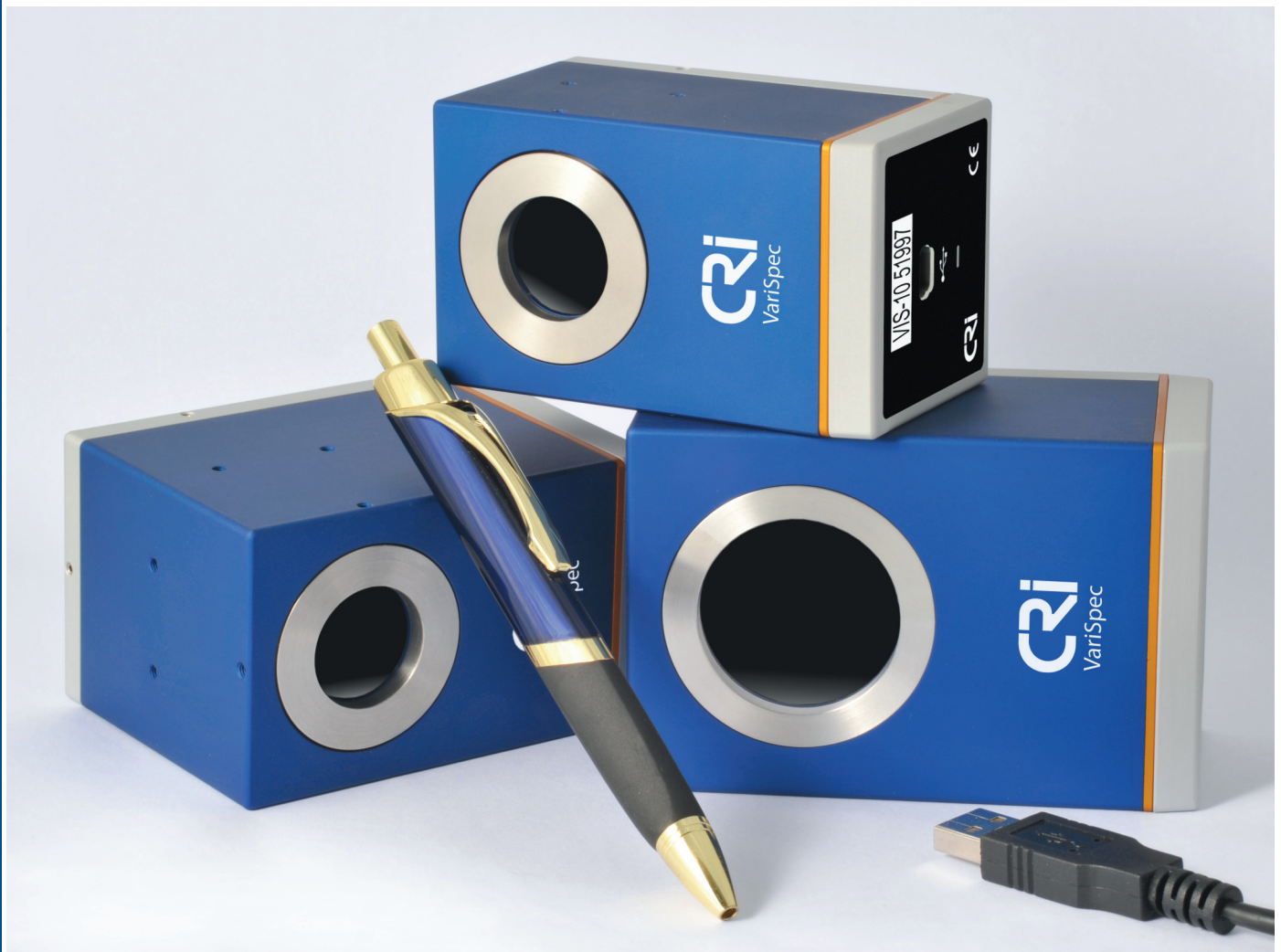


User's Manual for VariSpec



Notice

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Chapter 1

Introduction to VariSpec Liquid Crystal Tunable Filters

This chapter provides information about VariSpec liquid crystal tunable filters (LCTFs) that is common to all filter models. Appendices are used to provide additional information, specific to individual models.

