µm
Well Depth	~65,000 e
Digitization Rate	>2.0 MHz



Quest™ *X*

Compact High Performance, CCD Spectrometer

The Quest™ *X* is a linear CCD array spectrometer optimized for UV performance using a low straylight optical bench. It features a 2048 element detector, built-in 16-bit digitizer, USB 2.0 interface with a >2.0 MHz readout speed, and external trigger. The Quest™ *X* is also temperature compensated, which greatly reduces the thermal drift to ~15 counts/°C. This decreases baseline drift and sustains the dynamic range.

The Quest™ *X* is ideal for most UV, Vis, and NIR applications with spectral configurations from 200nm to 1050nm and resolutions between 0.5nm and 4.0nm. Custom configurations and RS232 communication interface are available for OEM applications.

Applications:

- **UV, Vis, and NIR: Spectroscopy / Spectroradiometry / Spectrophotometry**
- **Wavelength Identification**
- **Absorbance**
- **Reflectance**
- **OEM Optical Instrumentation**

Features:

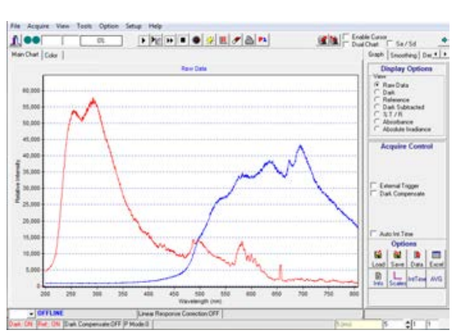
- Thermal Drift ~15 Counts/°C (Typical)
- UV - NIR (200nm - 1050nm)
- < 0.5nm Spectral Resolution
- 16-bit Digitizer
- 1ms Minimum Integration Time
- >2.0 MHz Readout Speed
- Plug-and-play USB 2.0

Accessories:

- Fiber Patch Cords
- Light Sources
- Cuvette Holders
- Inline Filter Holders
- Fiber Optic Probes

Software:

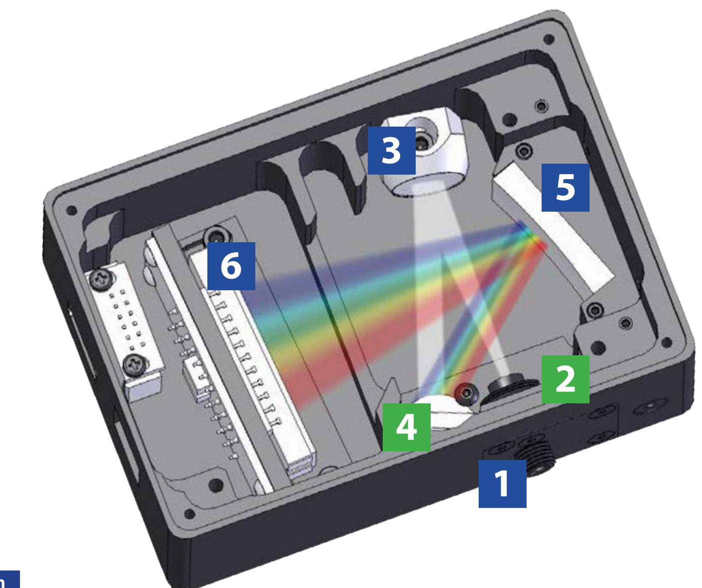
BWSpec™ is a spectral data acquisition software with a wide range of tools that are designed to perform complex measurements and calculations at the click of a button. It allows the user to choose between multiple data formats and offers optimization of scanning parameters, such as integration time. In addition to powerful data acquisition and data processing, other features include automatic dark removal, spectrum smoothing, and manual/auto baseline correction.



Specifications:

Power Input	USB @ < 0.35 Amps
Detector Type	Response Enhanced Linear CCD Array
Detector Pixel Format	2048 x 1 Elements @ 14µm x 200µm Per Element
Spectrograph f/#	3.6
Spectrograph Optical Layout	Crossed Czerny-Turner
Dynamic Range	275 (Typical)
Digitizer Resolution	16-bit or 65,535:1
Readout Speed	>2.0 MHz
Data Transfer Speed	Up to 660 Spectra Per Second Via USB 2.0
Integration Time	1 - 65,535ms
Thermal Drift	~29 Counts/°C (Max)
Aux Port	External Trigger, Digital IOs
Operating Temperature	5°C - 35°C
Operational Relative Humidity	85% Noncondensing
Weight	~ 0.75 lbs (0.34 kg)
Dimensions	4.02in x 2.64in x 1.34in (102mm x 67mm x 34mm)
Computer Interface	USB 2.0 / 1.1 and Enhanced RS232
Operating Systems	Windows: XP, Vista, 7

Technical Details



Standard

Fiber Coupler

1 Secures Fiber to Ensure Repeatable Results

By coupling a fiber optic to the SMA 905 adaptor, light will be guided to the slit and optically matched, ensuring reproducibility. For free space sampling, a diffuser or lens assembly can be connected directly to the SMA 905 adaptor.

Configurable

Entrance Slit

2 Determines Photon Flux and Spectral Resolution

Light entering into a spectrometer's optical bench is vinyetted by a pre-mounted and aligned slit. This ultimately determines the spectral resolution and throughput of the spectrometer after grating selection. We offer a variety of slit widths to match your specific application needs: from 10µm - 200µm wide, with custom slits available.

Slit Option	Dimensions	Approx. Resolution 350-1050nm
10µm	10µm wide x 1mm high	~1.0nm
25µm	25µm wide x 1mm high	~1.5nm
50µm	50µm wide x 1mm high	~2.2nm
100µm	100µm wide x 1mm high	~4.0nm
200µm	200µm wide x 1mm high	Call
Custom Slit Widths Available		

Standard

Collimating Mirror

3 Collimates and Redirects Light Towards Grating

Both mirrors are *f*/# matched focusing mirrors coated with $AlMg_2$, which produces approximately 95% reflectance when working in the UV-Vis spectrum. Aluminum (Al) provides reflectance and magnesium (Mg_2) protects the aluminum from oxidation.

Configurable

Diffraction Grating

4 Diffracts Light, Separating Spectral Components

The groove frequency of the grating determines two key aspects of the spectrometer's performance: the wavelength coverage and the spectral resolution. When the groove frequency is increased, the instrument will achieve higher resolution, but the wavelength coverage will decrease. Inversely, decreasing the groove frequency increases wavelength coverage at the cost of spectral resolution.

The blaze angle or blaze wavelength of the grating is also a key parameter in optimizing the spectrometer's performance. The blaze angle determines the maximum efficiency that the grating will have in a specific wavelength region.

Best Efficiency	Spectral Coverage (nm)	Grating
UV / NIR	200 - 850	600/250
UV / NIR	350 - 1050	600/400
Vis	380 - 750	900/500
Vis / NIR	550 - 1050	830/800
NIR	750 - 1050	1200/750
Custom Configurations Available		

Standard

Focusing Mirror

5 Refocuses Dispersed Light onto Detector

Both mirrors are *f*/# matched focusing mirrors coated with $AlMg_2$, which produces approximately 95% reflectance when working in the UV-Vis spectrum. Aluminum (Al) provides reflectance and magnesium (Mg_2) protects the aluminum from oxidation.

Standard

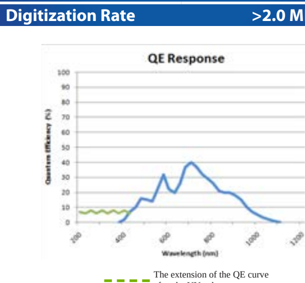
Array Detector

6 Measures Entire Spectrum Simultaneously

The Quest™ *X* features a 2048 x 1 linear CCD array detector with a 14µm pixel width and > 2000 active pixels. As the incident light strikes the individual pixels across the CCD, each pixel represents a portion of the spectrum that the electronics can then translate and display with a given intensity using BWSpec™ software.

The quantum efficiency (QE) and noise level of the array detector greatly influences the spectrometer's sensitivity, dynamic range and signal-to-noise ratio. The spectral acquisition speed of the spectrometer is mainly determined by the detector response over a wavelength region.

Specifications	
Wavelength Range	200nm - 1050nm
Pixels	2048
Pixel Size	14µm x 200µm
Well Depth	~65,000 e
Digitization Rate	>2.0 MHz



Spectrometer

Glacier® X

Compact High Performance TE Cooled CCD Spectrometer

The Glacier® X is a TE Cooled linear CCD array spectrometer. It features a 2048 element detector, built-in 16-bit digitizer, and USB 2.0 interface. Compared to non-cooled CCD spectrometers, the Glacier® X offers higher dynamic range, significantly reduced dark counts, and superior long-term operation stability, making it ideal for low light level detection and long-term monitoring applications.

The Glacier® X is ideal for most UV, Vis, and NIR applications with spectral configurations from 200nm to 1050nm and resolutions between 0.2nm and 4.5nm. Custom configurations and application support are available for OEM applications.

Applications:

- **UV, Vis, and NIR: Spectroscopy / Spectroradiometry / Spectrophotometry**
- **Wavelength Identification**
- **Absorbance**
- **Reflectance**
- **OEM Optical Instrumentation**

Features:

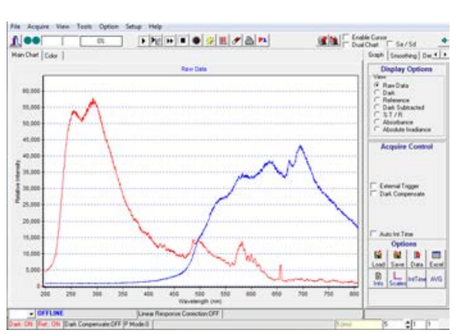
- UV - NIR Ranges
- <0.2nm Resolution
- TE Cooled / Regulated
- 16-bit Digitizer
- 500 kHz Readout Speed
- Plug-and-play USB 2.0
- OEM Version Available

Accessories:

- Fiber Patch Cords
- Light Sources
- Cuvette Holders
- Inline Filter Holders
- Fiber Optic Probes

Software:

BWSpec™ is a spectral data acquisition software with a wide range of tools that are designed to perform complex measurements and calculations at the click of a button. It allows the user to choose between multiple data formats and offers optimization of scanning parameters, such as integration time. In addition to powerful data acquisition and data processing, other features include automatic dark removal, spectrum smoothing, and manual/auto baseline correction.



Specifications:

DC Power Input	5V DC @ < 1.5 Amps
AC Adapter Input	100 - 240VAC 50/60 Hz, 0.5A @ 120VAC
Detector Type	Response Enhanced Linear CCD Array
Pixels	2048 x 1 Elements @ 14µm x 200µm Per Element
Spectrograph f/#	3.2
Spectrograph Optical Layout	Crossed Czerny-Turner
Dynamic Range	300 (Typical)
Digitizer Resolution	16-bit or 65,535:1
Readout Speed	500 kHz
Data Transfer Speed	Up to 180 Spectra Per Second Via USB 2.0
Integration Time	5 ~ 65,535ms x Multiplier
External Trigger	Aux Port
Operating Temperature	15°C - 35°C
Operational Relative Humidity	85% Noncondensing
TE Cooling	14°C
Weight	~ 1.32 lbs (0.60 kg)
Dimensions	5in x 1.5in x 3.6in (127.0mm x 39.0mm x 90.7mm)
Computer Interface	USB 2.0 / 1.1
Operating Systems	Windows: XP, Vista, 7

Technical Details

Spectrometer

Standard

Fiber Coupler

1 Secures Fiber to Ensure Repeatable Results

By coupling a fiber optic to the SMA 905 adaptor, light will be guided to the slit and optically matched, ensuring reproducibility. For free space sampling, a diffuser or lens assembly can be connected directly to the SMA 905 adaptor.

Configurable

Entrance Slit

2 Determines Photon Flux and Spectral Resolution

Light entering into a spectrometer's optical bench is vinyetted by a pre-mounted and aligned slit. This ultimately determines the spectral resolution and throughput of the spectrometer after grating selection. We offer a variety of slit widths to match your specific application needs: from 10µm - 200µm wide, with custom slits available.

Slit Option	Dimensions	Approximate Resolution 350 - 1050nm
10µm	10µm wide x 1mm high	~1.1nm
25µm	25µm wide x 1mm high	~1.4nm
50µm	50µm wide x 1mm high	~2.2nm
100µm	100µm wide x 1mm high	~4.3nm
200µm	200µm wide x 1mm high	Call
Custom Slit Widths Available		

Standard

Collimating Mirror

3 Collimates and Redirects Light Towards Grating

Both mirrors are f/# matched focusing mirrors coated with $AlMg_2$, which produces approximately 95% reflectance when working in the UV-Vis spectrum. Aluminum (Al) provides reflectance and magnesium (Mg_2) protects the aluminum from oxidation.

