QualitySpec® User Manual

ASD Document 600548 Rev. C

www.asdi.com

ASD Inc.

Trademark Information

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Technical support is committed to providing you with a timely response to your questions. We will work with you to provide solutions to your applications. Technical support is available to answer your questions Monday thru Friday, 8 am to 5 pm Mountain Standard Time. We will happily respond to your e-mail queries as well.

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Declaration of Conformity

According to IEC guide 22 and EN45014

Manufacturers Name: Analytical Spectral Devices, Incorporated.
Manufacturers Address: 5335 Sterling Drive, Suite A
Boulder, CO 80301
Phone: (303) 444 6522
European Contact: Your local Analytical Spectral Devices Representative.

Declares that the product(s)

Product Name: QualitySpec® Pro

Product Numbers	Description	Range (nm)
A100700	VNIR	350-1050
A100710	VNIR & SWIR1	350-1800
A100720	SWIR1	1000-1800
A100730	SWIR2	1800-2500
A100740	SWIR1 & SWIR2	1000-2500
A100750	Full Range (VNIR, SWIR1, & SWIR2)	350-2500
A100760	Full Range High Resolution	350-2500

Conforms to the following EU Directives:

Safety: Low Voltage Directive, 72/23/EEC, as amended by 93/68/EEC

EMC: Electromagnetic Compatibility Directive, 89/336/EEC, as amended by 93/68/EEC

Supplementary Information:

The product complies with the requirements of the following Harmonized Product Standards and carries the CE-Marking accordingly:

EN 61010-1: 2001 Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory use

EN 61326-1: 2002 Class A, Electrical Equipment for Measurement, control and Laboratory use – EMC requirements

Signature:
Title: Director of Engineering
Date: 11/02/2005

Notes:

Chapter 1 Introduction

The QualitySpec® Spectrometer is a general-purpose instrument that uses the visible near-infrared (VNIR: 350-1000 nm) and near infrared (NIR: 1000-2500 nm) spectra for material analysis and identification. It has a rapid data collection (10 spectra per second).

The QualitySpec spectrometer is specifically designed for laboratory analysis using visible and near infrared spectroscopy. It uses measurements of reflectance, transmission, or absorbance to analyze materials.

The ASD Accessories Guide contains an array of devices for the QualitySpec spectrometer, that extends the application areas.

Features and Advantages

Accurate and Precise - High signal-to-noise ratio and superior repeatability of results for better discrimination and analysis of materials.

Rugged - Resistant to vibration and changes in temperature or humidity.

Fast - 10 spectra per second data collection for the entire 350-2500 nm range.

- » 0.1 second scanning time provides an accurate average every second
- » Users can quickly scan several areas when analyzing bulk samples.
- » Rapid analysis allows the screening of all or most samples versus spot checking.

Compatible - Works with off the shelf chemometrics software, such as Grams™ PLS plus/IQ and Unscrambler®.

Symbols - Definitions

CAUTION: ***Risk of danger.*** This is a personal danager warning. Documentation must be consulted in all cases where this symbol is marked. Failure to acknowledge these warnings could result in personal injury to the user.

CAUTION: ***Risk of Electric Shock.*** This is a personal warning. Documentation must be consulted in all cases where this symbol is marked. Failure to acknowledge these warnings could result in personal injury to the user.

CAUTION: ***Hot Surface.*** This is a personal warning. Documentation must be consulted in all cases where this symbol is marked. Failure to acknowledge these warnings could result in personal injury to the user.

Recycle: Items with this symbol indicate that the item should be recycled and not disposed of as general waste.

Warnings and cautions are placed throughout this manual for convenience of the reader. However, the absence of warnings and cautions do not preclude the use of proper caution and handling. Usual precautions are recommended to be taken at all times, either written or otherwise, to avoid personal injury or damage to ASD equipment.

1.1 Hardware Specifications

This section contains details about the QualitySpec spectrometer.

1.1.1 Physical Specifications

Height (including stand)	32.5 cm	12.7 inches
Width	10.8 cm	4.2 inches
Depth	29.5 cm	11.5 inches
Weight (not including power supply)	6.8 kg	15 lbs

- All vital components are in a dust-proof enclosure and EMI sealed

1.1.2 Power Supply Input and Output Specifications

AC Power Supply Type	Auto ranging, Switching, SELV
AC Input	90-240 VAC, 50/60 Hz
DC Input	+12 VDC, 45 Watts

Instrument Configuration	Power Rating (Maximum)
350-1050 nm	12 VDC, 12 Watts
350-1800 nm	12 VDC, 20 Watts
1000-1800 nm	12 VDC, 20 Watts
1800-2500nm	12 VDC, 20 Watts
1000-2500 nm	12 VDC, 25 Watts
350-2500nm	12 VDC, 25 Watts

1.1.3 QualitySpec Wavelength Configuration

The near infrared (NIR) is also called the short-wave infrared (SWIR).

Wavelength Name	**Wavelength Range**
VNIR-SWIR1-SWIR2	350-2500 nm
VNIR-SWIR1-SWIR2 (high resolution)	350-2500 nm
VNIR-only	350-1050 nm
VNIR-SWIR1	350-1800 nm

The spectral resolution is:

- 3 nm (Full-Width-Half-Maximum) at 700 nm.
- 10 nm (Full-Width-Half-Maximum) at 1400 nm.
- 10 nm (Full-Width-Half-Maximum) at 2100 nm.

The sampling interval is:

- 1.4 nm for the spectral region 350-1000 nm.
- 2 nm for the spectral region 1000-2500 nm.

The QualitySpec spectrometer may be configured to have three separate holographic diffraction gratings with three separate detectors. Each detector is also covered with the appropriate order separation filters to eliminate second and higher order light.

- VNIR: 512 element silicon photo-diode array for the spectral region 350-1000 nm.

- NIR1: graded index, TE-cooled, extended range, InGaAs, photo-diode for the spectral region 1000 nm to 1800 nm.
- NIR2: graded index, TE-cooled, extended range, InGaAs, photo-diode for the spectral region 1800 nm to 2500 nm.

1.1.4 Interface Requirement

The QualitySpec spectrometer has 10/100 Base T Ethernet port. The spectrometer with an Ethernet cross-over cable can be directly connected to the Ethernet port provided on many laptop computers.

Note: For information about configuration of the Ethernet card and cable, please refer to the *Installation Manual*.

1.1.5 Standard Accessories

- QualitySpec® Spectrometer
- QualitySpec® User Manual (PDF on Flash Drive)
- IndicoPro Software Pack
- Power Supply 12 V
- RJ45 CAT 5e UTP Ethernet, Shielded, Crossover Cable
- 64 MB (min.) Flash Drive Memory USB Flash Drive
- Mylar Wavelength Reference

1.2 Computer Requirements

Note: The instrument controller is not included with the QualitySpec spectrometer.

The *instrument controller* is a computer that manages the QualitySpec spectrometer, stores data, and processes the results.

The minimum requirements for the instrument controller are:

- 1.2 GHz Pentium or better notebook or PC-w/monitor
- 256 MB RAM or more
- 20 GB of free disk space
- 1024 x 768 or better graphics resolution
- 24-bit color or better - 32-bit recommended
- Ethernet port: 10/100 Base T Ethernet interface

1.3 Software Requirement

The instrument controller requires the following software:

- IndicoPro Software from ASD.
- Microsoft Windows® 95/98/NT/2000/ME/XP Operating System.
- Microsoft Internet Explorer 6.0 or better.