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Introduction

CRI's VariSpec LCTF family are solid-state tunable birefringent filters that can be used for both imaging and non-imaging spectral analysis. The filters function like high-quality interference filters, but the wavelengths of light they transmit are electronically tunable and allow for the rapid, vibration-less selection of any wavelength in the visible (VIS) or near-infrared (NIR) region for which the filters have been constructed to operate.

VariSpec filters employ electronically controlled liquid crystal elements to select a transmitted wavelength range while blocking all others. Filter transmittance is sensitive to polarization of the input beam, and is increased by a factor of two if the input beam is polarized along the axis of the input polarizer, as compared with a non-polarized or

randomly-polarized beam. VIS models contain an integral, non-removable hot mirror for blocking unwanted NIR light. The product family includes the following models:

- **VIS:** Visible-wavelength filters with a wavelength range of 400 nm to 720 nm, bandwidths (FWHM) of 7 nm, 10 nm, or 20 nm, and working apertures of either 22 mm or 35 mm
- **SNIR:** Short-wavelength near-infrared filters with a wavelength range of 650 nm to 1100 nm, bandwidths (FWHM) of 7 nm or 10 nm, and a working aperture of 22 mm
- **LNIR:** Longer-wavelength near-infrared filters with a wavelength range of 850 nm to 1800 nm, bandwidths (FWHM) of 6 nm or 20 nm, and a working aperture of 22 mm
- **XNIR:** Longer-wavelength near-infrared filter with a wavelength range of 1200 nm to 2450 nm, bandwidth (FWHM) of 9 nm, and a working aperture of 22 mm
- **VISR:** Visible-wavelength filter with a wavelength range of 480 nm to 750 nm, extraordinarily narrow bandwidth (FWHM) of 0.25 nm (best effort), and a working aperture of 22 mm
- **NIRR:** Near-infrared wavelength filter with a wavelength range of 650 nm to 1100 nm, extraordinarily narrow bandwidth (FWHM) of 0.75 nm (best effort), and a working aperture of 22 mm

Important Features

Important features of VariSpec filters include:

- Ability to tune continuously over hundreds of nanometers in the VIS and NIR
- Excellent imaging quality
- Solid-state construction, with no moving parts
- Fast, random-access wavelength selection
- Compact, low-power design

Applications

VariSpec filters offer excellent imaging quality, making them ideal for use with imaging sensors such as silicon-based CCDs or InGaAs sensors. Additionally, they can be used as compact, robust spectrometers with high throughput, well-suited to applications where imaging may not even be required. Key applications include:

- Remote Sensing
- Machine vision QA/QC
- Astronomy
- CCD/Display characterization
- Raman chemical imaging
- General research involving spectral imaging

Glossary of VariSpec LCTF Terminology

Bandwidth

The Full-Width at Half-Maximum (FWHM), measured as the spectral separation between the two points where the filter's transmission attains 50% of the peak value. The passband center wavelength is the wavelength midway between these two points. VariSpec filters come in a variety of bandwidths, which are set during the design and manufacturing process and are not adjustable by the end-user.

Center Wavelength

Not necessarily the highest point in the T curve, this is defined as midway between the half-maxima points.

Off-Axis Performance at Limit of Angle-of-Acceptance

Off-axis rays at the limit of the angle-of-acceptance are permitted to be spectrally shifted by up to $\text{Bandwidth}/8$ from the on-axis ray value. So, in the worst case, the center ray could have a center wavelength which exceeds the ideal by $+\text{Bandwidth}/8$, and an off-axis ray could be shifted by $+\text{Bandwidth}/8$ red of that, or $+\text{Bandwidth}/4$ away from the ideal value.

Out-of-Band Transmittance or Contrast

The average ratio of transmission without the VariSpec filter in place to the transmission of unselected wavelengths with the filter in place. Typical performance is 0.01%.

Passband

The spectral region from $[\text{Center Wavelength} - 1.2 * \text{FWHM}]$ to $[\text{Center Wavelength} + 1.2 * \text{FWHM}]$.