Configurable

Diffraction Grating

4 Diffracts Light, Separating Spectral Components

The groove frequency of the grating determines two key aspects of the spectrometer's performance: the wavelength coverage and the spectral resolution. When the groove frequency is increased, the instrument will achieve higher resolution, but the wavelength coverage will decrease. Inversely, decreasing the groove frequency increases wavelength coverage at the cost of spectral resolution.

The blaze angle or blaze wavelength of the grating is also a key parameter in optimizing the spectrometer's performance. The blaze angle determines the maximum efficiency that the grating will have in a specific wavelength region.

Best Efficiency	Spectral Coverage (nm)	Grating
UV / Vis	200-400	1800/250
UV / NIR	200-800	716/222
UV / Vis	250-600	1200/250
UV	280-370	3600/240
UV / NIR	300-900	600/400
UV / NIR	350-1050	700/530
Vis	380-750	900/500
Vis / NIR	400-800	1200/500
Vis / NIR	450-1050	830/800
Vis	530-700	1800/500
Vis / NIR	600-800	1714/650
Vis / NIR	750-1050	1200/750
Custom Configurations Available		

Standard

Focusing Mirror

5 Refocuses Dispersed Light onto Detector

Both mirrors are f/# matched focusing mirrors coated with $AlMg_2$, which produces approximately 95% reflectance when working in the UV-Vis spectrum. Aluminum (Al) provides reflectance and magnesium (Mg_2) protects the aluminum from oxidation.

Standard

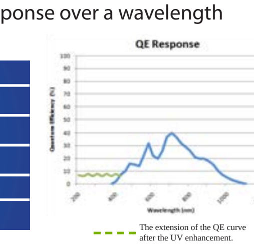
Array Detector

6 Measures Entire Spectrum Simultaneously

The Glacier® X features a 2048 x 1 linear TE Cooled CCD array detector with a 14µm pixel width and > 2000 active pixels. As the incident light strikes the individual pixels across the CCD, each pixel represents a portion of the spectrum that the electronics can then translate and display with a given intensity using BWSpec™ software.

The quantum efficiency (QE) and noise level of the array detector greatly influences the spectrometer's sensitivity, dynamic range and signal-to-noise ratio. The spectral acquisition speed of the spectrometer is mainly determined by the detector response over a wavelength region.

Specifications	
Wavelength Range	200nm - 1050nm
Pixels	2048
Pixel Size	14µm x 200µm
Well Depth	~90,000 e
Digitization Rate	500 kHz



Standard

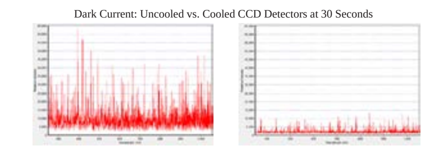
Thermoelectric Cooler

7 Reduces Dark Noise and Increases Detection Limits

Cooling an array detector with a built-in thermoelectric cooler (TEC) is an effective way to reduce dark current and noise, as well as to enhance the dynamic range and detection limit.

When the CCD detector array is cooled from a room temperature of 25°C down to 14°C by the TEC, the dark current is reduced by a factor of 4 and the dark noise is reduced by a factor of 2. This allows the spectrometer to operate at longer exposure times and to detect weaker optical signals.

Dark Current: Uncooled vs. Cooled CCD Detectors at 30 Seconds



Glacier® *X* Preconfigured Models

TE Cooled CCD Array Preconfigured Spectrometer

The Glacier® X is the smallest TE cooled spectrometer on the market and is ideal for low light level applications such as fluorescence and Raman spectroscopy. B&W Tek's proprietary TE Cooling technology allows light to be integrated for sufficient time to accumulate measurable signals for detection, without being saturated with dark noise. The result is a far superior signal-to-noise ratio for long integration times.

The Glacier X is available in two preconfigurations. The first is for 785nm Raman spectroscopy with a wavelength range of 3215cm^{-1} from the Rayleigh line and a resolution of ~10cm^{-1}. Second, the Glacier X is preconfigured for fluorescence, with a 100 micron slit, 350nm – 1050nm wavelength range. Both configurations include a cylindrical lens, which provides up to a 3x boost in sensitivity.

Features:

- High Dynamic Range
- Reduced Dark Noise
- Superior Long-term Stability

Fluorescence:

Spectral Range	350nm - 1050nm
Slit Width	100µm

Fluorescence Accessories:

- Fiber Optic Patch Cords
- Light Sources
- Cuvette Holder
- Inline Filter Holder

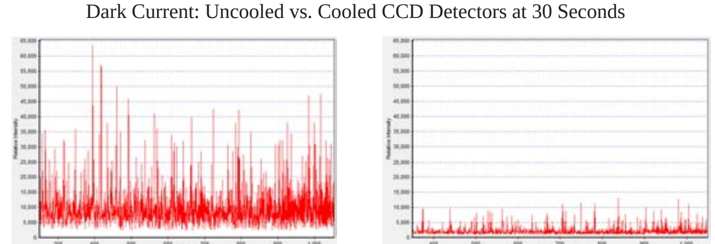
Raman:

Spectral Range	750nm - 1050nm
Slit Width	25µm

Raman Accessories:

- CleanLaze Spectrum Stabilized Laser
- Lab & Industrial Grade Raman Probes
- Raman Cuvette Holder
- Raman Liquid Sample Flow Cells

Dark Current: Uncooled vs. Cooled CCD Detectors at 30 Seconds



Room Temperature — Cooled to 14°C

View Pages 40-41 for More Detailed Specifications

Glacier® *T*

High Resolution TE Cooled CCD Spectrometer for Raman Spectroscopy

The Glacier® *T* is a high resolution TE Cooled linear CCD array spectrometer designed for Raman spectroscopy. The Glacier *T* comes preconfigured for 532nm or 785nm excitation with a wide spectral range or high resolution option.

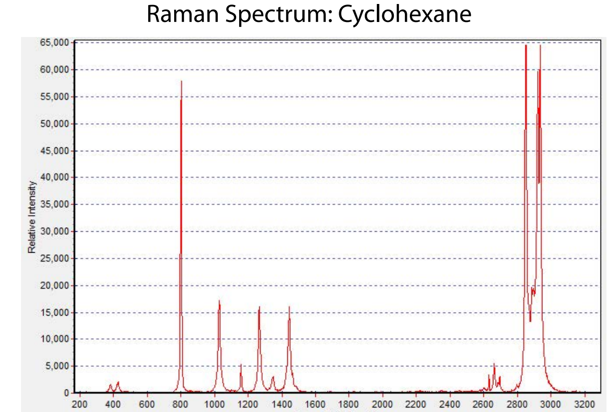
Equipped with 2048 elements, built-in 16-bit digitizer, and high-speed USB 2.0 interface, this double pass transmission based spectrometer will continuously deliver optimized high throughput results.

Combining a Glacier® *T* spectrometer to its corresponding excitation laser system and Raman probe provides a module level Raman system or OEM building block.

Features:

- 3.0cm^{-1} - 4.5cm^{-1} Resolution*
- 0cm^{-1} up to 4000cm^{-1} Raman Shift*
- Fast F/2 Spectrograph
- 14°C TE Cooled Detector
- 16-bit Digitizer
- OEM Building Block

Raman Spectrum: Cyclohexane



Specifications:

DC Power Input	5V DC < 1.5 Amps
AC Adapter Input	100 - 240VAC 50/60 Hz, 0.5A @ 120VAC
Detector Type	Response Enhanced 2048 Element Linear Silicon CCD Array
Pixels	2048 x 1 Elements @ 14µm x 200µm Per Element
Spectrograph f/#	2.0
Slit	20mm (785nm), 10mm (532nm)
Spectrograph Optical Layout	Transmission
Dynamic Range	300 (Typical)
Digitizer Resolution	16-bit or 65,535:1
Readout Speed	500 kHz
Data Transfer Speed	Up to 180 Spectra Per Second Via USB 2.0
Integration Time	5 ~ 65,535ms x Multiplier
External Trigger	Aux Port
Operating Temperature	15°C - 35°C
Operational Relative Humidity	85% Noncondensing
TE Cooling	14°C
Weight	~3.9 lbs (1.8 kg)
Dimensions	7.5in x 3.7in x 3.5in (191mm x 94mm x 90mm)
Computer Interface	USB 2.0 / 1.1
Operating Systems	Windows: XP, Vista (32-bit), 7 (32-bit)

Accessories:

- Lab Grade Probe
- Industrial Grade Probe
- 532nm Laser
- 785nm Laser

Available Configurations:

Model #	Spectral Range	Spectral Resolution	Approximate Raman Shift	Resolution*
BTC162E-532S	532 - 676nm	~ 0.15nm	0cm^{-1} - 4000cm^{-1}	~ 4.0cm^{-1} @ 614nm
BTC162E-532H	532 - 645nm	~ 0.11nm	0cm^{-1} - 3300cm^{-1}	~ 3.0cm^{-1} @ 614nm
BTC162E-785S	780 - 1050nm	~ 0.37nm	0cm^{-1} - 3200cm^{-1}	~ 4.5cm^{-1} @ 912nm
BTC162E-785H	784 - 996nm	~ 0.29nm	0cm^{-1} - 2700cm^{-1}	~ 3.5cm^{-1} @ 912nm

*Varies by Configuration

Prime™ *X*

High Performance Back-thinned CCD Spectrometer

The Prime™ *X* features a high sensitivity -10°C TE Cooled linearly summed 512 x 58 element back-thinned (BT) CCD detector. The BT CCD offers superior quantum efficiency, signal-to-noise, and dynamic range, making it ideal for a variety of UV/Vis/NIR applications. A 1024 x 58 BT CCD is also available for increased range and resolution. Other features include a built-in 16-bit digitizer, USB 2.0 interface and external trigger.

Standard spectral configurations range from 200nm - 1050nm and resolutions range between 1.0nm and 10.0nm. Custom configurations are available for OEM applications.

Applications:

- **Low Light Level UV and NIR Spectroscopy**
- **Raman and Fluorescence Spectroscopy**
- **Remote Sensing**
- **DNA Sequencing**
- **Semiconductor End Point Inspection**
- **LED Sorting and Characterizations**
- **LCD Display Measurements**

Features:

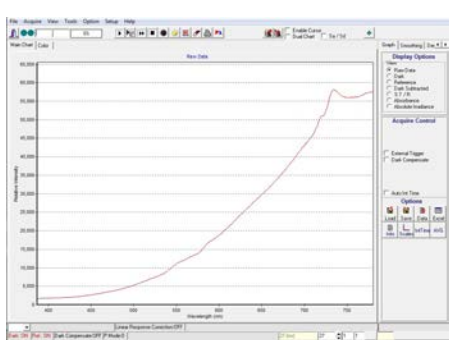
- Over 90% Peak QE
- Over 60% QE at 200nm
- High UV, Vis, and NIR Response
- 512 or 1024 Elements
- -10°C TE Cooled
- Optional Shutter Available

Accessories:

- Light Sources
- Fiber Patch Cords
- Fiber Sampling Probes
- Fiber Sample Holders

Software:

BWSpec™ is a spectral data acquisition software with a wide range of tools that are designed to perform complex measurements and calculations at the click of a button. It allows the user to choose between multiple data formats and offers optimization of scanning parameters, such as integration time. In addition to powerful data acquisition and data processing, other features include automatic dark removal, spectrum smoothing, and manual/auto baseline correction.



Specifications:

AC Power Input	100 - 240V AC, 50/60 Hz, 2.0 Amps @ 120V AC
Detector Type	Back-thinned CCD Array
Pixels	512 @ Equivalent 24mm x 1392mm (24x58) 1024 @ Equivalent 24mm x 1392mm (24x58)
Spectrograph *f*/#	3.5
Spectrograph Optical Layout	Crossed Czerny-Turner
Dynamic Range	75,000 (Typical) with Line Binning
Digitizer Resolution	16-bit or 65,535:1
Readout Speed	250 kHz
Data Transfer Speed	>50 Spectra Per Second Via USB 2.0
Integration Time	(512) 27 - 65,535ms x Multiplier (1024) 50 - 65,535ms x Multiplier
External Trigger	Aux Port
Operating Temperature	0°C to 35°C
TE Cooling	-10°C
Weight	Spectrometer: 3.1 lbs (1.4 kg) Power Supply: 2 lbs (0.9 kg)
Dimensions	Spectrometer: 4.2in x 7.0in x 3.5in (107mm x 178mm x 89mm) Power Supply: 9.8in x 6.6in x 2.2in (249mm x 169mm x 57mm)
Computer Interface	USB 2.0 / 1.1
Operating Systems	Windows: XP, Vista, 7

Technical Details

Fiber Coupler

Standard

1 Secures Fiber to Ensure Repeatable Results

By coupling a fiber optic to the SMA 905 adaptor, light will be guided to the slit and optically matched, ensuring reproducibility. For free space sampling, a diffuser or lens assembly can be connected directly to the SMA 905 adaptor.