Users need a basic understanding of the Microsoft Windows operating system including software installation.

International customers using non-English versions of Windows must alter the **Regional Settings** under **Start->Settings->Control Panel**. The default language must be set to English (United States) in order for the software to be registered and operate correctly. The numbering format must also be set to English.

1.4 Theory of Operation

The QualitySpec spectrometer measures the optical energy that is reflected by, absorbed into, or transmitted through a sample. *Optical energy* refers to a wavelength range that is greater than just the visible wavelengths, and is sometimes called *electromagnetic radiation* or *optical radiation*.

With accessories, various set-ups, and built-in processing of the optical energy signal, the QualitySpec spectrometer can measure:

- spectral reflectance,
- spectral transmittance, and
- spectral absorbance.

Fiber Optic Collection of Reflected/Transmitted Light

Optical energy is collected through a bundle of specially formulated optical fibers, precisely cut, polished, and sealed for extremely efficient energy collection. The fibers themselves are of low OH composition providing the maximum transmission available across the instrument's wavelength range.

Inside the QualitySpec® Spectrometer

The fiber cable delivers the collected optical energy into the instrument, where it is projected onto a holographic diffraction grating. The grating separates and reflects the wavelength components for independent measurement by the detectors.

Visible/Near-Infrared (VNIR)

The Visible/Near-Infrared (VNIR: 350-1000 nm wavelength) portion of the spectrum is measured by a 512-channel silicon photodiode array overlaid with an order separation filter. Each channel (or detector) is geometrically positioned to receive light within a narrow (1.4 nm) range. The VNIR spectrometer has a spectral resolution (full-width half maximum of a single emission line) of approximately 3 nm at around 700 nm.

Each detector converts incident photons into electrons. This photocurrent is continually converted to a voltage and is then periodically digitized by a 16-bit analog-to-digital (A/D) converter. This digitized spectral data is then transmitted to the instrument controller for further processing and analysis by the controlling software.

The 512-channel array permits the entire VNIR spectrum to be scanned in parallel at 1.4 nm wavelength intervals. A single sample can be acquired in as little as 17 ms.

Near Infrared (NIR) or Short-Wave Infrared (SWIR)

The Near-Infrared (NIR), also called Short-Wave Infrared (SWIR), portion of the spectrum is acquired with two scanning spectrometers:

- SWIR1 for the wavelength range of 1000 nm to 1800 nm.
- SWIR2 for the wavelength range of 1800 nm to 2500 nm.

The SWIR scanning spectrometers only have one detector for SWIR1 and another for SWIR2. This is different from the VNIR spectrometer, which has an array of 512 detectors. Thus, SWIR spectrometers collect wavelength information sequentially rather than in parallel.

Each SWIR spectrometer consists of a concave holographic grating and a single thermo-electrically cooled Indium Gallium Arsenide (InGaAs) detector. The gratings are mounted about a common shaft which oscillates back and forth through a 15 degree swing. As the grating moves, it exposes the SWIR1 and SWIR2 detectors to different wavelengths of optical energy. Each SWIR spectrometer has ~600 channels, or ~2 nm sampling interval per SWIR channel. The spectrometer firmware automatically compensates for the overlap in wavelength intervals.

Like the VNIR detectors, the SWIR1 and SWIR2 detectors convert incident photons into electrons. This photocurrent is continually converted to a voltage and is then periodically digitized by a 16-bit analog-to-digital (A/D) converter. This digitized spectral data is then transmitted to the instrument controller for further processing and analysis by the controlling software.

The grating is physically oscillating with a period of 200 ms. It performs a forward scan and a backward scan, resulting in 100 ms per scan. This is the minimum time required for any SWIR samples, or full-range samples.

Communicating with the Instrument Controller (Computer)

The QualitySpec spectrometer communicates with the instrument controller using an Ethernet interface. The amount of data that is sent depends on the configuration of the spectrometer.

- A single sample of VNIR is ~1024 bytes.
- A single sample of SWIR1 is ~2400 bytes.
- A single sample of SWIR2 is ~2400 bytes.

A full-range QualitySpec spectrometer can create packet data sizes over 5 KB. Other single or dual range configurations of the spectrometer create smaller data packets (adding the packet sizes as above.)

When features for spectrum averaging (or sample count) are turned on within the application software on the instrument controller, the averaging is performed at the spectrometer.

Dark Current Measurement

Dark Current (DC) refers to current generated within a detector in the absence of any external photons. DC is the amount of electrical current that is inherent in the spectrometer detectors and other electrical components and is additive to the signal generated by the measured external optical radiation.

Note: *Noise* is the uncertainty in a given measurement, one channel at a time. Noise by definition is random. Noise can be reduced by using more samples and averaging the signal. *Dark Current* is different from noise, because it is relatively stable and can be characterized.

This manual uses DC to refer to all systematic contributions to the detector signal. DC is a property of the detector and the associated electronics (not the light source). DC varies with temperature. In the VNIR region, DC also varies with integration time.

Whenever DC is taken, a mechanical shutter is used to block off the entrance slit of the VNIR spectrometer so the signal can be measured. This signal is subtracted from each subsequent spectrum until another DC is taken. The SWIR spectrometers take and subtract DC on every scan.

The DC measurement can be updated at any time, but should be updated more frequently in the beginning of a given session while the instrument warms up.

The VNIR spectrometer is fitted with a unique software and hardware combination feature called *Driftlock*. Driftlock corrects for DC changes over time. It automatically updates DC for every measurement by looking at a series of masked pixels at the front portion of the VNIR array. The Driftlock feature corrects for the majority of DC variation over time.

Baseline (or White Reference)

A material with approximately 100% reflectance across the entire spectrum is called a white *reference panel* or white *reference standard*.

The raw measurement made by the spectrometer is influenced by both the sample and the light source. An independent measure of the light source illumination on a reference of known reflectance is required to calculate the reflectance of the sample. The use of a white reference standard with near 100% reflectance simplifies this calculation.

Reflectance and transmittance are inherent properties of all materials and are independent of the light source.

Reflectance is the ratio of energy reflected from a sample to the energy incident on the sample. *Spectral Reflectance* is the reflectance as a function of wavelength.

Transmittance is the ratio of the radiant energy transmitted through a sample to the radiant energy incident on the surface of the sample. *Spectral Transmittance* is the transmittance as a function of wavelength.

Relative reflectance is computed by dividing the energy reflected from the sample by the energy reflected off a white reference panel or standard.

Accessories for Light Sources and Probes

ASD offers several accessories for:

- Delivering illumination to the sample.
- Collecting reflected or transmitted light from the sample.
- Transmitting the collected light to the spectrometer.

Some accessories, such as the Contact Probe, perform all of these functions. Other accessories, such as some of the optional foreoptic probes, rely on other illumination sources.

Accurate analysis of collected spectra requires an adequate level of incident light on the sample. The ASD accessories are designed for stability and accuracy and provide a controlled source of incident light. Characteristics of the light source are eliminated when the baseline spectrum is applied to each raw sample spectrum.

Chapter 2 Setup

Inspect the shipping container and take careful notes regarding any damage that might have occurred during shipping.

Note: Save all packing materials, foam spacers, and paperwork for possible future use.

Prepare a clear space on a sturdy bench or counter, ideally, a space near a wall-current receptacle and the controlling computer.

Carefully open the shipping container following all instructions and orientation labels on the container.

2.1 Unpacking the Instrument

Figure 2-1 QualitySpec spectrometer front-view showing fiber connection to a contact probe (sold separately).