Response Time

The time it takes to switch from one wavelength to another. The major factor that affects this number is the liquid crystal (LC) relaxation time from “charge” to “no charge” states under various ambient temperatures. Typically, this time is 50 ms to 150 ms.

Transmission

The percentage of linearly polarized light, oriented so that maximum transmission is attained, passing through the filter relative to the amount that entered. Since the entrance element of the filter is a linear polarizer, transmission of randomly polarized light is half that of linearly polarized light in the correct orientation. VariSpec transmission is wavelength-dependent.

Tuning Accuracy

The tuning accuracy specification is that the center wavelength be correct within the actual $\text{Bandwidth}/8 \pm 0.5 \text{ nm}$. Tuning accuracy is specified for on-axis rays.

Operator and Equipment Safety

It is the responsibility of the purchaser to ensure that all persons who will operate the VariSpec LCTF are aware of the following cautionary statements. As with any scientific instrument, there are important safety considerations, which are highlighted throughout this User's Manual.

Cautionary Statements

READ AND UNDERSTAND THIS USER'S MANUAL BEFORE ATTEMPTING TO OPERATE, TROUBLESHOOT, OR MAINTAIN THE VARISPEC LCTF. READING THIS MANUAL FIRST MAKES IT EASIER AND SAFER TO OPERATE AND MAINTAIN THE FILTER.

Do not expose the optics module to prolonged heat above 40 °C.

Do not drop the optics module or the electronics controller module.

Do not expose the optics module to intense light from laser, focused arc or Hg lamp sources.

Do not operate the filter in places where it may be splashed with liquid. The optics module may be cleaned using the procedure described in the troubleshooting section of this User's Manual.

Do not operate the filter in an environment with explosive or flammable gases.

Use only the supplied cables. Some cables supplied with the system have proprietary specifications. Do not connect components supplied by CRi using unqualified cables or adapters. Doing so could result in damage, and voids the Warranty.

Use only a host computer that has a properly grounded power outlet.

Disconnect the USB cable and any power cables before servicing the unit. Servicing should be performed by CRi authorized and trained personnel only.

For Technical Assistance

If you experience any difficulty setting up, operating, or maintaining your VariSpec LCTF, please contact your CRi representative. CRi's office hours are from 8:00 a.m. to 6:00 p.m. (US Eastern Standard/Daylight Time), Monday through Friday.

- Telephone (US Toll-Free): 1-800-383-7924
- Telephone (Worldwide): +1-781-935-9099
- Facsimile (Worldwide): +1-781-935-3388
- Email: techsupport@cri-inc.com.

About This Manual

This manual is designed to serve users of the CRi VariSpec LCTF product family. Operating instructions, functional descriptions, troubleshooting, illustrations, and other relevant information are contained in this manual.

Your particular VariSpec LCTF may include additional support documentation from third-party vendors. Bear in mind that the VariSpec LCTF may have been modified or custom-designed, so treat such third-party documentation as supplemental material only. In cases where CRi and third-party documentation differ, and you have any doubt as to which applies to your system, contact an authorized CRi distributor or service representative.

Design Change Disclaimer

Due to design changes and product improvements, information in this manual is subject to change without notice. CRi reserves the right to change product design at any time without notice to anyone, which may subsequently affect the content of this manual. CRi will make every reasonable effort to ensure that this User's Manual is up to date and corresponds with the VariSpec LCTF as currently shipped.

Reproduction Disclaimer

No part of this manual may be reproduced, photocopied, or electronically transmitted, except for reference by a user of the VariSpec LCTF, without the advance written permission of CRi.

CE Testing and Certification

The VariSpec LCTF has been tested by an independent CE testing facility, and bears the appropriate CE mark.



The following is the CRi distributor in the European Union region authorized to function as primary contact for CE-related matters concerning CRi products:

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VariSpec Hardware Components

VariSpec filters consist of either a single module containing both the optics and electronics assemblies or a matched set of two modules. The XNIR-09-20 model, due to its unique optical construction, utilizes two matched sets of optics and electronics modules connected by shielded cables. All VariSpec filters draw power from and are controlled by the Universal Serial Bus (USB) connector of a host computer.