Entrance Slit

Configurable

2 Determines Photon Flux and Spectral Resolution

Light entering into a spectrometer's optical bench is vinyetted by a pre-mounted and aligned slit. This ultimately determines the spectral resolution and throughput of the spectrometer after grating selection. We offer a variety of slit widths to match your specific application needs: from 10µm - 200µm wide, with custom slits available.

Slit Option	Dimensions	512 Pixel Array Approx. Resolution 350 - 750nm	1024 Pixel Array Approx. Resolution 750 - 1050nm
10µm	10µm wide x 1mm high	Call	Call
25µm	25µm wide x 1mm high	~2.6nm	~1.5nm
50µm	50µm wide x 1mm high	~3.8nm	~2.5nm
100µm	100µm wide x 1mm high	~10.0nm	~5.0nm
200µm	200µm wide x 1mm high	Call	Call
Custom Slit Widths Available			

Collimating Mirror

Standard

3 Collimates and Redirects Light Towards Grating

Both mirrors are *f*/# matched focusing mirrors coated with $AlMg_2$, which produces approximately 95% reflectance when working in the UV-Vis spectrum. Aluminum (Al) provides reflectance and magnesium (Mg_2) protects the aluminum from oxidation.

Diffraction Grating

Configurable

4 Diffracts Light, Separating Spectral Components

The groove frequency of the grating determines two key aspects of the spectrometer's performance: the wavelength coverage and the spectral resolution. When the groove frequency is increased, the instrument will achieve higher resolution, but the wavelength coverage will decrease. Inversely, decreasing the groove frequency increases wavelength coverage at the cost of spectral resolution.

The blaze angle or blaze wavelength of the grating is also a key parameter in optimizing the spectrometer's performance. The blaze angle determines the maximum efficiency that the grating will have in a specific wavelength region.

Best Efficiency	Spectral Coverage (nm)	Grating
512 Pixel Array		
Vis / NIR	500-850	400/400
Vis	380-750	400/400
1024 Pixel Array		
UV / Vis	200-400	1200/250
UV / NIR	203-975	400/400
Vis / NIR	750-1050	600/1000
Custom Configurations Available		

Focusing Mirror

Standard

5 Refocuses Dispersed Light onto Detector

Both mirrors are *f*/# matched focusing mirrors coated with $AlMg_2$, which produces approximately 95% reflectance when working in the UV-Vis spectrum. Aluminum (Al) provides reflectance and magnesium (Mg_2) protects the aluminum from oxidation.

Array Detector

Standard

6 Measures Entire Spectrum Simultaneously

The Prime™ *X* features a linearly summed 512 x 58 element back-thinned (BT) CCD detector where pixels are vertically binned, making an effective pixel size of 24µm x 24µm. As the incident light strikes the individual pixels across the BT CCD, each pixel represents a portion of the spectrum that the electronics can then translate and display with a given intensity using BWSpec™ software.

BT CCDs offer exceptional quantum efficiency from 200nm - 1000nm with a peak efficiency of > 90%. This BT CCD is ideal for low light level applications, featuring a large full-well capacity, low readout noise and MPP technology for dark current reduction. The BT CCD is different from a front-illuminated CCD in that it is mounted upside down on a rigid surface and thinned to less than 20 microns. This allows incoming photons to fall directly onto the individual pixels without having to penetrate though the gate structures, greatly reducing the probability that the photons will be absorbed or reflected.

Specifications		
	512 Pixel Array	1024 Pixel Array
Wavelength Range	380nm - 1050nm	200nm - 1050nm
Pixels	512 x 58	1024 x 58
Pixel Size	24µm x 24µm	
Well Depth	~30,000 e (typical)	
Digitization Rate	250 kHz	

Thermoelectric Cooler

Standard

7 Reduces Dark Noise and Increases Detection Limits

Cooling an array detector with a built-in thermoelectric cooler (TEC) is an effective way to reduce dark current and noise, as well as to enhance the dynamic range and detection limit.

When the CCD detector array is cooled from a room temperature of 25°C down to -10°C by the TEC, the dark current is reduced by a factor of 14 and the dark noise is reduced by a factor of 3.7. This allows the spectrometer to operate at longer exposure times and to detect weaker optical signals.

Spectrometer

i-trometer™

High Performance Back-thinned CCD Spectrometer

The *i*-trometer™ features a linearly summed 2048 x 64 element back-thinned (BT) CCD detector, and is optimized for UV performance through the use of an aberration corrected concave holographic grating, to minimize stray light. The BT CCD offers superior quantum efficiency, signal-to-noise, and dynamic range, making it ideal for a variety of UV/Vis/NIR applications. The *i*-trometer™ features a built-in 16-bit digitizer, USB 2.0 interface and external trigger.

Standard spectral configurations range from 180nm - 1050nm and resolutions range between 0.6nm and 6.0nm. Custom configurations are available for OEM applications.

Applications:

- **UV / Vis / Short-wave NIR Spectroscopy**
- **UV / Vis / NIR Lamp Characterization**
- **HPLC Detection**
- **Solar Monitoring**

Features:

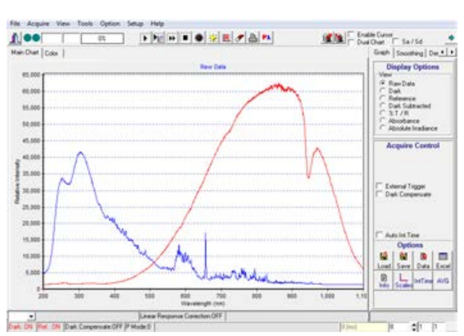
- High UV, Vis, NIR Response
- Wide Dynamic Range
- High Throughput
- High Stray Light Rejection
- USB 2.0 High Speed Interface

Accessories:

- Light Sources
- Fiber Patch Cords
- Fiber Sampling Probes
- Fiber Sample Holders

Software:

BWSpec™ is a spectral data acquisition software with a wide range of tools that are designed to perform complex measurements and calculations at the click of a button. It allows the user to choose between multiple data formats and offers optimization of scanning parameters, such as integration time. In addition to powerful data acquisition and data processing, other features include automatic dark removal, spectrum smoothing, and manual/auto baseline correction.



Specifications:

DC Power Input	5V DC @ < 0.8 Amps
AC Adapter Input	100 - 240VAC 50/60 Hz, 0.5A @ 120VAC
Detector Type	Back-thinned CCD Array
Pixels	2048 @ Equivalent 14mm x 896mm (14x64)
Spectrograph f/#	3.0
Spectrograph Optical Layout	Concave Holographic, Aberration Corrected, Flat Field
Dynamic Range	33,300
Digitizer Resolution	16-bit or 65,535 to 1
Readout Speed	375 kHz
Data Transfer Speed	Up to 65 Spectra Per Second Via USB 2.0
Integration Time	7ms to >= 20,000ms
External Trigger	Aux Port
Operating Temperature	15°C to 35°C
Weight	~ 2.6 lbs (1.2 kg)
Dimensions	6.22in x 4.01in x 3.30in (158mm x 102mm x 84mm)
Computer Interface	USB 2.0 / 1.1
Operating Systems	Windows: XP, Vista, 7

Technical Details

Spectrometer

Standard

Fiber Coupler

1 Secures Fiber to Ensure Repeatable Results

By coupling a fiber optic to the SMA 905 adaptor, light will be guided to the slit and optically matched, ensuring reproducibility. For free space sampling, a diffuser or lens assembly can be connected directly to the SMA 905 adaptor.

Configurable

Entrance Slit

2 Determines Photon Flux and Spectral Resolution

Light entering into a spectrometer's optical bench is vinyetted by a pre-mounted and aligned slit. This ultimately determines the spectral resolution and throughput of the spectrometer after grating selection. We offer a variety of slit widths to match your specific application needs: from 10µm - 200µm wide, with custom slits available.

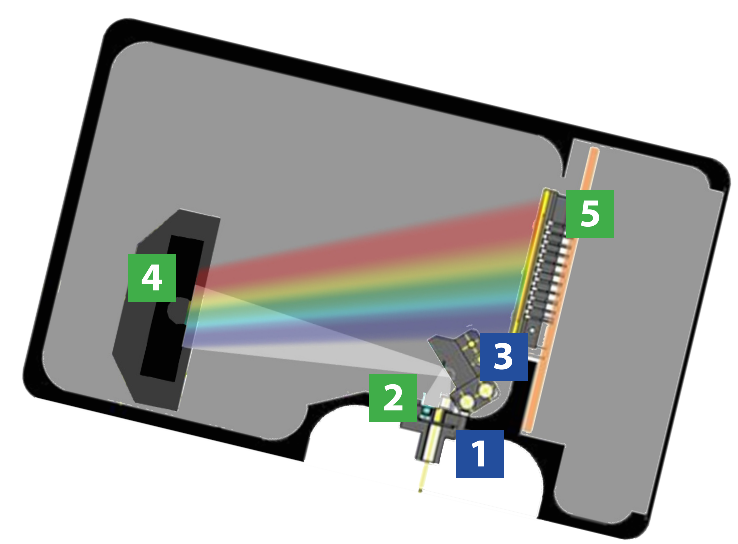
Slit Option	Dimensions	Approx. Resolution 190-1100nm
10µm	10µm wide x 2mm high	~2.0nm
25µm	25µm wide x 2mm high	~2.5nm
50µm	50µm wide x 2mm high	~3.2nm
100µm	100µm wide x 2mm high	~6.0nm
200µm	200µm wide x 2mm high	Call
Custom Configurations Available		

Standard

Folding Mirror

3 Redirects Light Towards Grating

The folding mirror redirects the light from the slit towards the holographic grating to be dispersed and refocused. This mirror is coated with $AlMg_2$ which produces approximately 95% reflectance when working in the UV-Vis spectrum. Aluminum (Al) provides reflectance and magnesium (Mg_2) protects the aluminum from oxidation.



Configurable

Concave Holographic Grating

4 Collects, Disperses and Refocuses Light

This one compact optical component collects, disperses, and refocuses light onto the detector by effectively combining the grating and focusing mirror found in standard Czerny-Turner optical benches. The optimized holographic grating delivers excellent efficiency and stray-light reduction and is able to provide a faster f/#, delivering higher throughput.

Best Efficiency	Spectral Coverage (nm)
UV / Vis	180-450
UV / NIR	190-800
Vis / NIR	400-800
UV / Vis	200-550
UV / NIR	190-1100
UV / Vis	350-750
UV - NIR	350-1050
Custom Configurations Available	

Configurable

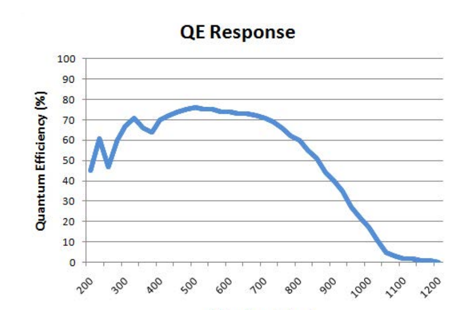
Array Detector

5 Measures Entire Spectrum Simultaneously

The *i*-trometer™ features a linearly summed 2048 x 64 element back-thinned (BT) CCD detector where pixels are vertically binned, making an effective pixel size of 14µm x 896µm and > 2000 active pixels. As the incident light strikes the individual pixels across the CCD, each pixel represents a portion of the spectrum that the electronics can then translate and display with a given intensity using BWSpec™ software.

The quantum efficiency of this BT CCD is increased by > 30% compared to most front illuminated linear CCD arrays. This detector also has very low read out noise, allowing for low light level detection.

Specifications	
Wavelength Range	190nm - 1100nm
Pixels	2048 x 64
Pixel Size	14µm x 14µm
Well Depth	~200,000 e
Digitization Rate	375 kHz



Spectrometer

Cypher® *H*

High Performance Photodiode Array Spectrometer

The Cypher® *H* is a high performance linear photodiode array (PDA) spectrometer and is optimized for UV performance through the use of an aberration corrected concave holographic grating to minimize stray light. The PDA offers improved quantum efficiency in the NIR and UV regions, extremely wide dynamic range, and exceptionally low read noise; making it ideal for the detection of small variations in light intensity. The Cypher® *H* features 512 (standard) or 1024 pixels, a built-in 16-bit digitizer, USB 2.0 interface and external trigger.

The Cypher® *H* is available in two standard spectral configurations: 185nm - 800nm and 300nm - 1050nm. Custom configurations are available for OEM applications.