Step 1 Carefully remove the instrument from the shipping case.

Figure 2-2 QualitySpec spectrometer front-view showing fiber connection to USP filter wheel and light box.

WARNING! The fiber cable should never be stored with a bend of less than a 5" diameter for long periods of time, because the cable can be damaged with undetectable longitudinal fractures that can cause light leakage and weaker signals.

2.2 Power Supply

The QualitySpec spectrometer requires input power to be 12 VDC (50 W). It does not contain an internal power supply to convert AC voltage to DC, nor does it have internal batteries.

An external power supply that converts 100 VAC to 240 VAC (50 Hz or 60 Hz) to 12 VDC (shown in Figure 2-3).

- An external adapter for vehicle cigarette lighters (sold separately and should not be used with vehicle engine running).

Use only ASD approved power supplies or connectors to power the instrument.

Figure 2-3 QualitySpec spectrometer power supply and cables.

Figure 2-4 QualitySpec spectrometer power connector which plugs into the instrument.

Insert power (battery or power supply) into the receptacle on the back panel labeled "**INPUT 12 VDC 50 WATT**". Lock the connector in place by twisting the barrel end of the connector clockwise.

Figure 2-5 QualitySpec spectrometer back panel showing Ethernet connection, power switch, and power input jack.

2.3 Ethernet Cables

For Information about configuration of the Ethernet card and cable please refer to the *Installation Guide*. Only use shielded Ethernet cables to reduce electromagnetic interference with the instrument.

Note the location of the computer interface connection. Figure 2-5 shows the back panel containing the Ethernet port, which is labeled "**RJ45/ETHERNET**".

With the QualitySpec spectrometer and the instrument controller fully powered-down and turned-off, plug the shielded cross-over Ethernet computer cable (as shown in Figure 2-6) into the Ethernet ports of the QualitySpec spectrometer and your instrument controller.

Figure 2-6 Shielded cross-over Ethernet cable.

Chapter 3 Usage and Maintenance

For your safety and to prevent damage to the instrument, please review the following safety precautions. All operators should be familiar with this information.

3.1 Light Sources

Use only light sources supplied by ASD Inc. Light sources supplied by ASD are designed to provide levels of illumination and stability of output that complement the performance of ASD's instrumentation.

- Never touch the light source bulb and avoid contact with hot metal components near the bulb! Heat transfer from the light source may make these metal components uncomfortably warm to the touch.
- Prevent dirt and oils from contacting the bulb and reflector.
- Do not touch the glass envelope of the bulb. Oils on the hand may transfer to the glass envelope, which can significantly affect the bulb temperature and corrupt important operating physics of the bulb.

Note: Please refer to the *ASD Accessories Manual* or the instructions for that specific accessory for detailed information.

3.2 Access and Ventilation

When used inside, provide adequate room ventilation for the spectrometer. Insufficient ventilation can result in overheating of the spectrometer and subsequently corrupted data and possibly physical damage to the spectrometer.

Do not cover the vents of the instrument.

Do not place objects on the unit or the power supplies. Prevent objects from obstructing ventilation slits.

Keep objects and spills from entering or falling onto the instrument, power supplies, and software disks.

3.3 Cleaning

Step 1 Turn off the unit.

Step 2 Disconnect from all power.

Step 3 Allow the unit to cool down.

Step 4 Clean unit with a slightly damp cloth and mild soap.

Note: Be sure all soap residue is removed and all surfaces are dry before use.

3.4 Annual Maintenance

ASD recommends that the instrument be serviced once a year. This will ensure the proper function of the instrument. Annual maintenance is covered under ASD warranty or the extended service contract. Annual maintenance can be purchased separately. If you are interested in purchasing annual maintenance or an extended service contract, please contact your sales representative.

3.5 Returning Instrument to ASD for Service

In order to return the instrument to ASD for maintenance or repair, a Return Merchandise Authorization (RMA) must be issued by ASD technical support. The RMA includes scheduling details, contact information, shipping instructions, as well as a brief description of the maintenance or repair requirements. Please contact the technical support department at 303-444-6522 X-144 or support@asdi.com.

Chapter 4 Fiber Optic Interface

ASD offers a variety of fiber optic cable lengths to interface with the QualitySpec spectrometer. These fiber optic cables are used for reflectance and transmittance measurements.

Fiber optic cables should be loosely coiled and stored in the compartments provided. All accessories should be stored in the designated compartments of the carrier or in a separate protective case.

4.1 Fiber Optics Cables

The spectrometer includes an internal fiber optic cable (built into the instrument.) The *Accessories Guide* offers many options for the external cable (ordered separately), which is used for making measurements.

- The built-in fiber optic cable is made up of fifty-seven (57) randomly distributed, ultra low-OH, silica glass fibers. Nineteen (19) of these fibers are 100 micron and are distributed to the VNIR region. The remaining thirty-eight (38) fibers are 200 micron and are evenly divided between the two SWIR regions.
- The external fiber optic cable is made up of forty-four (44) randomly distributed, ultra low-OH, silica glass fibers that are 200 micron. This cable has a Numerical Aperture (NA) of 0.22.

The external fiber optic cable length is typically 1 meter. Additional external fiber optic cables can be ordered in a variety of lengths. However, as the length increases, the cable's transmission decreases at wavelengths below 400 nm and above 2000 nm.

The external fiber optic cable protects the fibers with a metal spiral inside the black PVC cable casing. If there are kinks in the cable, the fibers are not necessarily damaged. If, however, the cable has been damaged so severely that the protective metal spiral can be seen, the fibers may have been damaged. Each broken fiber results in a ~5% loss of response.

WARNING! **The fiber optic cable should never be stored with a bend of less than a 5" diameter for long periods of time.**

The fibers can be damaged by coiling the cable up too tightly. If left in a tight coil for longer than a week, the fibers are likely to develop longitudinal fractures that will not be detectable. These fractures in the fiber will cause light leakage, resulting in a weaker signal. The fiber optic cables should be stored loosely.

Tips on care for the fiber optic cable:

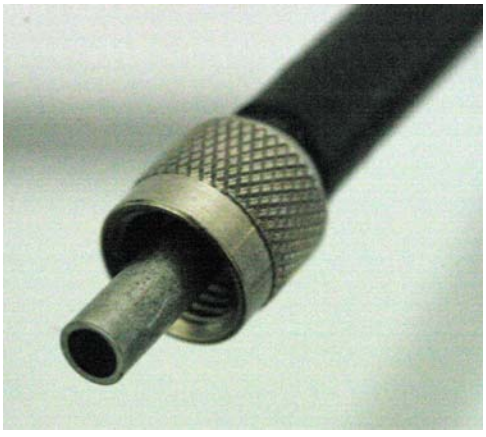
- Do not pull or hang the spectrometer by the fiber optic cable.
- Do not use wires, ties, or clamps to tightly attach the fiber optic cable to objects, these might pinch or penetrate the protective jacket thereby damaging the fibers inside.
- Avoid whipping the fiber optic cable, dropping it, or slamming it into objects, this can cause fractures to the glass fibers.
- Avoid twisting the fiber optic cable, such forces may cause fractures to fibers.

While the tip of the fiber optic cable is not particularly susceptible to damage, a tip cover is recommended to protect against abrasion and exposure to contamination. Replacement covers can be made by cutting pieces of eighth-inch shrink tubing to about 1.5" lengths and shrinking them onto the fiber cable tip. The covers will slide on and off the cable easily.