Figure 1. VariSpec with 20 mm Optics



Figure 2. VariSpec with 35 mm Optics



Figure 3. LNIR-06-20, Dual VariSpec with 20 mm Optics

VariSpec Filter Module

- The entrance aperture receives the light, and for VIS models is the side that contains the integral hot mirror. For filters with a blue and silver housing, the entrance aperture is the blue side.
- The exit aperture passes linearly polarized light. The orientation is the same or perpendicular to the input polarizer, depending on the design. For filters with a blue and silver housing, the exit aperture is the silver side.
- With the exception of the XNIR-09-20 model, the rear panel of the filter module contains a USB connector and a Status LED.

USB Peripheral Type-A to Mini-B Cable

A USB Type-A to Mini-B cable connects the filter module to the host computer or a powered USB hub. For the XNIR-09-20 model, a USB Type-A to Type-B cable connects the VariSpec electronics controller module to the host computer or a powered USB hub.

VariSpec XNIR-09-20 Electronics Controller Module

The front panel of the XNIR-09-20 electronics controller module (Figure 4) contains an LED labeled **Init** and an LED labeled **Status**.

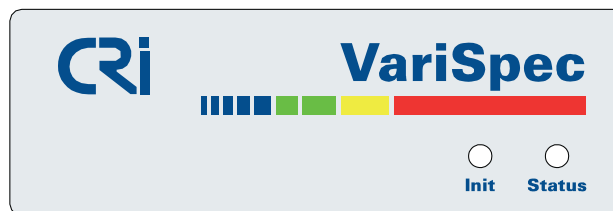


Figure 4. Front Panel of VariSpec Electronics Controller

- **Init** LED flashes during data communication between the electronics controller module and the host computer.
- **Status** LED momentarily flashes Green during power-up and initialization (approximately 30 seconds).

The rear panel contains four clearly labeled interface ports (left to right, viewed from the rear).

- **Optics A** is a 26-pin connector for the HD D-sub cable connecting the Optics and Electronics Controller modules.
- **TTL Sync** is a connector with a single trigger-detect line that can be configured to allow the filter to respond to a synchronization pulse generated by cameras, shutters, and other equipment.
- **USB** is a “Type-B” USB connector.
- **Optics B** is not used and has a blank cover.

Optics-to-Electronics Cable

For the XNIR-09-20 model, a drive signal connector on the optics module connects to its paired electronics module through a 26-pin high-density (HD) D-sub cable. This cable is shielded and the present model utilizes twisted-pair construction for reduced crosstalk.

WARNING! DO NOT connect a computer, function generator, or other signal source to this connector, as the liquid crystal elements may be destroyed. Doing so voids the warranty. The optics module is designed to be driven by the electronics controller module **ONLY**. Do not disconnect the cable while the electronics controller module is turned ON.

Mounting Block

Mounting blocks may be attached to three sides of the optics module, to allow the use of the filters on an optical table or on conventional 1/4-20 UNC-2B threaded tripods. One mounting block is included per optics module. You may order more if you wish.

Mounting Inserts (optional accessory)

Stainless-steel dovetailed inserts with either male or female C-mount threads or a male T-mount thread can be placed into the round inset on either the front or rear of the small-aperture 20 mm optics module and held in place with setscrews. By default, a “blank” flat dovetailed insert with no threaded side is mounted on each side of new filters.

52 mm Camera Lens Thread Adapter (optional accessory)

The 52 mm camera lens thread adapter allows you to convert a male T-mount thread to a common 52 mm size. This enables you to attach the filter to the front of a camera lens. If the front of your camera lens is a different diameter, you can purchase “stepping rings” from camera stores or photographic supply companies to go from the 52 mm thread to nearly any other thread size. For example, a 62 mm to 52 mm step-down ring lets you mount the VariSpec filter in front of a lens with a 62 mm thread diameter.