Applications:

- **UV, Vis and NIR Spectroscopy**
- **LED and Other Display Device Tests**
- **Color Measurement**
- **Small Light Difference Detection**

Features:

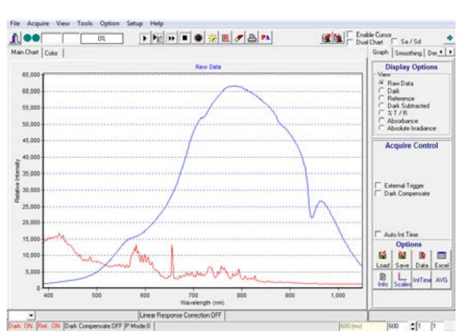
- Enhanced QE in NIR
- High UV Response as Low as 185nm
- High Dynamic Range
- 512 or 1024 Pixels

Accessories:

- Light Sources
- Fiber Patch Cords
- Fiber Sampling Probes
- Fiber Sample Holders

Software:

BWSpec™ is a spectral data acquisition software with a wide range of tools that are designed to perform complex measurements and calculations at the click of a button. It allows the user to choose between multiple data formats and offers optimization of scanning parameters, such as integration time. In addition to powerful data acquisition and data processing, other features include automatic dark removal, spectrum smoothing, and manual/auto baseline correction.



Specifications:

DC Power Input	5V DC @ < 0.8 Amps
AC Adapter Input	100 - 240VAC 50/60 Hz, 0.5A @ 120VAC
Detector Type	Self-scanning Photodiode Linear Array
Pixels	512 @ 25mm x 2500mm 1024 @ 25mm x 2500mm
Spectrograph f/#	3.0
Spectrograph Optical Layout	Concave Holographic, Aberration Corrected, Flat Field
Dynamic Range	5 x 10⁴ (Typical)
Digitizer Resolution	16-bit or 65,535:1
Readout Speed	250 kHz
Data Transfer Speed	>70 Spectra Per Second Via USB 2.0
Integration Time	3 - 65,535ms x Multiplier
External Trigger	Aux Port
Operating Temperature	5°C - 35°C
Weight	~ 2.6 lbs (1.2 kg)
Dimensions	6.22in x 4.01in x 3.3in (158mm x 102mm x 84mm)
Computer Interface	USB 2.0 / 1.1
Operating Systems	Windows: XP, Vista, 7

Technical Details

Spectrometer

Standard

Fiber Coupler

1 Secures Fiber to Ensure Repeatable Results

By coupling a fiber optic to the SMA 905 adaptor, light will be guided to the slit and optically matched, ensuring reproducibility. For free space sampling, a diffuser or lens assembly can be connected directly to the SMA 905 adaptor.

Configurable

Entrance Slit

2 Determines Photon Flux and Spectral Resolution

Light entering into a spectrometer's optical bench is vinyetted by a pre-mounted and aligned slit. This ultimately determines the spectral resolution and throughput of the spectrometer after grating selection. We offer a variety of slit widths to match your specific application needs: from 25μm - 200μm wide, with custom slits available.

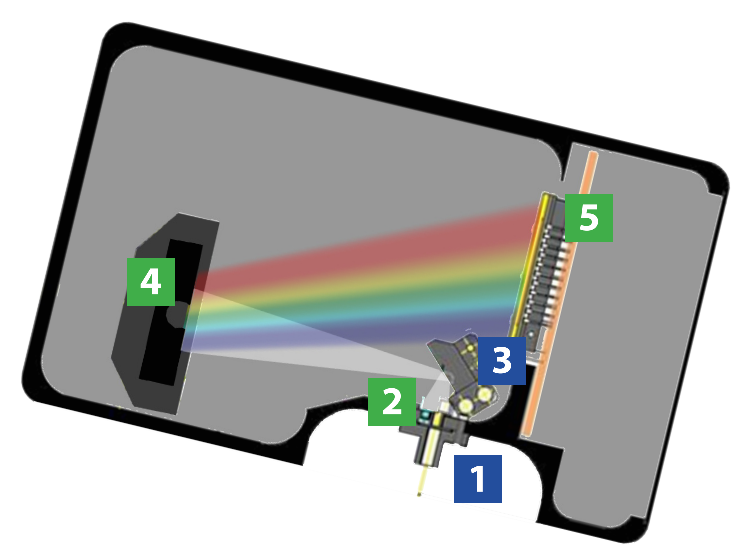
Slit Option	Dimensions	Approx. Resolution 350-1050nm
25μm	25μm wide x 2mm high	~2.7nm
50μm	50μm wide x 2mm high	~4.2nm
100μm	100μm wide x 2mm high	~7.2nm
200μm	200μm wide x 2mm high	Call
Custom Configurations Available		

Standard

Folding Mirror

3 Redirects Light Towards Grating

The folding mirror redirects the light from the slit towards the holographic grating to be dispersed and refocused. This mirror is coated with $AlMg_2$ which produces approximately 95% reflectance when working in the UV-Vis spectrum. Aluminum (Al) provides reflectance and magnesium (Mg_2) protects the aluminum from oxidation.



Configurable

Concave Holographic Grating

4 Collects, Disperses and Refocuses Light

This one compact optical component collects, disperses, and refocuses light onto the detector, by effectively combining the grating and focusing mirror found in standard Czerny-Turner optical benches. The optimized holographic grating delivers excellent efficiency and stray-light reduction and is able to provide a faster *f*/#, delivering higher throughput.

Best Efficiency	Spectral Coverage (nm)
UV / Vis	185-800
UV / NIR	350-1050
Custom Configurations Available	

Configurable

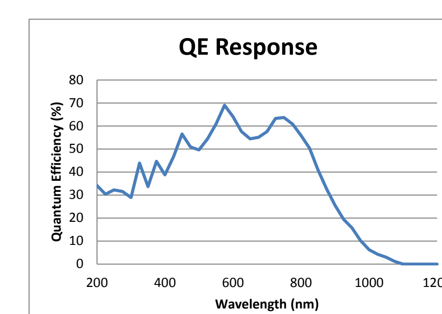
Array Detector

5 Measures Entire Spectrum Simultaneously

The Cypher® *H* features a linear 512 or 1024 element PDA detector with a pixel size of 25μm x 2500μm. As the incident light strikes the individual pixels across the CCD, each pixel represents a portion of the spectrum that the electronics can then translate and display with a given intensity using BWSpec™ software.

The PDA offers improved quantum efficiency in the NIR and UV regions, extremely wide dynamic range, and exceptionally low read noise; making it ideal for the detection of small variations in light intensity.

Specifications	
Wavelength Range	185nm - 1050nm
Pixels	512, 1024
Pixel Size	25μm x 2500μm
Well Depth	~156,000,000 e
Digitization Rate	250 kHz



Sol™ *1.7*

900 - 1700nm NIR TE Cooled InGaAs Array Spectrometer

The Sol™ *1.7* is a high performance linear InGaAs array spectrometer, featuring 256, 512 (standard), and 1024 pixels with TE Cooling down to -10°C, all while providing high throughput and large dynamic range.

Each spectrometer features an SMA 905 fiber optic input, a built-in 16-bit digitizer, and is USB 2.0 plug-and-play compatible. With our spectral acquisition software, you can select between High Sensitivity and High Dynamic Range mode within your pre-configured spectral range. Customized spectral resolution and application support are available.

Applications:

- **Process Monitoring**
- **NIR Spectroscopy**
- **Quality Control**
- **On-line Analyzer**
- **Material Identification**

Features:

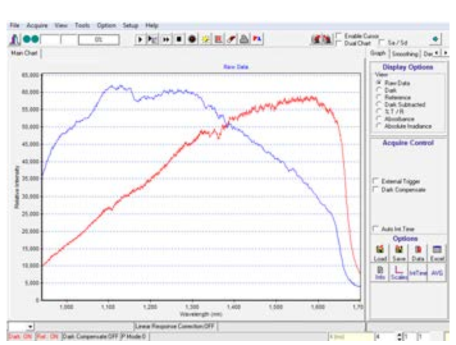
- 900nm - 1700nm Spectral Range
- Resolution as Fine as 0.35nm
- Built-in 16-bit Digitizer
- -10°C TE Cooling
- Two Gain Modes for Specific Application Needs

Accessories:

- Light Sources
- Fiber Patch Cords
- Fiber Sampling Probes
- Fiber Sample Holders

Software:

BWSpec™ is a spectral data acquisition software with a wide range of tools that are designed to perform complex measurements and calculations at the click of a button. It allows the user to choose between multiple data formats and offers optimization of scanning parameters, such as integration time. In addition to powerful data acquisition and data processing, other features include automatic dark removal, spectrum smoothing, and manual/auto baseline correction.



Specifications:

DC Power Input	5V DC @ 3.5 Amps
AC Power Input	100 - 240VAC 50/60 Hz, 0.5A @ 120VAC
Detector Type	Linear InGaAs Array
Pixels	512 x 1 @ 25μm x 500μm Per Element
Spectrograph *f/#*	3.5
Spectrograph Optical Layout	Crossed Czerny-Turner
Dynamic Range	High Dynamic Mode: 13,000:1 High Sensitivity Mode: 6,250:1
Digitizer Resolution	16-bit or 65,535:1
Readout Speed	500 kHz
Data Transfer Speed	>200 Spectra Per Second Via USB 2.0
Integration Time	200μs to >= 64 Seconds
External Trigger	Aux Port
Operating Temperature	0°C - 35°C
TE Cooling	Two-Stage: -5°C @ Relative Humidity = 90% (-10°C Option Available)
Weight	~ 3.1 lbs (1.4 kg)
Dimensions	7.8in x 4.3in x 2.7in (197mm x 109mm x 68mm)
Computer Interface	USB 2.0 / 1.1
Operating Systems	Windows: XP, Vista, 7

Technical Details

Standard

Fiber Coupler

1 Secures Fiber to Ensure Repeatable Results

By coupling a fiber optic to the SMA 905 adaptor, light will be guided to the slit and optically matched, ensuring reproducibility. For free space sampling, a diffusor or lens assembly can be connected directly to the SMA 905 adaptor.

Configurable

Entrance Slit

2 Determines Photon Flux and Spectral Resolution

Light entering into a spectrometer's optical bench is vinyetted by a pre-mounted and aligned slit. This ultimately determines the spectral resolution and throughput of the spectrometer after grating selection. We offer a variety of slit widths to match your specific application needs: from 25μm - 100μm wide, with custom slits available.

Slit Option	Dimensions	Approximate Resolution 900 -1700nm
25μm	25μm wide x 1mm high	~4.0nm
50μm	50μm wide x 1mm high	~5.0nm
100μm	100μm wide x 1mm high	~8.4nm
Custom Slit Widths Available		

Standard

Collimating Mirror

3 Collimates and Redirects Light Towards Grating

Both mirrors are *f/#* matched focusing mirrors coated with a special coating, which enhances the NIR signal.

Configurable

Diffraction Grating

4 Diffracts Light, Separating Spectral Components

The groove frequency of the grating determines two key aspects of the spectrometer's performance: the wavelength coverage and the spectral resolution. When the groove frequency is increased, the instrument will achieve higher resolution, but the wavelength coverage will decrease. Inversely, decreasing the groove frequency increases wavelength coverage at the cost of spectral resolution.

The blaze angle or blaze wavelength of the grating is also a key parameter in optimizing the spectrometer's performance. The blaze angle determines the maximum efficiency that the grating will have in a specific wavelength region.

Spectral Coverage (nm)	Grating	Approximate Resolution 25μm Slit
1500-1600	1000/1310	0.35nm
1260-1355	1000/1310	0.4nm
1450-1650	600/1200	0.8nm
1200-1400	600/1200	0.7nm
900-1300	300/1200	1.5nm
1200-1600	300/1200	1.5nm
900-1700	150/1250	4.0nm
Custom Configurations Available		

Standard

Focusing Mirror

5 Refocuses Dispersed Light onto Detector

Both mirrors are *f/#* matched focusing mirrors coated with a special coating, which enhances the NIR signal.

Standard

Array Detector

6 Measures Entire Spectrum Simultaneously

The Sol™ *1.7* features a 512 x 1 TE Cooled linear InGaAs photo diode array detector with pixel dimensions of 25μm x 500μm and 512 active pixels. Using BWSpec™, the detector mode can be switched between High Sensitivity and High Dynamic Range modes, allowing for greater control over the detector's sensitivity.

Specifications	
Wavelength Range	900nm - 1700nm
Pixels	256, 512 (standard), 1024
Pixel Size	25μm x 500μm
Well Depth	High Dynamic Mode: ~100 Me High Sensitivity Mode: ~40 Me
Digitization Rate	500 kHz

Standard

Thermoelectric Cooler

7 Reduces Dark Noise and Improves Detection Limits

Cooling an array detector with a built-in thermoelectric cooler (TEC) is an effective way to reduce dark current and noise, as well as to enhance the dynamic range and detection limit.

When the InGaAs array detector is cooled from a room temperature of 25°C down to -10°C by the TEC, the dark current is reduced by 12.25 times and the dark noise is reduced by 3.5 times. This allows the spectrometer to operate at longer exposure times and to detect weaker optical signals.