4.2 Fiber Optic Cable Interface

All fiber optic cables come with a standard SMA style 905 connector, as shown in Figure 4-1

Figure 4-1 Connector for the fiber optic cable.



In order to achieve the best response from ASD instruments it may be necessary to adjust the fiber optic interface between the external fiber optic cable (shown in Figure 4-2 and Figure 4-3) and the instrument connection.

Figure 4-2 View of the fiber optic bundle matcher and the fiber optic port.

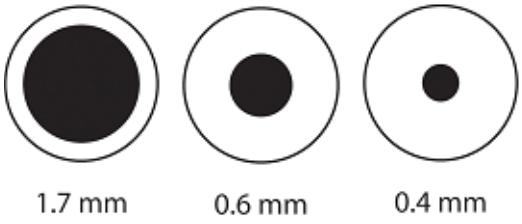
Note: The fiber optic bundle matcher has a standard 1.7 mm fiber optic bundle input.

Figure 4-3 View of the fiber optic cable, fiber bundle matcher, and fiber connection. The fiber bundle matcher should be screwed into the fiber connection as far as possible.

Figure 4-4 QualitySpec spectrometer front-view showing fiber connection to USP filter wheel and light box.

ASD external fiber optic cables most commonly come in one of the configurations listed in Figure 4-5. The millimeter size (mm) is the internal diameter of the fiber optic bundle.

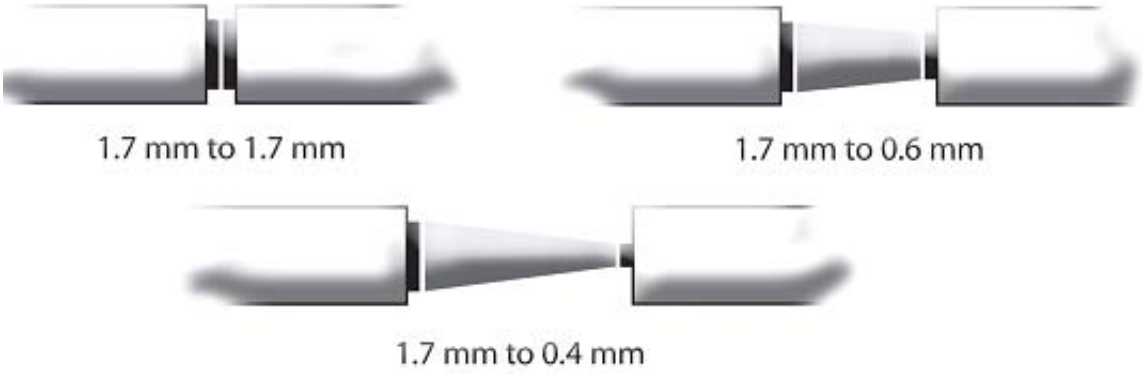
Figure 4-5 Examples of the external fiber optic cable diameters.



4.3 Matching Fiber Bundles

Now that there is an understanding of how the external fiber optic cables and the fixed fiber optic bundle matcher are configured, they need to be combined. The three scenarios in Figure 4-6 show how the fiber optic bundles are matched.

Figure 4-6 Matching fiber bundles to the QualitySpec spectrometer's fiber port.



Note: The optimal setting for this fiber optic bundle matcher is adjusted at the ASD factory. If the customer has ordered several fiber optic configurations, it may be necessary to adjust this bundle matcher in order to achieve the highest signal to noise ratio and best instrument response. Changing the bundle matcher can effect the performance of the spectrometer.

In order to match the bundles:

1 Unlock the hex-nut bolt at the front of the bundle matcher on the spectrometer with the 3/8 in hex-nut driver (included with the instrument.)

2 The QualitySpec spectrometer should be set up with the adjustment barrel of the matcher fully threaded into the body of the matcher any time a full 1.7 mm bundle is used (which is almost always).

3 With the ASD software application (RS^3 or Indico) running and the fiber optic cables attached, hand screw the fiber optic bundle matcher until the optimal signal is achieved. *Do not over twist the fiber optic bundle!*

The optimal signal will be achieved by watching the RAW DN (DN = digital numbers) in the ASD application as the fiber optic bundle matcher is being hand adjusted.

Note: The QualitySpec spectrometer should be set up with the adjustment barrel of the matcher fully threaded into the body of the matcher any time a full 1.7 mm bundle is used.

4 Once the optimal signal is achieved, lock down the fiber optic bundle matcher. Tighten the 3/8 hex-nut by turning the wing nut against the face of the instrument. Use the hex wrench to hold the 3/8 hex-nut in place while you tighten the wing nut.

When the bundle matcher is removed, clean the fiber optic cable and the exposed fiber optic on the spectrometer. This can be done by using de-ionized water, cleaning the end, and then gently wiping the excess off. Canned air to blow off any dust that may have accumulated can also be used.

4.4 LED Check for Fiber Optic Cable

The QualitySpec spectrometer allows you to perform a visual verification of the internal fiber optic cable using built-in LEDs, a magnifier placed on the fiber optic bundle matcher, and the **Fiber Check** software.

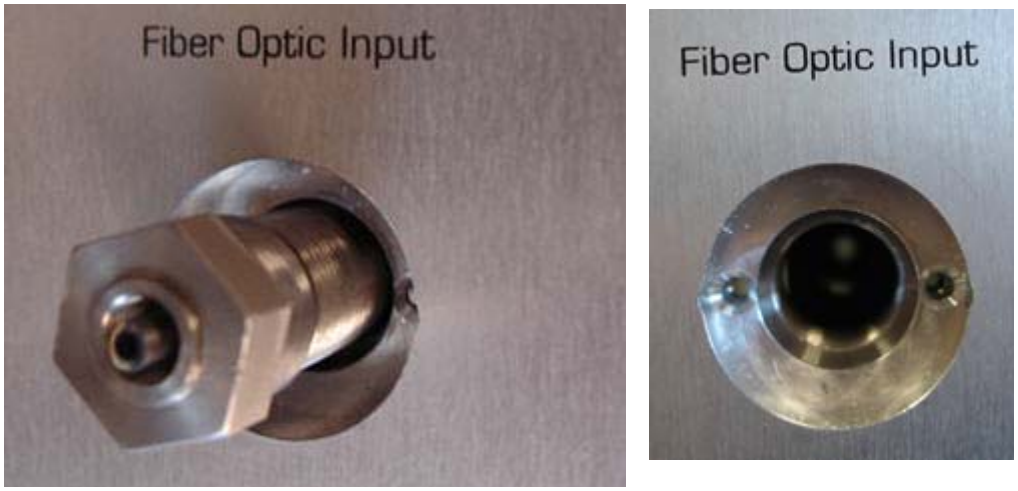
WARNING! **The Fiber Check utility produces rapid flashing lights in the SWIR 1 and 2 region's optical fibers. If you are susceptible to epileptic seizures, exercise caution or avoid using the Fiber Check utility.**

Step 1 Remove any external fiber optic cable from the spectrometer.

Step 2 Remove the bundle matcher. Use the 3/8 inch hex-nut driver to loosen the bundle matcher if necessary.

Step 3 Remove the Fiber Optic Port using the 9/16 nut driver (included with the instrument.)

Figure 4-7 Fiber Optic Port



Step 4 Carefully insert the tip of the magnifier until it butts up against the internal fiber optic, as shown in Figure 4-8.