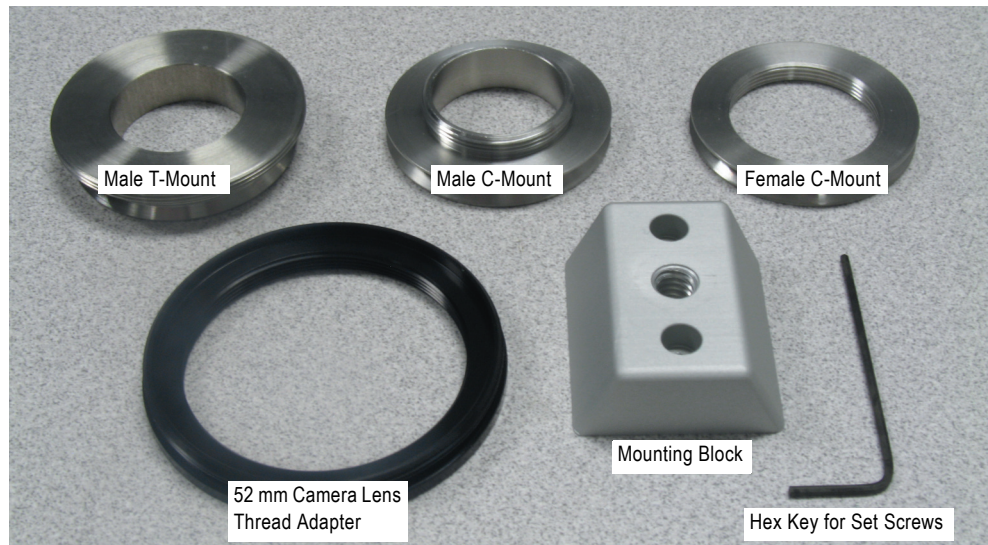


Figure 5. Mounting Block and Adapters for 20 mm Filter

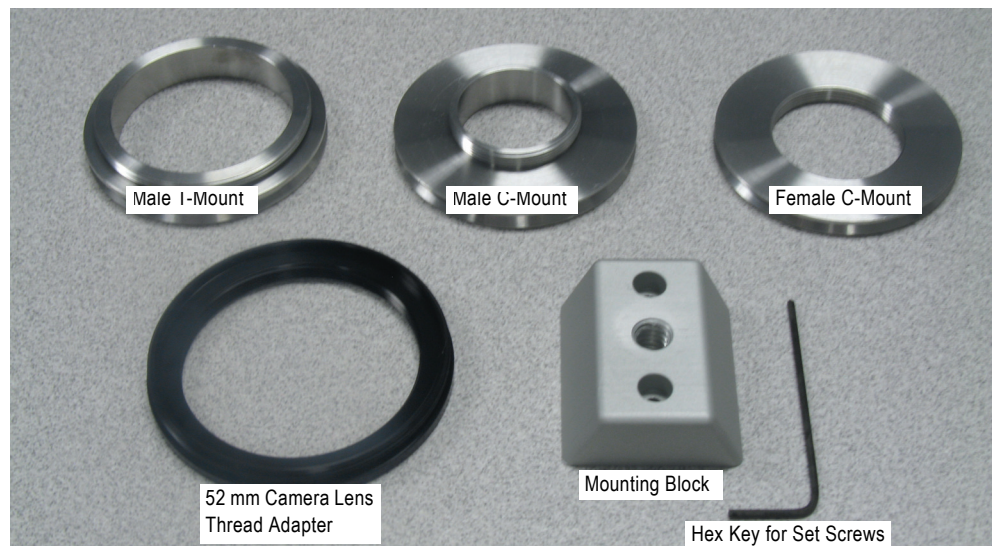


Figure 6. Mounting Block and Adapters for 35 mm Filter

VariSpec Software Developer's Kit (SDK) installation CD

The CD-ROM that comes with each filter is a Windows[®]-compatible CD-ROM containing the following components:

- Windows-compatible operating system installer for the CRi SDK
- Apple[®] Mac[®] OS X drivers for the USB interface
- Linux[®] drivers for the USB interface
- VariSpec User's Manual as an Adobe[®] PDF file

Chapter 2

Setting Up a VariSpec Filter

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• Unpacking the VariSpec Filter and Accessories	11
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• VsGui Program for Windows XP and Windows 7	15