Sol™ 2.2

900 - 2200nm NIR TE Cooled InGaAs Array Spectrometer

The Sol™ *2.2* is a high performance linear InGaAs array spectrometer, featuring 512 (standard) and 1024 pixels with TE Cooling down to -15°C, all while providing high throughput and large dynamic range.

Each spectrometer features an SMA 905 fiber optic input, a built-in 16-bit digitizer, and is USB 2.0 plug-and-play compatible. Using the included software, you can choose between High Sensitivity and High Dynamic Range mode. Flexible custom configurations and application support are available for OEM applications.

Applications:

- **Process Monitoring**
- **NIR Spectroscopy**
- **Quality Control**
- **On-line Analyzer**
- **Material Identification**

Features:

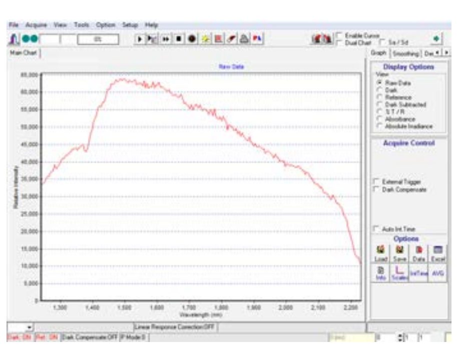
- 900nm - 2200nm Spectral Range
- Resolution as Fine as 2.5nm
- Built-in 16-bit Digitizer
- -15°C TE Cooling
- Two Gain Modes for Specific Application Needs

Accessories:

- Light Sources
- Fiber Patch Cords
- Fiber Sampling Probes
- Fiber Sample Holders

Software:

BWSpec™ is a spectral data acquisition software with a wide range of tools that are designed to perform complex measurements and calculations at the click of a button. It allows the user to choose between multiple data formats and offers optimization of scanning parameters, such as integration time. In addition to powerful data acquisition and data processing, other features include automatic dark removal, spectrum smoothing, and manual/auto baseline correction.



Specifications:

DC Power Input	5V DC @ 3.5 Amps
AC Power Input	100 - 240VAC 50/60 Hz, 0.5A @ 120VAC
Detector Type	Linear InGaAs Array
Pixels	512 x 1 @ 25µm x 250µm Per Element
Spectrograph f/#	3.5
Spectrograph Optical Layout	Crossed Czerny-Turner
Dynamic Range	High Dynamic Mode: 13,000:1 High Sensitivity Mode: 6,250:1
Digitizer Resolution	16-bit or 65,535:1
Readout Speed	500 kHz
Data Transfer Speed	>200 Spectra Per Second Via USB 2.0
Integration Time	200µs to >= 64 Seconds
External Trigger	Aux Port
Operating Temperature	0°C - 35°C
TE Cooling	Three-Stage: -15°C @ Relative Humidity = 90%
Weight	~ 3.1 lbs (1.4 kg)
Dimensions	7.8in x 4.3in x 2.7in (197mm x 109mm x 68mm)
Computer Interface	USB 2.0 / 1.1
Operating Systems	Windows: XP, Vista, 7

Technical Details

Standard

Fiber Coupler

1 Secures Fiber to Ensure Repeatable Results

By coupling a fiber optic to the SMA 905 adaptor, light will be guided to the slit and optically matched, ensuring reproducibility. For free space sampling, a diffuser or lens assembly can be connected directly to the SMA 905 adaptor.

Configurable

Entrance Slit

2 Determines Photon Flux and Spectral Resolution

Light entering into a spectrometer's optical bench is vinyetted by a pre-mounted and aligned slit. This ultimately determines the spectral resolution and throughput of the spectrometer after grating selection. We offer a variety of slit widths to match your specific application needs: from 25µm - 100µm wide, with custom slits available.

Slit Option	Dimensions	Approximate Resolution 1100 - 2200nm
25µm	25µm wide x 1mm high	~5.5nm
50µm	50µm wide x 1mm high	~9.0nm
100µm	100µm wide x 1mm high	~14.0nm
Custom Slit Widths Available		

Standard

Collimating Mirror

3 Collimates and Redirects Light Towards Grating

Both mirrors are *f/#* matched focusing mirrors coated with a special coating, which enhances the NIR signal.

Configurable

Diffraction Grating

4 Diffracts Light, Separating Spectral Components

The groove frequency of the grating determines two key aspects of the spectrometer's performance: the wavelength coverage and the spectral resolution. When the groove frequency is increased, the instrument will achieve higher resolution, but the wavelength coverage will decrease. Inversely, decreasing the groove frequency increases wavelength coverage at the cost of spectral resolution.

The blaze angle or blaze wavelength of the grating is also a key parameter in optimizing the spectrometer's performance. The blaze angle determines the maximum efficiency that the grating will have in a specific wavelength region.

Spectral Coverage (nm)	Grating	Approximate Resolution 25µm Slit
1100-2200	100/1600	5.5nm
900-2200	85/1350	7.0nm
1600-2030	300/2000	3.5nm
Custom Configurations Available		

Standard

Focusing Mirror

5 Refocuses Dispersed Light onto Detector

Both mirrors are *f/#* matched focusing mirrors coated with a special coating, which enhances the NIR signal.

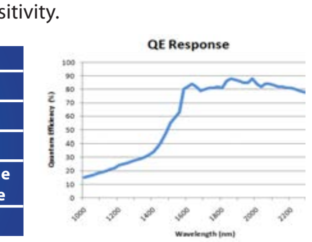
Standard

Array Detector

6 Measures Entire Spectrum Simultaneously

The Sol™ *2.2* features a 512 x 1 TE Cooled linear InGaAs photo diode array detector with pixel dimensions of 25µm x 500µm and 512 active pixels. Using BWSpec™, the detector mode can be switched between High Sensitivity and High Dynamic Range modes, allowing for a greater control over the detector's sensitivity.

Specifications	
Wavelength Range	900nm - 2200nm
Pixels	512 (standard), 1024
Pixel Size	25µm x 250µm
Well Depth	High Dynamic Mode : ~130 Me High Sensitivity Mode: ~5 Me
Digitization Rate	500 kHz



Standard

Thermoelectric Cooler

7 Reduces Dark Noise and Improves Detection Limits

Cooling an array detector with a built-in thermoelectric cooler (TEC) is an effective way to reduce dark current and noise, as well as to enhance the dynamic range and detection limit.

When the InGaAs array detector is cooled from a room temperature of 25°C down to -15°C by the TEC, the dark current is reduced by 12.25 times and the dark noise is reduced by 3.5 times. This allows the spectrometer to operate at longer exposure times and to detect weaker optical signals.

Sol™ 2.2A

900 - 2200nm NIR TE Cooled InGaAs Array Spectrometer

The Sol™ *2.2A* is a high performance linear InGaAs array spectrometer featuring 256 pixels and providing high throughput and large dynamic range with TE Cooling down to -15°C via a built-in 3-stage cooler.

Each spectrometer features an SMA 905 fiber optic input, built-in 16-bit digitizer, and is USB 2.0 plug-and-play compatible. The built-in autozero function automatically reduces dark current and dark non-uniformity, resulting in an increased signal-to-noise ratio.

Software control allows the user to choose from four types of operation modes: Maximum Dynamic, High Dynamic, High Sensitivity, and Maximum Sensitivity. Customized spectral resolution and application support are also available.

Applications:

- **Process Monitoring**
- **NIR Spectroscopy**
- **Quality Control**
- **On-line Analyzer**
- **Material Identification**

Features:

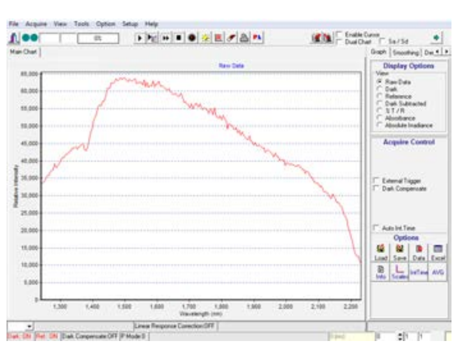
- 900nm - 2200nm Spectral Range
- Resolution as Fine as 9.0nm
- -15°C TE Cooling
- Built-in Autozero (Noise Level Reduction)
- Four Sensitivity & Dynamic Range Modes for Specific Application Needs

Accessories:

- Light Sources
- Fiber Patch Cords
- Fiber Sampling Probes
- Fiber Sample Holders

Software:

BWSpec™ is a spectral data acquisition software with a wide range of tools that are designed to perform complex measurements and calculations at the click of a button. It allows the user to choose between multiple data formats and offers optimization of scanning parameters, such as integration time. In addition to powerful data acquisition and data processing, other features include automatic dark removal, spectrum smoothing, and manual/auto baseline correction.



Specifications:

DC Power Input	5V DC @ 5 Amps
AC Adapter Input	100 - 240VAC 50/60 Hz, 1.0A @ 120VAC
Detector Type	Linear InGaAs Array
Pixels	256 x 1 @ 50µm x 250µm Per Element
Spectrograph f/#	3.5
Spectrograph Optical Layout	Crossed Czerny-Turner
Dynamic Range	Maximum Dynamic Mode: 20,000:1 High Dynamic Mode: 10,000:1 High Sensitivity Mode: 2,500:1 Maximum Sensitivity Mode: 250:1
Digitizer Resolution	16-bit or 65,535:1
Readout Speed	500 kHz
Data Transfer Speed	>300 Spectra Per Second Via USB 2.0
Integration Time	250µs to >= 64 Seconds
External Trigger	Aux Port
Operating Temperature	0°C - 35°C
TE Cooling	Three-Stage: -15°C @ Relative Humidity = 90%
Weight	~ 3.1 lbs (1.4 kg)
Dimensions	7.5in x 4.3in x 2.7in (192mm x 109mm x 68mm)
Computer Interface	USB 2.0 / 1.1
Operating Systems	Windows: XP, Vista, 7

Technical Details

Standard

Fiber Coupler

1 Secures Fiber to Ensure Repeatable Results

By coupling a fiber optic to the SMA 905 adaptor, light will be guided to the slit and optically matched, ensuring reproducibility. For free space sampling, a diffuser or lens assembly can be connected directly to the SMA 905 adaptor.

Configurable

Entrance Slit

2 Determines Photon Flux and Spectral Resolution

Light entering into a spectrometer's optical bench is vinyetted by a pre-mounted and aligned slit. This ultimately determines the spectral resolution and throughput of the spectrometer after grating selection. We offer a variety of slit widths to match your specific application needs: from 50µm - 100µm wide, with custom slits available.

Slit Option	Dimensions	Approximate Resolution 1100 - 2200nm
50µm	50µm wide x 1mm high	~9.0nm
100µm	100µm wide x 1mm high	~18.0nm
Custom Slit Widths Available		

Standard

Collimating Mirror

3 Collimates and Redirects Light Towards Grating

Both mirrors are *f/#* matched focusing mirrors coated with a special coating, which enhances the NIR signal.

Configurable

Diffraction Grating

4 Diffracts Light, Separating Spectral Components

The groove frequency of the grating determines two key aspects of the spectrometer's performance: the wavelength coverage and the spectral resolution. When the groove frequency is increased, the instrument will achieve higher resolution, but the wavelength coverage will decrease. Inversely, decreasing the groove frequency increases wavelength coverage at the cost of spectral resolution.

The blaze angle or blaze wavelength of the grating is also a key parameter in optimizing the spectrometer's performance. The blaze angle determines the maximum efficiency that the grating will have in a specific wavelength region.

Spectral Coverage (nm)	Grating	Approximate Resolution 50µm Slit
1100-2200	100/1600	9.0nm
900-2200	85/1350	15.0nm
Custom Configurations Available		

Standard

Focusing Mirror

5 Refocuses Dispersed Light onto Detector

Both mirrors are *f/#* matched focusing mirrors coated with a special coating, which enhances the NIR signal.

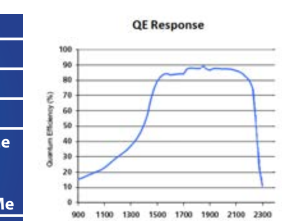
Standard

Array Detector

6 Measures Entire Spectrum Simultaneously

The Sol™ 2.2A features a 256 x 1 TE Cooled linear InGaAs photo diode array detector with pixel dimensions of 50µm x 250µm and 256 active pixels. Using BWSpec™, the detector mode can be switched between two sensitivity and two dynamic modes, allowing for greater control over the detector's sensitivity.

Specifications	
Wavelength Range	1100nm - 2200nm
Pixels	256
Pixel Size	50µm x 250µm
Well Depth	Maximum Dynamic Mode: ~250 Me High Dynamic Mode: ~125 Me High Sensitivity Mode: ~12.5 Me Maximum Sensitivity Mode: 1.25 Me
Digitization Rate	500 kHz



Standard

Thermoelectric Cooler

7 Reduces Dark Noise and Improves Detection Limits

Cooling an array detector with a built-in thermoelectric cooler (TEC) is an effective way to reduce dark current and noise, as well as to enhance the dynamic range and detection limit.