Note: **Be careful not to apply any load or torque to the magnifier which could break the tip off.**

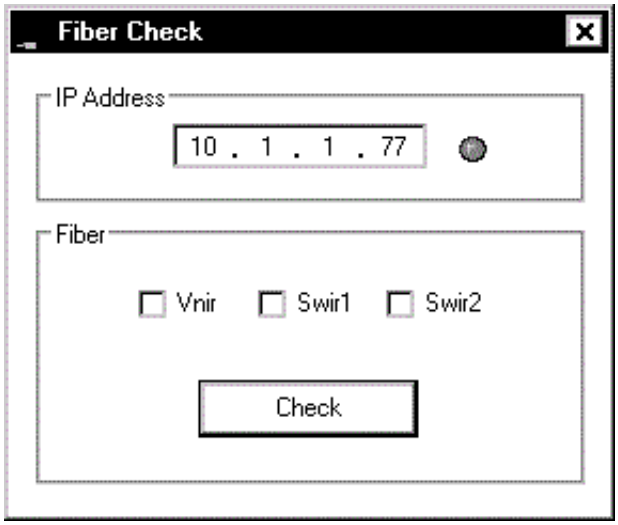
Figure 4-8 Magnifier for testing the internal fiber optic cable.

Step 5 On the instrument controller, exit any ASD applications that might be running and communicating with the unit. Such applications include RS^3 and Indico.

Step 6 Ensure that the spectrometer is turned on.

Step 7 Start the **Fiber Check** application from the **Start** menu under **All Programs->ASD Programs->Indico Pro Tools->Fiber Check**.

Figure 4-9 **Fiber Check** Program



Step 8 Ensure that the IP address configured is the one for the spectrometer.

Step 9 Use the mouse to select the checkbox for the LED to turn on: VNIR, SWIR1, or SWIR2. One or more may be selected at once.

Note: If a range is selected that the spectrometer does not have, that particular LED will not be available to turn on. Nothing will be harmed.

Step 10 Select the **Check** button which turns on the selected LEDs.

Step 11 Look through the magnifier to see which fibers light up.

- Count the number of fibers that show light. Refer to Details about the Fiber Optic Cable and LEDs.
- If applicable, use the checkboxes and the **Check** button shown in Figure 4-9 to turn on and off different LEDs to help determine which range might be affected.

Note: The RED LED for VNIR may be hard to see when the other ranges are enabled.

Figure 4-10 Internal spectrometer LED shining to test internal fiber optic cable.

Step 12 When you are finished, shutdown the **Fiber Check** application.

Step 13 Carefully remove the magnifier and re-attach the bundle matcher and fiber optic port using the 9/16 nut driver.

Step 14 Inspect the external fiber optic cable disconnected from the instrument.

1 Unscrew the lens from the magnifier and place it onto the short magnifier assembly

Figure 4-11 Short and Long Magnifier Assemblies

2 Attach the magnifier to one end of the fiber optic cable.

3 Point the other end of the fiber optic cable close to a light.

4 Observe which fibers transmit light.

Details about the Fiber Optic Cable and LEDs

- The LEDs will only turn on for the ranges installed in the spectrometer. Selecting one that the spectrometer does not have will not cause a problem.
- Each range has a different LED color so that you can see the fibers in the cable that are associated with it: RED for VNIR; WHITE for SWIR1; GREEN for SWIR2.
- The fiber bundle of the internal cable for each range contains 19 fibers.
- The fiber bundle of the external cable contains 44 fibers.
- Each broken *internal* fiber results in an approximate 5% loss of response in that particular range (VNIR, SWIR1, or SWIR2). Each broken *external* fiber results in a few percentage loss of response over the entire range. It is hard to quantify how a broken fiber in the external cable affects the response of any given range, each time the external cable is connected to the spectrometer, the alignment with the fibers of the internal cable will most likely be different.

The instrument can be successfully used with a few broken fibers in each range, although with a reduction in signal strength.

For severely damaged internal fiber optic cables, send the instrument back to ASD Inc. in its carrying case for repairs. For severely damaged external fiber optic cables, order replacements from ASD Inc.

Chapter 5 Measurements

Accurate and repeatable material analysis or identification requires the accurate and repeatable measurement of reflectance, transmission, or absorption. It requires an awareness of the influences of:

- Sources of illumination.
- Instrument field-of-view.
- Sample viewing and illumination geometry.
- Instrument scanning time.
- Spatial and temporal variability of the sample characteristics.

Many of these parameters are controlled when using one of ASD's standard sampling interfaces (e.g., MugLite or Contact Probe).

5.1 Illumination

In order to determine the reflectance or transmittance of a material, two measurements are required:

- The spectral response of a reference sample.
- The spectral response of the target material.

The reflectance or transmittance spectrum is then computed by dividing the spectral response of the target material by that of a reference sample.

5.2 Suggested Set-up

Step 1 Follow the instructions for plugging in the instrument and starting the Indico software.

Step 2 Attach an appropriate accessory. Remember that the QualitySpec spectrometer requires an external (artificial) light source.

Step 3 Open a new project either by selecting **File->New Project** from the pull-down menu.

Step 4 Type in a name for this project and press the **OK** button.

Step 5 Select **Spectrum->Sample Count/Average** from the pull-down menu.

Step 6 Set the **Instrument Sample Count** to 30 for indoor or artificial illumination.

Note: The actual spectrum average will be determined by striking a compromise between noise reduction through averaging the spectra and the time desired for each spectrum collection. For instance, if the instrument is being used in the field, a large area is being walked, and frequent spectral readings are being taken, a shorter average setting is required than if collecting spectra in-situ and the cleanest spectra possible is desired.

The project screen will return, and the sample count will be displayed in the status box at the bottom of the graph.

Step 7 Ensure the light source is on and the probe input end is pointed at the white reference panel.

Step 8 Select **Spectrum->Take a Baseline [Alt+S, B] [Ctrl+R]**. When prompted, press **Yes, take a new white reference**.

- The QualitySpec spectrometer optimizes the detector sensitivities for the probe and light source currently being used.
- The dark offset and white reference will also be measured and saved.
- Status bars will indicate each process.

When optimization and white reference are complete, a straight baseline across the Project Graph should be seen at 1.00 (100%).

Step 9 Select the **Display->Reflectance [Alt+D, R]** for the reflectance mode.

Step 10 Place the sample on the white reference panel and the spacer end in contact against the sample.

This assumes that the reflectance probe has appropriate spacing or spacers on the end.

Step 11 Press the Space Bar once or select the **Spectrum->Take a Scan [Alt+S, T]**.

When the QualitySpec spectrometer finishes recording and averaging the Spectra, the graph in the project window will be updated to show the reflectance spectrum of the sample.

Step 12 Observe samples.

5.3 Baseline Collection (or White Reference)

A material with 95-99% reflectance across the entire spectrum is called a white *reference panel* or white *reference standard*.

The raw measurement made by the spectrometer is influenced by both the sample and the light source. An independent measure of the light source illumination on a reference of known reflectance is required to calculate the reflectance of the sample. The use of a white reference standard with near 100% reflectance simplifies this calculation.

The ASD application software, such as RS^3 and Indico, can calculate the ratios for reflectance or transmittance of the material being sampled by the QualitySpec spectrometer using the white reference as the standard.

Spectralon from Labsphere is the white reference standard that is very suitable for the VNIR and SWIR spectral ranges of ASD instruments.

Spectralon is made of polytetraflouroethylene (PTFE) and cintered halon. It has the characteristic of being nearly 100% reflective within the wavelength range of 350 nm to 2500 nm. A Spectralon white reference scatters light uniformly in all directions within that wavelength range.