Unpacking the VariSpec Filter and Accessories

Upon receiving your VariSpec LCTF, carefully unpack the components and compare the contents against the shipping list. Be careful with the glass surfaces of the optics module, since they have anti-reflective (AR) coatings that can be scratched if not handled carefully. Most models include the following items:

- VariSpec optics module (you will receive two if you ordered a dual-housing model)
- USB interface cable (Type-A to Mini-B) for connecting the filter to your host computer (you will receive two if you ordered a dual-housing model)
- If you ordered an XNIR-09-20 model, you will receive two electronics controller modules, two 26-pin HD cables, and two USB interface cables (Type-A to Type-B)
- CD-ROM containing the VariSpec software installer
- Additional adapters and mounts for optics module(s), if ordered
- VariSpec User's Manual in printed form
- Spectral Scan in printed form

Important! Do not connect the VariSpec filter to your host computer until you have installed the appropriate USB drivers.



Installing the VariSpec Software

CRi supplies a Windows-compatible SDK installation CD-ROM with each VariSpec filter. Included hardware drivers are specific to the Windows operating system. However, you may contact CRi if you are interested in drivers for other operating systems.

Note that these instructions apply to standard single-housing filter designs. Dual-housing designs have two VariSpec modules. The demonstration software does not support dual module filters. But the existing drivers or LabVIEW sub-VIs can be used to write programs fully capable of controlling these dual models. You can also use HyperTerminal or similar terminal emulators to send the appropriate serial (ASCII character-based) commands to each VariSpec module.

Your host computer needs to be running Windows XP or Windows 7. Log in as an Administrator to install the software. You must have a USB port available and the port must be able to provide the standard USB power load. If you have multiple USB devices connected to the same port through an unpowered USB hub, you may need to utilize a powered hub.

1. DO NOT attach the VariSpec filter hardware to the computer yet. Turn on the computer and allow it to boot into the Windows XP or Windows 7 operating system.
2. Insert the CD-ROM containing the VariSpec demonstration and SDK software into your CD-ROM drive. Or, if you downloaded the installer, open the zip file.
3. Locate the Microsoft installer file, most likely named something similar to “VsRev1p37.msi” or “VsRev1p37.exe.” Double-click the executable to start the Installation Wizard.
4. Choose the “Full” installation type. Continue with the Wizard until you can click the **Finish** button to complete the installation.

Connecting the VariSpec Filter (except XNIR-09-20 models)

1. Connect the VariSpec filter to the computer using the included USB Type-A to Mini-B cable (Figure 7).



Figure 7. Mini USB cable connects to the filter and computer

2. The blinking LED indicates that the filter is initializing and exercising the liquid crystal (LC) elements in the optics module and bringing the filter to a known state. For example, 550 nm in the case of a visible-wavelength (VIS) model.
3. If this is a first time installation, the computer should launch a *Found New Hardware Wizard*. Click the **Next** button to proceed. (If the wizard did not start automatically, launch the *New Hardware Wizard* from the Windows Control Panel.)
4. Choose to “Search for a suitable driver for my device” and click the **Next** button. A **Files Needed** window may appear. Windows may ask if it can install the software automatically or from a list or special location. Choose “automatically or the CDROM/ installation folder” as the search location. Windows should find a file on the CD-ROM named “ftdibus.inf.” Click **Next**. Windows should then find a file named “ftdiport.inf.” Click **Next** and then click **Finish**. If Windows cannot find the files, go back and manually locate the files.
5. After the *Add New Hardware Wizard* has finished, you will see a new program group icon appear: **Start > Programs > CRi**. This program group includes the demonstration software “VsGui.exe” and a PDF copy of the User’s Manual.

Connecting XNIR-09-20 Dual-Housing Filter Models

The host computer must have two available USB ports.