When the InGaAs array detector is cooled from a room temperature of 25°C down to -15°C by the TEC, the dark current is reduced by ~32 times and the dark noise is reduced by ~5.7 times. This allows the spectrometer to operate at longer exposure times and to detect weaker optical signals.

Sol™ 2.6

1550nm - 2550nm* NIR TE Cooled InGaAs Array Spectrometer

The Sol™ *2.6* is a high performance linear InGaAs array spectrometer featuring 256 pixels and providing high throughput and large dynamic range with TE Cooling down to -15°C via a built-in 3-stage cooler.

Each spectrometer features an SMA 905 fiber optic input, built-in 16-bit digitizer, and is USB 2.0 plug-and-play compatible. The built-in autozero function automatically reduces dark current and dark non-uniformity, resulting in an increased signal-to-noise ratio.

Software control allows the user to choose from four types of operation modes: Maximum Dynamic, High Dynamic, High Sensitivity, and Maximum Sensitivity. Customized spectral resolution and application support are also available.

Applications:

- **Process Monitoring**
- **NIR Spectroscopy**
- **Quality Control**
- **On-line Analyzer**
- **Biological Applications**

Features:

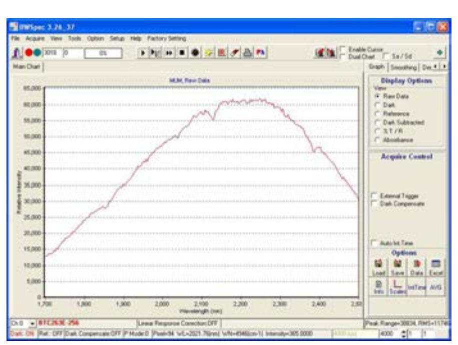
- 1550nm - 2550nm* Spectral Range
- Built-in Autozero (Noise Level Reduction)
- Built-in 16-bit Digitizer
- Low Dark Noise and High Sensitivity
- Four Sensitivity & Dynamic Range Modes for Specific Application Needs

Accessories:

- Light Sources
- Fiber Patch Cords
- Fiber Sampling Probes
- Fiber Sample Holders

Software:

BWSpec™ is a spectral data acquisition software with a wide range of tools that are designed to perform complex measurements and calculations at the click of a button. It allows the user to choose between multiple data formats and offers optimization of scanning parameters, such as integration time. In addition to powerful data acquisition and data processing, other features include automatic dark removal, spectrum smoothing, and manual/auto baseline correction.

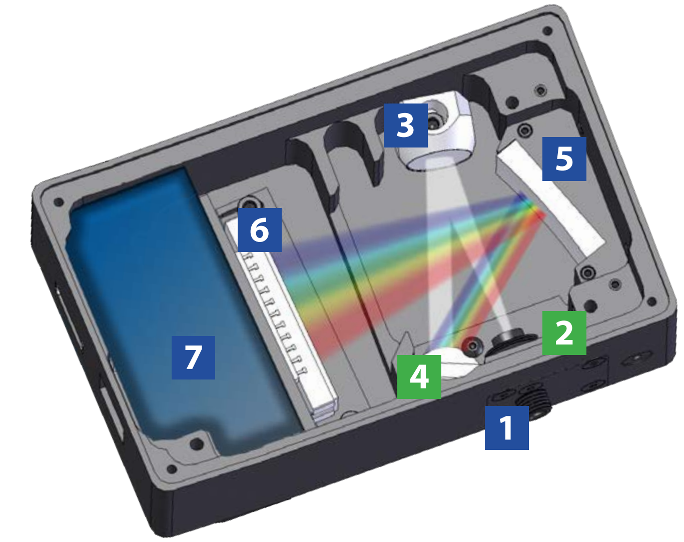


Specifications:

DC Power Input	5V DC @ 5 Amps
AC Adapter Input	100 - 240VAC 50/60 Hz, 1.0A @ 120VAC
Detector Type	Linear InGaAs Array
Pixels	256 x 1 @ 50µm x 250µm Per Element
Spectrograph f/#	3.5
Spectrograph Optical Layout	Crossed Czerny-Turner
Dynamic Range	Maximum Dynamic Mode: 20,000:1 High Dynamic Mode: 10,000:1 High Sensitivity Mode: 2,500:1 Maximum Sensitivity Mode: 250:1
Digitizer Resolution	16-bit or 65,535:1
Readout Speed	500 kHz
Data Transfer Speed	>300 Spectra Per Second Via USB 2.0
Integration Time	250µs to >= 64 Seconds
External Trigger	Aux Port
Operating Temperature	0°C - 35°C
TE Cooling	Three-Stage: -15°C @ Relative Humidity = 90%
Weight	~ 3.1 lbs (1.4 kg)
Dimensions	7.8in x 4.3in x 2.7in (197mm x 109mm x 68mm)
Computer Interface	USB 2.0 / 1.1
Operating Systems	Windows: XP, Vista, 7

**Custom Ranges Available*

Technical Details



Standard

Fiber Coupler

1 Secures Fiber to Ensure Repeatable Results

By coupling a fiber optic to the SMA 905 adaptor, light will be guided to the slit and optically matched, ensuring reproducibility. For free space sampling, a diffuser or lens assembly can be connected directly to the SMA 905 adaptor.

Configurable

Entrance Slit

2 Determines Photon Flux and Spectral Resolution

Light entering into a spectrometer's optical bench is vinyetted by a pre-mounted and aligned slit. This ultimately determines the spectral resolution and throughput of the spectrometer after grating selection. The Sol™ *2.6* has a slit width of 75µm with custom slits available.

Slit Option	Dimensions	Approximate Resolution 1550 -2550nm
75mm	75mm wide x 1mm high	~15.0nm
Custom Slit Widths Available		

Standard

Collimating Mirror

3 Collimates and Redirects Light Towards Grating

Both mirrors are *f/#* matched focusing mirrors coated with a special coating, which enhances the NIR signal.

Configurable

Diffraction Grating

4 Diffracts Light, Separating Spectral Components

The groove frequency of the grating determines two key aspects of the spectrometer's performance: the wavelength coverage and the spectral resolution. When the groove frequency is increased, the instrument will achieve higher resolution, but the wavelength coverage will decrease. Inversely, decreasing the groove frequency increases wavelength coverage at the cost of spectral resolution.

The blaze angle or blaze wavelength of the grating is also a key parameter in optimizing the spectrometer's performance. The blaze angle determines the maximum efficiency that the grating will have in a specific wavelength region.

Spectral Coverage (nm)	Grating	Approximate Resolution 75µm Slit
1550-2550	100/2500	15.0nm
Custom Configurations Available		

Standard

Focusing Mirror

5 Refocuses Dispersed Light onto Detector

Both mirrors are *f/#* matched focusing mirrors coated with a special coating, which enhances the NIR signal.

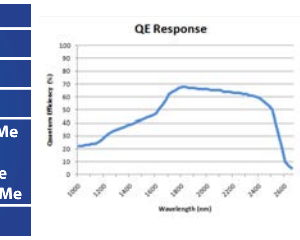
Standard

Array Detector

6 Measures Entire Spectrum Simultaneously

The Sol™ *2.6* features a 256 x 1 TE Cooled linear InGaAs photo diode array detector with pixel dimensions of 50µm x 250µm and 256 active pixels. Using BWSpec™, the detector mode can be switched between two sensitivity and two dynamic modes, allowing for greater control over the detector's sensitivity.

Specifications	
Wavelength Range	1550nm - 2550nm*
Pixels	256
Pixel Size	50µm x 250µm
Well Depth	Maximum Dynamic Mode: ~250 Me High Dynamic Mode: ~125 Me High Sensitivity Mode: ~12.5 Me Maximum Sensitivity Mode: 1.25 Me
Digitization Rate	500 kHz



**Custom Ranges Available*

Standard

Thermoelectric Cooler

7 Reduces Dark Noise and Improves Detection Limits

Cooling an array detector with a built-in thermoelectric cooler (TEC) is an effective way to reduce dark current and noise, as well as to enhance the dynamic range and detection limit.

When the InGaAs array detector is cooled from a room temperature of 25°C down to -15°C by the TEC, the dark current is reduced by ~32 times and the dark noise is reduced by ~5.7 times. This allows the spectrometer to operate at longer exposure times and to detect weaker optical signals.

Accessories

BDS100 Deuterium/Tungsten Light Source

The BDS100 is a DC powered turnkey SMA 905 fiber coupled UV/Vis/NIR light source with spectral output from 200 to > 1100nm. The 3W UV lamp is an electrode-less, RF induced deuterium lamp which shares a single optical path with the 3W tungsten halogen lamp. Features include a safety shutter and individual On/Off controls for both the deuterium and tungsten sources.

BDS130 Deuterium/Tungsten Light Source

The BDS130 is an AC powered turnkey SMA 905 fiber coupled UV/Vis/NIR light source with a spectral output of 190 to > 2500nm. The 30W deuterium lamp and 5W tungsten halogen lamp share a single optical path. Features include a safety shutter and individual On/Off controls for both the deuterium and tungsten lamps.

BPS101 Tungsten Halogen Light Source

The BPS101 is a DC powered high performance SMA 905 fiber coupled constant current tungsten halogen light source with a spectral output of 350 to > 2600nm. A user replaceable 5W input power bulb has a ~10,000 hour lifetime with a color temperature of 2800K. Constant current provides precision current control for stable performance. A remote control port provides On/Off modulation, operating current monitoring, and external operating current control.

BPS120 Tungsten Halogen Light Source

The BPS120 is a DC powered high performance SMA 905 fiber coupled constant current tungsten halogen light source with a spectral output of 350 to > 2600nm. A replaceable 20W input power bulb has a ~5,000 hour lifetime with a color temperature of 2900K. Constant current provides precision current control for stable performance. A remote control port provides On/Off modulation, operating current monitoring, and external operating current control.

Accessories

BPS2.0 Tungsten Halogen Light Source

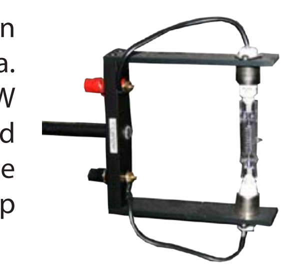
The BPS2.0 is a DC powered, high performance, SMA 905 fiber coupled, constant current tungsten halogen light source with a spectral output of 350 to > 2600nm. A user replaceable 20W bulb has a ~2,000 hour lifetime with a color temperature of 2900K. Constant current provides precision current control for stable performance. The BPS2.0 incorporates a fan for thermal stability for low drift. A remote control port provides On/Off modulation, operating current monitoring, and external operating current control.

BPX100 Pulsed Xenon Light Source

The BPX100 is an AC powered compact SMA 905 fiber coupled 5W Xenon flash lamp module with a spectral output of 185 - 2000nm. By passing an electrical current through a Xenon gas, the BPX100 produces both continuous and line spectra. Low pulse-to-pulse variations and long operating life characteristics makes the BPX100 ideal as an excitation light source for fluorescence spectroscopy and UV rich sources for reflectance and transmittance spectrophotometry.

ICL Irradiance Lamps

The ICL series calibrated lamp standards are tungsten coiled-coil filaments enclosed in quartz envelopes. Calibrated Lamps provide reliable spectral irradiance calibration data. Calibrated 100W lamps can cover 350-1050nm and 350-1700nm. Calibrated 1000W lamps can cover 350-1700nm, 350-2200nm, and 250-1100nm. Lamps are seasoned and calibration is traceable to the National Institute of Standards and Technology (NIST) scale of spectral irradiance. The lamps are provided with calibration data and respective lamp holders for easy installation and adjustment.



SCL100 Spectral Calibration

The SCL100 is a series of DC powered compact SMA 905 fiber coupled spectral calibration light sources. The SCL100 can be used for wavelength calibration of monochromators, spectrometers, and spectroradiometers. By exciting these various gases, they will produce narrow intense lines of the corresponding element(s). There are 6 lamp models to select from: Argon (Ar), Krypton (Kr), Mercury (Hg), Mercury/Argon (Hg/Ar), Neon (Ne), and Xenon (Xe).

Accessories

BCH100A & BCH103A Cuvette Holders

The BCH100A & BCH103A cuvette sample holders are designed for fiber optic illumination/ detection. A standard 12.5 x 12.5mm (OD) (1 cm path length) cuvette can be used for liquid sample transmittance and absorbance. Two SMA 905 fiber couplers with collimated optics come with the BCH100A and three come with the BCH103. Both can be used with any B&W Tek, Inc. fiber, array spectrometer and BPS or BDS light sources. The BCH100A comes with two "straight through" SMA 905 ports. The BCH103A can be used for fluorescence when set up for right angle measurements with respect to illumination.