5.3.1 Maintaining Spectralon References

Spectralon is an optical standard and should be handled in much the same way as other optical standards. Although the material is very durable, care should be taken to prevent contaminants such as finger oils from contacting the material's surface. Always wear clean gloves when handling Spectralon.

To clean a lightly soiled Spectralon white reference

If the material is lightly soiled, it may be air brushed with a jet of clean dry air or nitrogen.

WARNING! DO NOT use Freon.

To clean a heavily soiled Spectralon white reference

Sand the Spectralon material under running water with a 220-240 grit waterproof emery cloth or sandpaper until the surface is totally hydrophobic (water beads and runs off immediately).

Step 1 Use a flat surface, such as a thick, flat piece of glass.

Step 2 Place the glass into the sink.

Step 3 Place 220 grade wet sandpaper onto the glass.

Step 4 Gently move the Spectralon reference in a figure 8 motion on the sandpaper, using water as needed to wash away the thin layer that is sanded off.

Step 5 Blow dry with clean air or nitrogen or allow the material to air dry.

Step 6 If the material requires high resistance to deep UV radiation, the piece should be prepared as above, then either of the following two treatments performed.

1 Flush the Spectralon piece with >18 milli-ohm distilled, deionized water for 24 hours.

2 Vacuum bake the Spectralon piece at 75° C for a 12 hour period at a vacuum of 1 Torr or less. Then purge the vacuum oven with clean dry air or nitrogen.

WARNING! Do not use oils or soaps to clean the Spectralon white reference.

5.3.2 Baseline Reference Procedures

Baseline references, or white references, should be collected approximately every 15 minutes while the instrument is warming up; thereafter, every hour or so is sufficient. The Spectralon puck should be used when optimizing and taking a white reference measurement.

The QualitySpec spectrometer should be re-optimized for:

- Light changes.
- Temperature changes.
- Whenever accessory probes are changed.

Appendix A Troubleshooting

A.1 Common Communication Fixes

To fix many communication errors (particularly if the instrument has been functioning at some point), power cycle the instrument and/or the instrument controller.

The sequence to use will vary depending on the computer manufacturer. Either:

- Leave the computer on. Turn off the instrument. Wait for 10 seconds. Turn the instrument back on.
- Or, turn off the computer and the instrument. Turn on the instrument. Then turn on the instrument controller.

A.2 Does Not Connect to the Spectrometer

- Refer to section A.1, Common Communication Fixes.
- Check that the Ethernet cable is securely inserted into the spectrometer and host computer. Check that the Ethernet LED is on.
- For an isolated network, check that the Ethernet cable is a cross-over Ethernet cable.
- For an established network, check that the Ethernet cable is a standard Ethernet cable.
- Check that the IP Address is in the same range or subnet as the ASD spectrometer. The same subnet means that the first three octets of the IP address (xxx.xxx.xxx.___) match the spectrometer and the computer.

- Do a ping test to make sure the spectrometer is responding.
  - » Open up a command window by select **Start->Run**
  - » Type **cmd** in the **Run** window.
  - » Select **OK** to open the window.
  - » For an Ethernet connection, type: ping 10.1.1.11
  - » For a wireless connection, type: ping 10.1.1.77

Figure A-1 **Run** window with **cmd**.

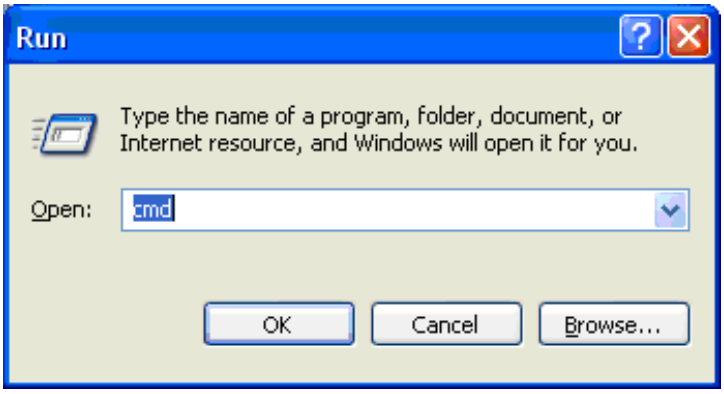
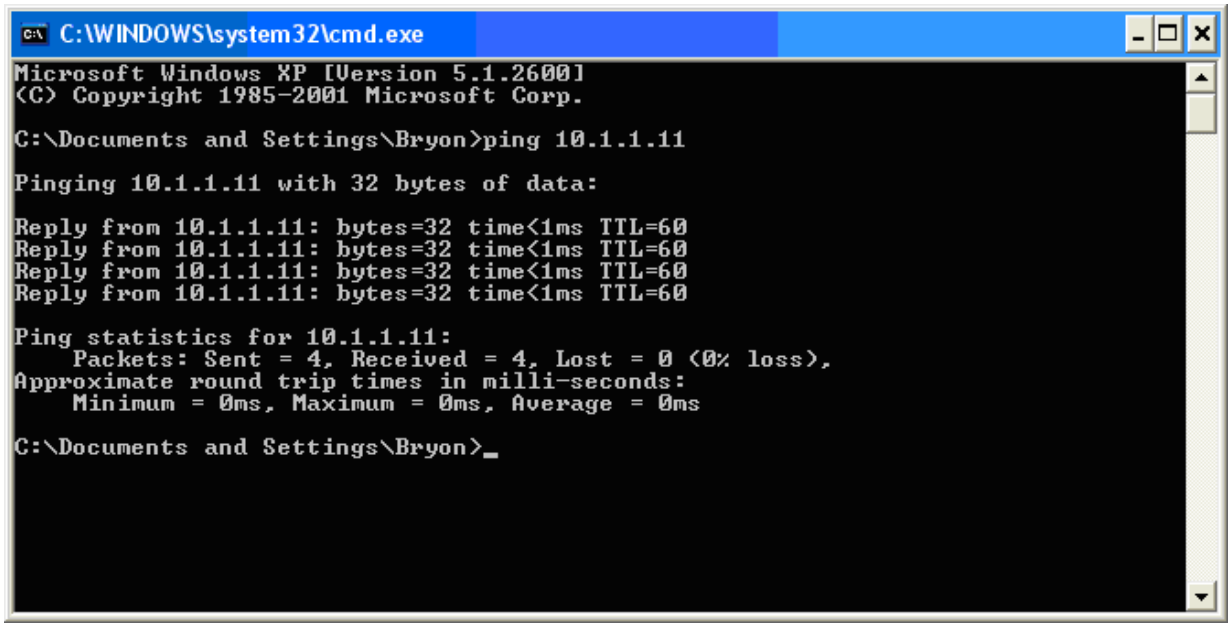


Figure A-2 Successful result of a **ping** operation.



The default IP Address for the ASD spectrometer is:

- 10.1.1.11 for the Ethernet interface, or
- 10.1.1.77 for the wireless interface.

The default subnet mask is 255.255.255.0.

The computer's Ethernet adapter or wireless adapter must have a unique IP address in the same range as the spectrometer, such as 10.1.1.x where **x** is a unique number. The subnet mask must also be the same as the spectrometer. such as 255.255.255.0.

Notes:

Appendix B Reference Information

B.1 Frequently Asked Questions (FAQ)

B.1.1 What is a spectrometer?

Spectrograph - An optical instrument for forming the spectrum of a light source and recording it on a film. The dispersing medium may be a prism or a diffraction grating. This term was common prior to the digital age. ASD instruments do not use film.