1. Click on the Windows **Start** button and go to **Settings > Control Panel > System**.
2. Click on the **Hardware** tab and then the **Device Manager** button.
3. Click on the '+' symbol next to the **Ports (COM & LPT)** list item. Note the COM ports that you have on your computer. If you have any other serial devices, such as modems, filter wheels, mice, or keyboards attached to your computer, they will be represented by a particular COM port.
4. Use a 26-pin HD D-sub cable to connect the VariSpec electronics controller module whose serial number has the suffix “A” to the optics module whose serial number has suffix “A”. (Refer to Figure 8 on page 14.)
5. Use a second 26-pin HD D-sub cable to connect the electronics module whose serial number has the suffix “B” to the optics module whose serial number has suffix “B”.
6. Be careful not to bend any of the pins. Tighten the locking screws on both cables.
7. Connect the square end of one of the USB Type-A to Type-B cables to the USB connector on the rear panel of the electronics module labeled “A”. Connect the rectangular end of the cable to a USB port on your host computer. (You will connect the other electronics controller module later.)



Figure 8. 26-pin HD D-Sub cables connect to the VariSpec optics modules and electronics controller modules; USB cables connect to the electronics module and computer

8. If you have not previously used a VariSpec USB filter on your host computer, it will detect the presence of the filter and ask you to locate the USB driver file. If you have the VariSpec CD-ROM in your disk drive, check the box indicating that you wish to have the computer search the CD-ROM for the driver file(s). If you downloaded the driver files from the web site, click **Browse** and select the location of the downloaded and decompressed driver folder.
9. Once the driver files have been installed, your host computer should be able to recognize the filter. You may notice a new COM port or two appear in the **Device Manager Ports** list if your computer has previously assigned the COM ports to other devices. You may close the **Device Manager**.
10. Now connect the other electronics module, as follows: Connect the second USB cable to the USB connector on the electronics module labeled “B”. Connect the rectangular end of the cable to a USB port on your host computer.
11. When this initial setup is complete, refer to “Using HyperTerminal™ for Manual Control” on page 49 to learn how to control the dual-housing filter.

VsGui Program for Windows XP and Windows 7

The VsGui demonstration program on the host can be used to verify correct filter operation and demonstrate the filter's capabilities.

1. When launched (select **Start > Programs > CRI > VsGui.exe**), the **VariSpec Control Panel** will appear (Figure 9).

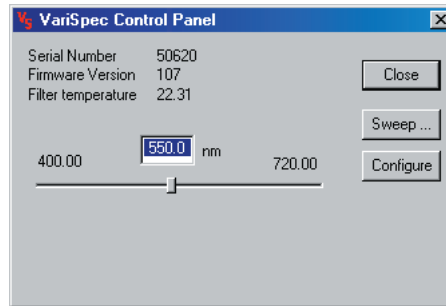


Figure 9. VariSpec Control Panel

2. You may initially receive an error message saying that software cannot connect to a COM port (Error Code 104). If this occurs, click **OK**. Then click the **Configure** button to open the **VariSpec Configuration** window (Figure 10).
3. Click the **Auto-detect** button to search for the correct virtual COM port. If not found, you can manually select it; choose COM3, COM4, or COM5.

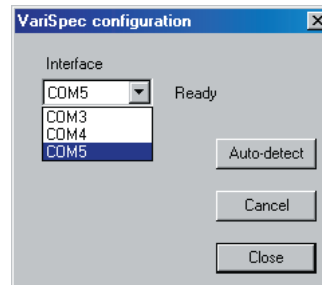


Figure 10. VariSpec Configuration Panel

4. Click the **Close** button when finished to return to the **VariSpec Control Panel** (Figure 9).
5. The **VariSpec Control Panel** lets you select a wavelength by manually entering a wavelength in nm or by dragging the slider along a linear scale representing your filter's wavelength range. Your filter's **Serial Number** and **Firmware Version** are displayed and cannot be edited.
6. Click the **Sweep** button to open the **Sweep** window (Figure 11 on page 16). This window lets you set a **Wavelength Range** and **Step Size** (in nanometers) for the filter to cycle through. You can also set the amount of time you want the filter to remain at each wavelength and whether or not you want the filter to cycle once or repeat indefinitely.