BFH105 Inline Filter Holder

The BFH105 inline filter holder is designed to hold up to three standard Ø 1 in x 5 mm filters (sold separately). The BFH105 has two SMA 905 fiber connections with collimated optics and can be used with any B&W Tek, Inc. array spectrometer and light source.

BIP2.0 Integrating Sphere

The BIP2.0 is a compact, fiber coupled integrating sphere with an integrated 20W tungsten halogen lamp which emits over the UV-NIR Spectrum. The two inch diameter integrating sphere is machined from PTFE. PTFE is reflective and highly Lambertian over the broad spectral range of 250-2500nm and 99% from 400-800nm. The BIP2.0 incorporates a fan for thermal stability for low drift and operates on 12 V DC. It is designed for measuring diffused reflectance using any B&W Tek, Inc. array spectrometer.

BIS1.5 Integrating Sphere

The BIS1.5 is a compact, integrating sphere designed as a sampling accessory for measuring diffused transmittance using any B&W Tek, Inc. array spectrometer. The 1.5 inch diameter integrating sphere is machined from PTFE. PTFE is reflective and highly Lambertian over the broad spectral range of 250-2500nm and 99% from 400-800nm.

Accessories

Fiber Patch Cords

The Fiber Patch Cords (FPC) are fiber optic cables terminated with SMA905 connectors on both ends (FC connectors available upon request). These are available in UV, NIR, and MIR grade fused silica optical fibers with various core diameters. Fiber core sizes range from 50µm to 1000µm with a standard length of 1.5 meters with custom lengths available upon request.

BFA & BRS Bifurcated Fibers

The Bifurcated Fiber Assembly (BFA) series combines optical fibers at a common end with the fiber bundle bifurcated into two separate channels. These channels can connect to a light source and a spectrometer or split an incoming signal into two separate spectrometer channels. When a collimating lens is attached to the common end of the assembly and positioned correctly, the specular reflectance for 0° angle of incidence can also be measured.

Fiber Dip Probe

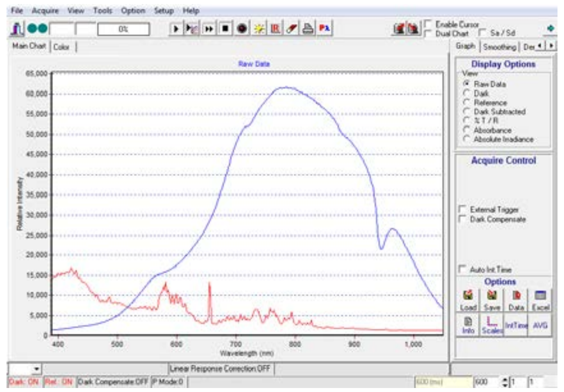
The fiber dip probe (FDP) series can be used for measuring the transmittance and absorbance of liquid solutions. The fiber dip probe can be inserted into liquids for *in situ* transflectance measurements. Typical applications include observing changes in solutions for kinetic reaction studies or dissolution testing.

Fiber Reflectance Probe

The Fiber Reflectance Probe (FRP) series combines 7 optical fibers at the sample end into a bifurcated fiber. This bifurcated fiber splits into one fiber and 6 stacked fibers with the single fiber connecting to a light source and the 6 stacked fibers connecting to a spectrometer. These stacked fibers align to the spectrometer's slit for increased signal input. When properly setup, the FRP can measure diffuse or specular reflectance from surfaces.

For more information and additional accessories, please visit our website at www.bwtek.com

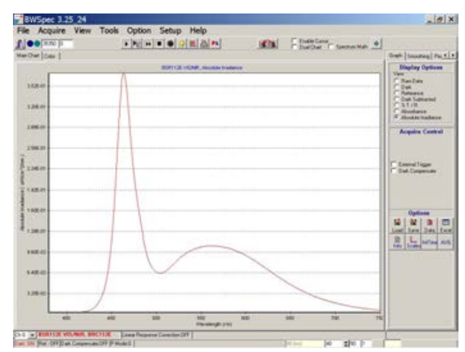
BWSpec™



BWSpec™ is a spectral data acquisition software developed by B&W Tek, Inc. and is the foundation for all B&W Tek, Inc. software platforms. It is included with the purchase of all B&W Tek products that use it to operate, which include spectrometers, systems, and accessories. BWSpec™ is ideal for broad range applications since it delivers a wide range of features designed to perform complex measurements and calculations at the click of a button. It features multiple data formats and the capability to optimize scanning parameters, such as integration time and laser output power control. In addition to data acquisition and data processing, other features include automatic dark removal, spectrum smoothing, and manual/auto baseline correction.

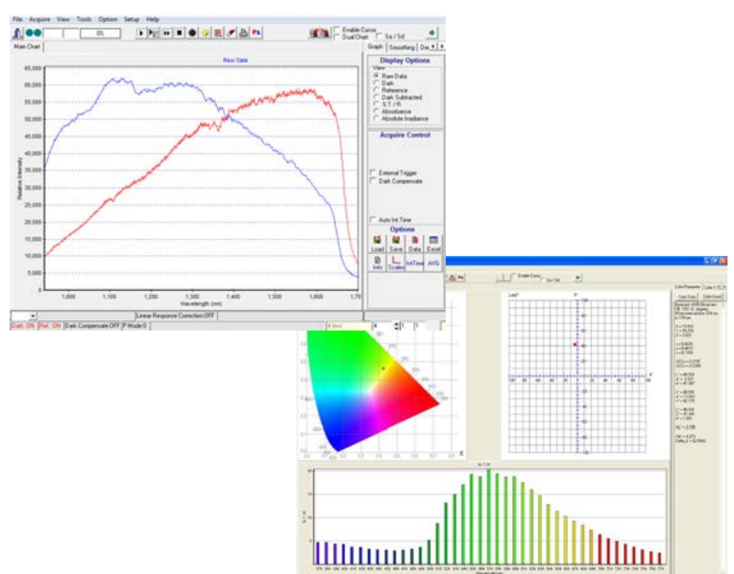
Features:

- Included with B&W Tek Spectrometers, Systems, and Accessories (if applicable)
- Performs Emission, Absorbance, Percent Transmission / Reflection, and Raman Measurements
- Capable of Continuous and Single Scan Acquisition
- Subtracts Dark Noise
- Offers Spectral File Formats: txt & spc
- Exports Spectral Files to Excel®
- Features Manual and Automatic Baseline Correction
- Includes Peak Smoothing Algorithms: FFT, Savitzky-Golay, & Boxcar
- Includes Derivative Algorithms: Point Diff, Savitzky-Golay, & Differentiate
- Performs Area Calculations
- Offers Peak Analysis Options: Center Wavelength, Integrated Power Density, FWHM Calculations, and More
- Contains Basic Spectral Math: Addition, Subtraction, Multiplication, and Division
- Also Features: Tristimulus, Chromaticity, and Color Calculations

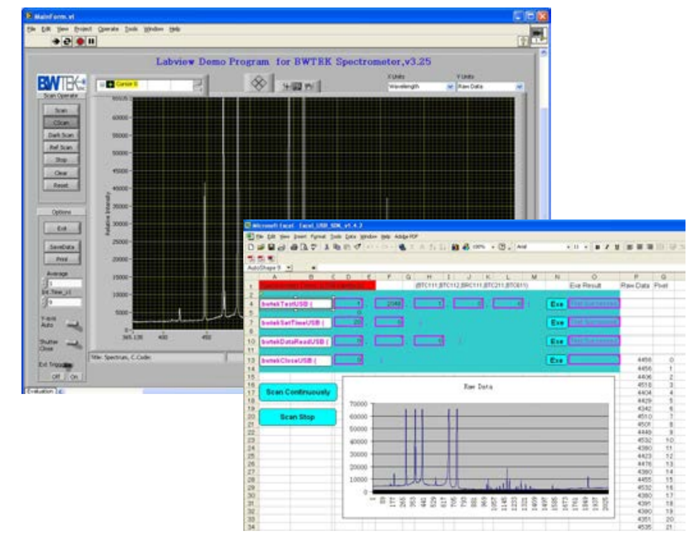


Applications:

- **Transmission**
- **Absorption**
- **Reflectance**
- **Fluorescence**
- **Raman**
- **Color / Irradiance**

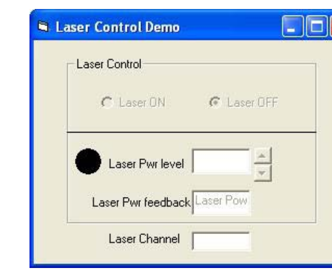


Software Development Kit



B&W Tek's SDK (Software Development Kit) provides you with the detailed function calls to our .DLL files. This package is designed for customers who wish to create their own custom software interface allowing complete control over your spectrometer or system.

Every spectrometer / system we sell can be run using the SDK, including RS232 and USB units, from non-cooled spectrometers to complete Raman systems with laser power control.



Features:

The SDK Package comes complete with simple programming examples done with our various spectrometer models to get you started.

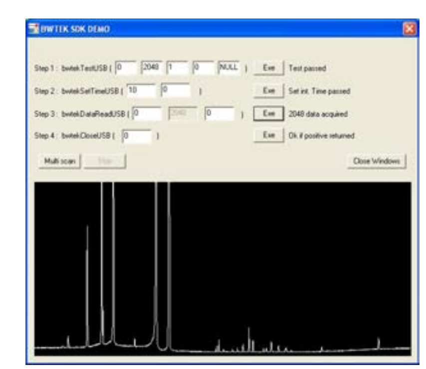
- C#
- C++ Builder 6
- Visual C++ 6.0
- Visual Basic 6.0
- VBA
- Labview
- VB.NET

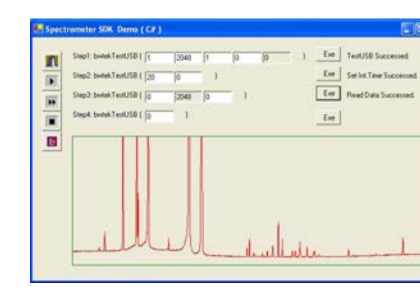
Program Examples:

Specification	Interface
C# SDK	USB Spectrometers
VB.Net SDK	USB Spectrometers
C++ Builder 6 SDK	USB Spectrometers
Visual C++ 6.0 SDK	USB Spectrometers
Visual Basic 6.0 SDK	USB Spectrometers / Lasers
VBA SDK	USB Spectrometers
Labview 8.2 SDK	USB Spectrometers
RS232 Interface SDK	RS232 Spectrometers

SDK Supports:

- Raman Systems
- Reflectance Systems
- Transmittance Systems
- USB Cleanlaze® Lasers
- RS232 Spectrometers
- USB Spectrometers





Innovative Solutions for

Spectral Irradiance & Spectrophotometry

SpectraRad®

TE Cooled Miniature Spectral Irradiance Meter

The SpectraRad® is a miniature TE Cooled spectral irradiance meter designed for industrial applications and lab use with a USB 2.0 interface. The SpectraRad® is equipped with a fiber coupled right angle transmissive cosine corrector, which is irradiance calibrated against a NIST traceable tungsten light source. BWSpec™ software is provided for characterization and measurement of many application lighting devices and systems. The SpectraRad® is ideal for lamp and LED characterization, color analysis, photostability testing, photobiology and photochemistry. Standard software features include timeline recording, data smoothing, illuminance (lux), chromaticity, color temperature, and other data-handling functions.

Applications:

Illumination and Color Characterization

UV Curing System QC

LED Characterization

Visible Spectroscopy / Spectroradiometry

WL Identification

Color Absorbance & Reflectance

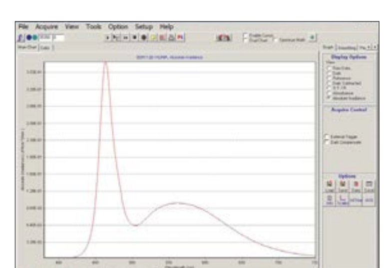
Specifications:

Optical	
Spectral Range	380nm - 750nm, 350nm - 1050nm
Spectral Resolution	~1.5nm, ~2.0nm
Irradiance Range	25 nW/cm²/nm - 4 mW/cm²/nm
Electrical	
Detector Type	Response Enhanced 2048 Element Linear Silicon CCD Array
TE Cooling	14°C
External Trigger	Aux Port
Computer Interface	USB 2.0 / 1.1
Data Transfer Speed	Up to 180 Spectra Per Second Via USB 2.0
DC Power Input	5V DC < 1.5 Amps
Software	
Effective Integration Time	5 - 120,000ms
Operating Systems	Windows: XP, Vista (32-bit), 7 (32-bit)
Environmental	
Operating Temperature	15°C - 35°C
Operational Relative Humidity	85% Non-condensing

Advantages of Spectral vs. Filter Based Instruments:

Although filter based instruments are desired for certain properties such as cost, speed and portability, they are not always the best choice for analytical measurements. Filter based instruments only acquire three data points across the entire spectrum of light to yield colorimetric values. This is accomplished by the use of filters corresponding to the normal human eye response. These filters can only be manufactured to a certain degree of accuracy. Due to these facts, filter based meters are susceptible to errors because of the deviation of the filter response from the ideal human eye response and the lack of resolution needed to accurately describe narrow bandwidth light sources.