Spectrometer - An optical instrument which uses detectors other than photographic film to measure the distribution of radiation in a particular wavelength region. All ASD instruments are spectrometers.

Spectroradiometer - An optical instrument for measuring the radiant energy (radiance or irradiance) from a source at each wavelength throughout the spectrum. A spectroradiometer is a special kind of spectrometer.

Note: Only the FieldSpec spectrometer is configured as a spectroradiometer. The reason is that the fiber optic cable significantly affects the calibration required to measure radiance. The FieldSpec instrument has a fixed fiber optic cable routed directly through the front panel to the internal spectrometers, while the other ASD spectrometers are designed to detach and even interchange fiber optic cables. To be meaningful, radiance measurements with non-FieldSpec instruments would have to be performed using the **same fiber optic cable** and the **same connector orientation** of the plugged in fiber optic cable **as the factory calibration**.

The SWIR component of the ASD spectrometer is a *scanning spectrometer*, while the VNIR component is an *array spectrometer.*

B.1.2 What are the differences between the ASD spectrometers?

FieldSpec - is a general-purpose spectrometer specifically designed for field environmental remote sensing. The FieldSpec is a spectroradiometer in that it is calibrated to be able to perform radiance and irradiance measurements, as well as reflectance and transmittance. The fiber optic cable is routed through the front panel and is fixed to the internal spectrometers, which provides a superior signal-to-noise ratio than the other ASD spectrometers with detachable fiber optic cables. (The FieldSpec spectrometer can also be specially ordered as a high-resolution instrument, the main TerraSpec feature.)

TerraSpec - is a high-resolution spectrometer specially designed for mining and geology applications. It is ideally suited for performing reflectance spectral measurements of rocks, minerals, and core samples. Its higher resolution is optimized for samples that have high absorption features. The Hi-Brite MugLite and Hi-Brite Contact Probe are designed to work with this spectrometer.

AgriSpec - is a general-purpose spectrometer designed for agriculture and the field analysis of vegetation and soils. Its resolution is ideally suited for performing reflectance and transmittance spectral measurements of samples that have broad absorptions features. This spectrometer can use nearly all of the accessories containing a light source, such as the plant probe and leaf clip.

LabSpec - is a general-purpose spectrometer designed not only for laboratory analysis, but also for the plant floor, receiving, and even field work. It is meant to be portable for multiple uses requiring visible and near infrared reflectance, transmission, or absorbance to analyze and identify materials. The LabSpec is similar to the AgriSpec. The LabSpec 2500 has a 10 nm resolution, while the LabSpec 2600 has a 6 nm resolution.

QualitySpec - is a general-purpose spectrometer specifically designed for material analysis and identification in the laboratory. The QualitySpec features are equivalent to the AgriSpec except that it is not field-portable.

B.1.3 How often do I need a (baseline) White Reference?

When using the instrument inside under constant lighting conditions or when using an accessory with its own light source, collect a (baseline) white reference every 10 to 15 minutes while the instrument is warming up and then every hour or so thereafter.

B.1.4 What spectrum average (or sample count) should I use?

When used with a MugLite, Contact Probe, or other accessory, it is usually sufficient to use 10-20 scans in the spectrum averaging (or sample count) for the sample and 20-40 scans for the white reference. The white reference isn't taken as often, which is why you would want to include more scans in its averaging.

The signal-to-noise measurement increases with the square root of the number of scans used in the averaging.

Note: The actual spectrum average will be a compromise between noise reduction through spectra averaging and the time required for each spectra collection. For instance, if you are using the instrument in the field to measure a large number of samples, you will want a smaller number of spectra in the average to decrease the collection time required. If you are collecting spectra in the lab, you'll want to increase the number of spectra in the averaging to obtain the cleanest spectra possible.

B.1.5 Can I post-process my data?

Yes. ViewSpec is one of many applications that can post-process your data. Various software packages are available for chemometric model. The spectral data can be imported into many different applications.

The complete specification of the ASD file format is available upon request.

B.1.6 Why do I see oscillations (sine wave) in my data?

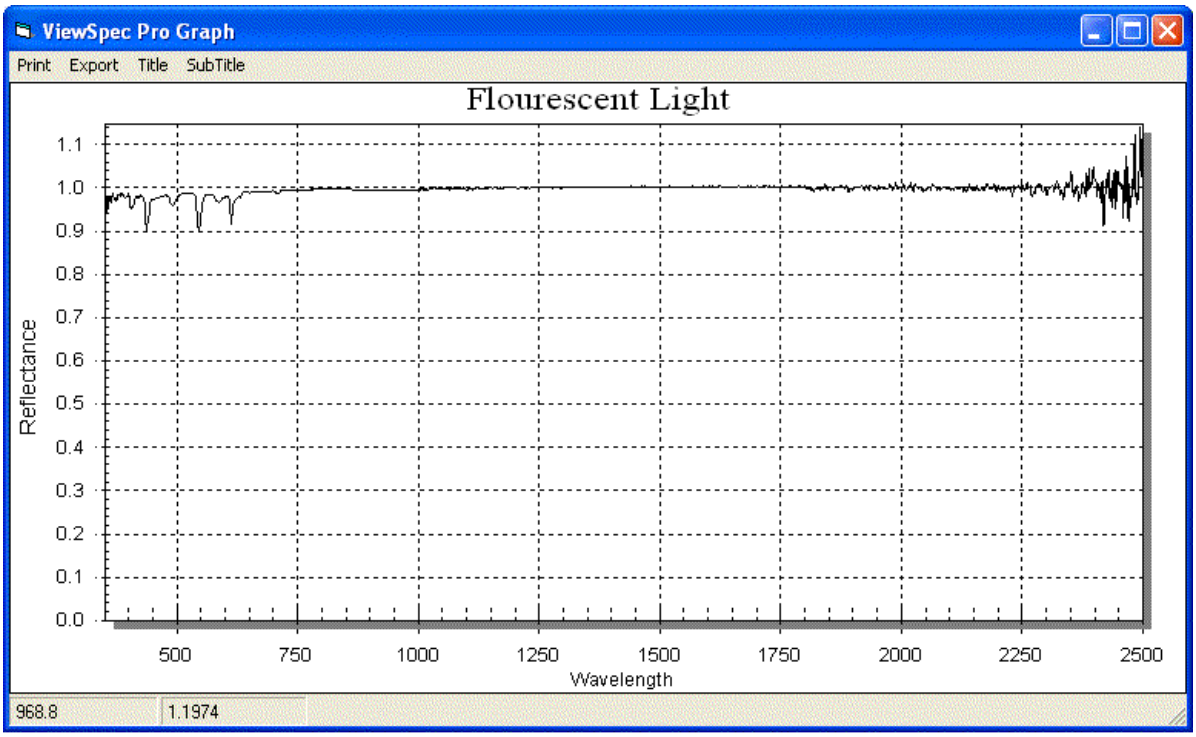
Your light source may use AC power. A single SWIR band is about 100 ms. If you observe five (5) or six (6) waves in a single SWIR, the AC light source is the cause.

Waves can also occur if the lamp reflector and/or cover glass behave as a white-light interferometer. Solution: remove the glass and/or use a more diffuse reflector.

B.1.7 What are these upward or downward spikes in VNIR data?

These result from artificial light sources, in particular fluorescent lights.

Figure B-1 Spectrum of fluorescent lights



B.1.8 What are these steps in my data?

Light is brought into the instrument by various combinations of the strands in the fiber optic cable. Each strand has its own field-of-view (FOV). When the cable is held close to the sample, each strand views slightly different portions of the sample. This can result in the stepped data.