The SpectraRad™ avoids these problems at a comparable cost, higher speed and small footprint because it acquires hundreds of data points across the visible spectrum. In addition, the 2048 pixel linear CCD array provides the precision required to accurately measure narrow bandwidth light sources or LEDs. Having multiple sensors also enables the unit to report spectral data and display spectral graphs, making it the ideal instrument for evaluating LEDs, which are today's dominant light source.



SpectraRad® Xpress

The SpectraRad® Xpress is a miniature spectral irradiance meter designed for field, industrial, and lab applications with a plug-and-play USB 2.0 interface. A transmissive cosine corrector is coupled to a spectrometer which then is irradiance calibrated against a NIST traceable Tungsten light source. Optimized software is provided for characterization and measurement of many application lighting devices and systems. Standard software features include timeline recording, data smoothing, illuminance (lux), chromaticity, color temperature, external triggered pulsed light capturing, and other data handling functions. The SpectraRad® Xpress is ideal for lamp and LED characterization (requires input optic option), color analysis, solar studies, photostability testing, photobiology and photochemistry.

Features:

- Spectral Range: 380-750nm, 350-1050nm
- Input Optics: Transmissive Cosine Corrector (Default)
- CIE 127 Compliant Adaptor (ADP-CIE127 Option)
- NIST Traceable Calibration
- Wavelength Accuracy: Better Than 0.3nm

Applications:

Illumination and Color Rendering from Lighting

Solar Irradiance Monitoring (Outdoors)

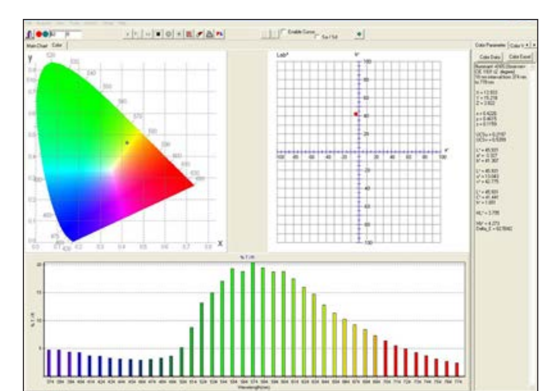
Solar Simulator Validation (Indoors)

UV Curing System QC

LED Characterization

Color Software:

BWSpec™ features a wide range of tools designed to perform complex measurements and calculations at the click of a button. It allows the user to choose between multiple data formats and offers automatic optimization of integration time. BWSpec™ color software graphically displays positioning in the CIE 1931 Chromaticity Chart and in Lab* space. BWSpec™ also provides tristimulus values (X, Y, Z), Correlated Color Temperature (CCT), Dominant Wavelength, Ev (lux), x, y, u', v', and many more radiometric and color metrics in an easy-to-follow display window.



Specifications:

Power Input	USB at < 350mA
Detector Type	Response Enhanced 2048 Element Linear Silicon CCD Array
Detector Pixel Format	2048 x 1 Elements @ 14µm x 200µm Per Element
Spectrograph *f/#*	3.0
Spectrograph Optical Layout	Crossed Czerny-Turner
Dynamic Range	275 (Typical)
Digitizer Resolution	16-bit or 65,535:1
Readout Speed	500 kHz
Data Transfer Speed	Up to 180 Spectra Per Second Via USB 2.0
Effective Integration Time	1 to >=20,000 ms
External Trigger	Aux Port
Operating Temperature	15°C - 35°C
Relative Humidity	0 - 85% RH Non Condensing
Weight	~ 0.5 lbs (0.23 kg)
Computer Interface	USB 2.0/1.1
Operating Systems	Windows XP, Vista (32 bit), & 7 (32 bit)

Model	BSR112E-VIS	BSR112E-VIS/NIR
Range	380-750nm	350-1050
Slit	100µm	100µm
Resolution	~3.0nm	~4.0nm
Irradiance Range	20nW/cm²/nm - 400µW/cm²/nm	30nW/cm²/nm - 600µW/cm²/nm

i-Spec™ Series

Broadband Transmission / Reflection / Absorption Spectrophotometers

i-Spec™ series products are broadband transmission / reflection / absorption spectrophotometers with various accessory options for bench-top, as well as portable uses. Systems can employ TE Cooled CCD array, Photodiode Array, TE Cooled InGaAs array, and/or TE Cooled Extended InGaAs array detectors for optimal sensitivity and dynamic range in the UV, Vis, and NIR. The *i*-Spec™ products feature a standard external triggering port with flexible fiber optic coupling of sampling accessories. *i*-Spec™ series products use high intensity and long lifetime tungsten halogen 5 Watt or 20 Watt sources and high speed detection systems, enabling fast spectral capturing of 20 to >100 spectra per second, making them ideal for spectrophotometric studies where high-speed spectrum capture rates are essential.

Applications :

Agricultural, Pharmaceutical, and Petrochemical

Material Diffuse Property Characterization

Opaque Chemical Solution Analysis

Bench-top and In-field Spectrophotometric Measurements

Sampling Accessories:

- Fiber Reflectance Probes
- Dark Field Reflectance Probes
- Fiber Dip Probes
- Assembly Options:
  Trifurcated, Bifurcated, & Round-to-slit

Features:

- Broadband Transmission, Reflection, Absorption Measurements
- Portable, Rugged Turnkey Design
- USB 2.0 Plug-and-play Interface
- Flexible Fiber Coupling of Sampling Accessories
- Battery Option Available

Light Source Options:

Light Source	Application
5W Tungsten Halogen	Best For Transmittance Measurements Can Support Transflectance and Some Reflectance Measurements
20W Tungsten Halogen	System Performance is Optimized For Reflectance Measurements

Spectrophotometry

Common Specifications (Typical):

	System	
Measurements	Transmittance, Reflectance, Absorbance Fiber Optic Probes and Sampling Accessories Required (Sold Separately)	
Connections	Illumination and Collection SMA905 Ports For Fiber Optic Coupling	
Triggering	Front Panel Connection For Use With Sampling Probes With Triggering Feature	
Computer Interface	USB 2.0/1.1	
Software	iSpec™	
Software Options	Software Developer's Kit (SDK) Sample Code: C#, C++, Visual C++, Visual Basic, VBA, Labview, VB.NET	
Instrument Dimensions	9.5 (H) x 6.7 (W) x 13.7 (D) in (242 (H) x 170 (W) x 347 (D) mm)	
Weight (model dependant)	7.9 - 10.8lbs (3.6 - 4.9kg)	
Power	12V DC @ 10.8 Amps, Battery Option Available	
Operating Temperature	0°C to 45°C	
	Spectrometer	
Optical Design	Crossed Czerny-Turner Spectrograph	
Digitization Resolution	16-bit or 65,535 to 1	
Integration Time	250ms - 5ms (Min. Spectrometer Dependant), 63,535ms x Multiplier (Max.)	
Light Source	Tungsten Halogen 5W	Tungsten Halogen 20W
Spectral Output Range	350 to > 2600nm	350 to > 2600nm
Color Temperature	2800 K	2900 K
Warm Up Time	~40 Minutes	~40 Minutes
Rated Life	10,000 Hours	2,000 Hours

Available Configurations:

Model Number	Wavelength Range (nm)	Spectral Resolution (nm FWHM) & Detector Array	Tungsten Halogen Light Source (W)
BWS005A-05	400 - 2200	~5.8 (400-1150nm) Photodiode Linear Array ~13 (1100-2200nm) TE Cooled Extended InGaAs Array	5
BWS005A-20			20
BWS015-05	350 - 1700	~1.2 (350-1050nm) TE Cooled Silicon CCD Array ~4.0 (900-1700nm) TE Cooled InGaAs Linear Array	5
BWS015-20			20
BWS035-05	900 - 1700	~ 4.0 (900-1700nm) TE Cooled InGaAs Array	5
BWS035-20			20
Call	400 - 2550	Contact B&W Tek, Inc. For More Information	5
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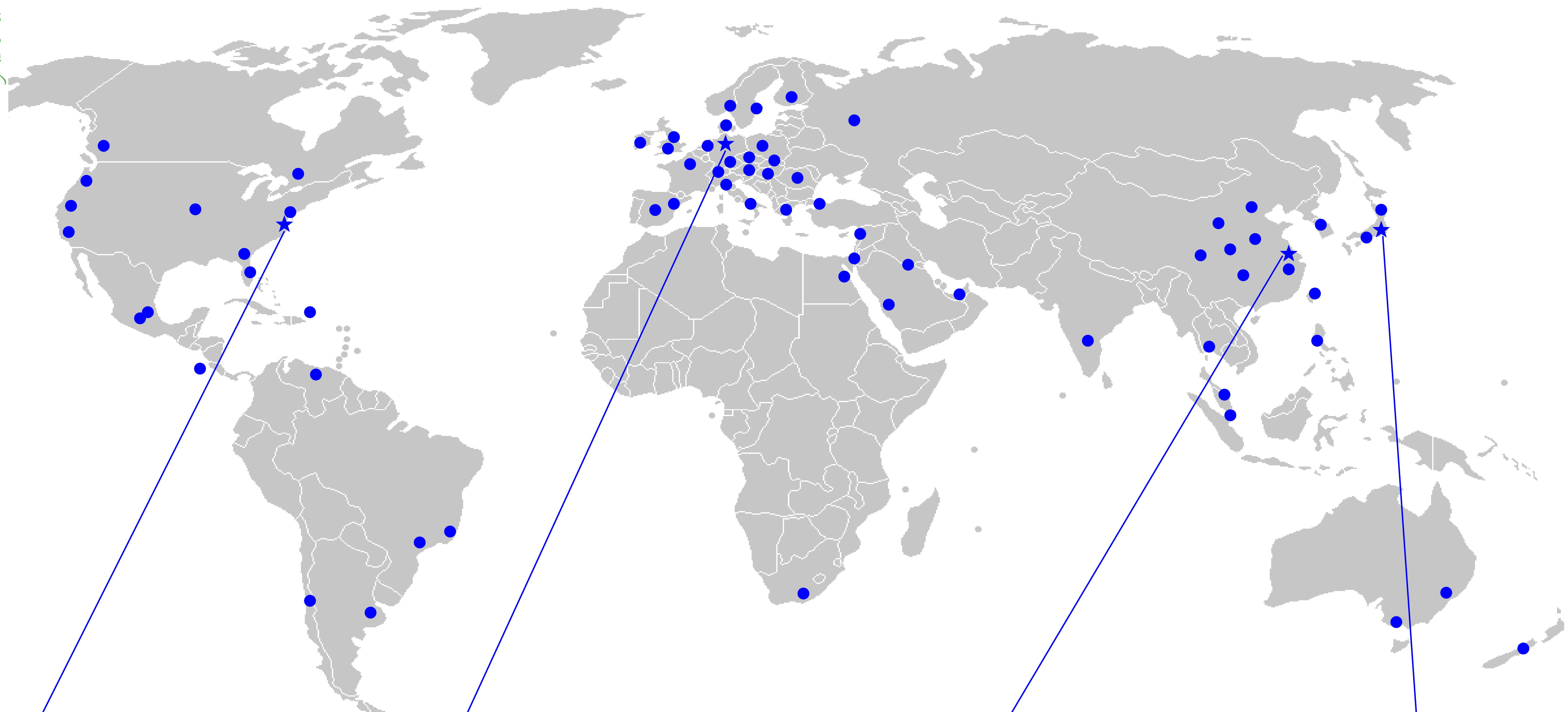
Where can I find a B&W Tek location or distributor near me?

With offices and distributors in over 18 countries, B&W Tek's global presence makes it easy to get in touch with us, no matter where you are.



★ **United States** – Our headquarters is located in Newark, DE, where much of the engineering, design, and manufacturing for B&W Tek takes place. This location, along with a second facility in Delaware and our R&D facility in Princeton, New Jersey make up half of our total employees and 40% of our engineering capabilities.

★ **Europe** – In Lübeck, Germany (near Hamburg) B&W Tek has a dedicated sales and marketing office to provide additional support, training, and materials to all of our current European customers, as well as to cultivate new sales channels and customers in Europe.

★ **China** – B&W Tek has two state-of-the-art facilities located in Shanghai, both with ISO-13484 and ISO-9001 certifications. Our 30,000 square feet of laboratory space is used for research, development, customization and testing.

★ **Japan** – In Saitama, Japan (near Tokyo) B&W Tek has an office with sales and marketing capabilities, as well as engineering and QA/QC support. This office also manages several major OEM accounts in addition to multiple channel partners, including Konica Minolta.

Key Distributors:

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Opton Laser International
Phone: +33 (0) 1-69-41-04-05
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