Stepping of data is common when the foreoptic has a lens, and less common when using the bare optics or sampling devices.

B.1.9 What can cause more noise in my data from last time?

Many factors can cause noise in your data from one session to another. Noise in a measurement is related to the instrument, the signal level, and noise in the light source. Many times the appearance of noise is actually a decrease in the strength of the signal, as opposed to an increase in noise.

Under normal operating conditions, noise visible in a spectrum is always the result of a trade-off between the inherent noise in the system and the signal.

Check how the external fiber optic cable is aligned with the internal cable for changes in signal through-put.

Also, broken fibers in the fiber optic cable can contribute to noise. Perform a fiber optic check to verify.

An increase in noise can be due to a problem in the instrument such as an electronic component malfunction or a grounding problem. This will many times be indicated by a regular pattern to the noise or periodic bursts of noise that are visible over the normal spectra.

B.1.10 What does a broken fiber mean?

The internal fiber-optic cable is made up of fifty-seven (57) randomly distributed glass fibers.

- 19 fibers are 100 micron for the VNIR region.
- 19 fibers are 200 micron for the SWIR1 region.
- 19 fibers are 200 micron for the SWIR2 region.

Therefore, a single broken fiber in the internal cable results in a ~5% reduction in the signal in a given region.

The external fiber-optic cable is made up of forty (44) 200 micron glass fibers.

Note: Each broken external fiber results in a few percentage loss of response over the entire range. It is hard to quantify how this affects the response of any given range, because each time the external cable is connected to the spectrometer, its alignment with the fibers of the internal cable will most likely be different.

A few broken fibers is not critical when measuring reflectance, because this is a ratio. Any noise introduced by the broken fibers in measuring the sample were also present when measuring the white reference, and therefore cancels out.

The fibers are protected by a metal spiral inside the black cable casing. If there are kinks in your cable, the fibers are not necessarily damaged. However, if your cable has been crunched so severely that you are able to see the protective metal spiral, the chances are high that the fibers have been damaged too. Refer to the Fiber Optic Check utility to determine if any fibers are broken.

The fibers can be damaged by coiling the cable up too tightly. If left in a tight coil for longer than a week, the fibers are likely to develop longitudinal fractures that will not be detectable. These fractures in the fiber will cause light leakage, resulting in a weaker signal. The fiber optic cables should be stored by placing them loosely within the netting compartment on the instrument.

WARNING! The fiber cable should never be stored with a bend of less than a 5" diameter for long periods of time.

B.1.11 What type of Ethernet cable can I use for the static IP configuration?

The spectrometer can be plugged directly into the instrument controller using a cross-over, shielded Ethernet cable.

When the spectrometer and instrument controller communicate over a network, use standard shielded Ethernet cables and IP addresses compatible with the network. The spectrometer imposes significant traffic on the network, which can cause packet delays to other users. More importantly, network traffic from other users can negatively impact the reliability of the communication between spectrometer and instrument controller.

B.1.12 Can I install additional software on the instrument controller?

Yes, but with qualifications.

The types of applications that can interfere with the measurement of data are utility programs, network programs, and those working in the background, such as virus checkers.

ASD programs, such as RS^3 and Indico, require real-time access to the data that is being streamed from the QualitySpec spectrometer at a high rate of speed. Programs running in the background can cause packets to be lost.

Microsoft Office, image processing programs, and other software applications generally do not interfere with ASD programs, particularly if they are not running and competing for CPU cycles and RAM at the same time that data is being collected from the QualitySpec spectrometer.

B.1.13 Why does the software seem to do unexpected things?

To assure accuracy in the collection and processing of data, the ASD application software is designed to finish its current operation before moving on. The QualitySpec spectrometer outputs a lot of data at a high rate of speed for the ASD application software to collect.

In addition, the ASD application software will *stack up your keystroke entries* and execute them later in the order they were received.

It is important that you wait for the collection to finish before entering the commands to launch another operation. Don’t rush into new operations or into issuing new commands until you see the results of the current command.

B.1.14 How long does it take for the QualitySpec spectrometer to warm up?

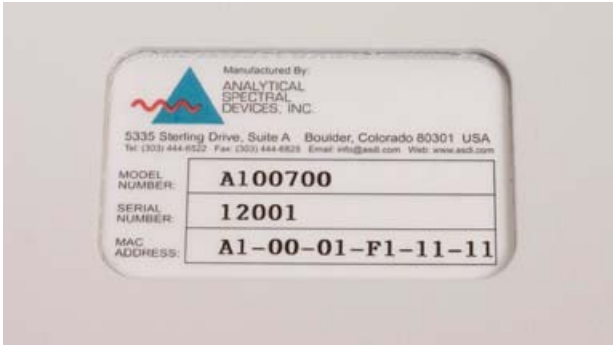
The warm-up time of the instrument depends on the environment in which it is used.

Only 15 minutes is needed for reflectance measurements.

B.1.15 Where is my serial number?

The serial number is a five (5) digit number located on a label on the rear of the QualitySpec spectrometer where the power switch is. The label also contains the model number and MAC address for the spectrometer.

Figure B-2 Label with serial number.



The serial number is also accessible in the RS^3 and Indico applications from the splash screen or the **Help->About** menu item.

B.2 Data Conversion

When using the Indico application, converters are available for Grams/AI, Unscrambler, and ASCII.

Conversion can be done one file at a time. Or, several files can be merged into a single text file, which is a useful feature when inputting data into other analysis programs.

B.3 Optimization

The QualitySpec spectrometer must be re-optimized for:

- Every 30 minutes when used with artificial light sources.

- Changes in temperature.

Optimization depends on the response to light in a particular spectral region. A well-optimized instrument will display between 20,000 and 35,000 raw digital numbers, if the source is within the gain and integration time abilities of the system. The magnitude of the VNIR raw DN will be directly dependent on the light intensity.

The Spectralon blank should be used when optimizing and for taking a white reference measurement.

Note: It is important that the position of the reference sample when taking a white reference is as similar as possible to the position for capturing data from the samples.

B.4 Spectrum Averaging (or Sample Count)

If signal levels are low, the only way to increase S/N is by reducing noise through spectrum averaging. However, spectrum averaging takes more time per spectrum.

B.5 Temperature Effects

The QualitySpec spectrometer instruments have thermo-electrically cooled SWIR detectors (to -25 C), significantly reducing noise in those areas.

When the system fails due to extreme temperature, it will fail gradually but the data won't make perfect sense. Shut down and let the instrument cool before operating again.

The ASD applications provide a warning when the SWIR detectors are out of thermal regulation.

B.6 Technical Support

If you have any questions or concerns, please contact ASD Inc. by phone, fax, or email:

Phone: 303-444-6522 X-144
Fax: 303-444-6825
email: support@asdi.com
Web: www.asdi.com
ftp: ftp.asdi.com

Technical support is committed to providing you with a timely response to your questions. We will work with you to provide solutions to your applications. Technical support is available to answer your questions Monday thru Friday, 8 am to 5 pm Mountain Standard Time. We will happily respond to your e-mail queries as well.

B.7 W.E.E.E. Compliance

Analytical Devices supports the W.E.E.E. Regulation. ASD marks the instrument with the symbol at the left to show that this product has entered the market place after August 13, 2005.

If you decide to end the use of the spectrometer, please do not discard it as general waste. ASD will accept the return of the instrument for recycling purposes. Contact ASD Customer Service to arrange for the return of your instrument.

Notes:

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