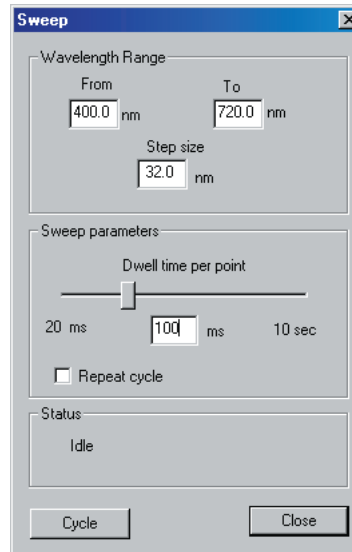


Figure 11. VariSpec Sweep Panel

The VsGui program does not interface with commercial image-capture hardware, but the underlying DLL can be used, along with the SDK, to create your own application. If you want to write software to control the VariSpec filter using CRI's DLL driver, refer to the publication "*Programmer's Guide to VsDrvr*". The most recent revision of this installer program can be downloaded from CRI's web site at <http://www.crii-inc.com>.

Chapter 3

Controlling VariSpec Filters

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Components of the VariSpec SDK

The VariSpec SDK is available on a Windows-compatible CD-ROM, as well as a downloadable file from the CRi web site. The SDK consists of an executable installation program (.EXE) with a name similar to “VsRev1p35.exe”, as well as support files in a folder or ZIP-compressed archive.

Windows DLL

CRi provides a set of functions to control VariSpec filters, which may be called from C or C++ programs. The package incorporates all aspects of filter communications, including low-level serial routines. With these routines, you can address filters as virtual objects, with little need for detailed understanding of their behavior. This simplifies the programming task for those who want to integrate VariSpec filters into larger software projects. See the documentation that comes with the SDK for more detail.

National Instruments® LabVIEW™ Sub-VIs

CRi provides five sub-VI (virtual instrument) files for basic control of VariSpec filters. The .VI files may be copied to the user library directory within LabVIEW and then accessed from the functions palette to drag and drop into higher-level VIs. A “VS Getting Started” VI is also supplied, in order to illustrate a way to interconnect the lower-level sub-VI files.

MATLAB® M-Files

CRi provides a set of MATLAB m-files to control VariSpec filters. There is a core support .DLL file and a series of “.m” functions.

VsGui Program for Windows XP Professional and Windows 7 (32-bit)

The CRi VsGui program is a Windows XP Professional and Windows 7 (32-bit) compatible program that was written to demonstrate the capabilities of the VariSpec SDK. The VsGui program requires that the proper USB driver files be present, as well as the VsDrv.dll be located in the same folder as the executable itself. The VsGui program is a very good troubleshooting tool, since it can help confirm that the filter is working properly with the host computer without the need to resort to using a terminal emulator to send ASCII character-based commands to the filter.

Controlling VariSpec Filters with Direct Serial Commands

This information is provided for standard single-housing models. See “Using HyperTerminal™ for Manual Control” on page 49 for more information on dual-housing models such as the LNIR-06-20, XNIR-09-20, VISR-0.25-20, and NIRR-0.75-20 filter models.

Each filter module offers a USB interface. All serial commands sent through the USB interface are ASCII text. The filter appears as a virtual COMx device, but the actual data transmission occurs over the USB interface. The terminator is always <c/r>.

Note:  Previous-generation VariSpec filters utilized an RS-232 interface with essentially the same command set. However, these older filters had a slower response time and needed supplementary power transformers. (See Legacy Hardware and Software Considerations for additional information.) Table 4 on page 22 gives a list of commands for the VariSpec filter.

Initialization

The VariSpec filter performs an initialization sequence automatically at power-up. A listing of the commands performed during this sequence may be found later in this section. For additional information on the commands used during initialization and power-up, see the descriptions of the “E” and “I” commands.

Palette Commands

After the VariSpec filter has been initialized, there are two ways to select the passband wavelength. The first is to issue a request to tune to a wavelength using the “W” command. This is the easiest method with current-generation filters.

Another method is to define a “palette” of wavelengths. When a wavelength is added to a palette as an “element,” the computer within the VariSpec filter module calculates the required drive level for each tunable element within the optical portion of the filter, and stores the result in a table. Once a palette is defined, any of its elements may be rapidly accessed using the tabulated results. This results in a slight decrease in the amount of time required for a tuning operation (perhaps one or two milliseconds), but not as much as for previous-generation filters (tens to hundreds of milliseconds). The commands that provide for palette definition, revision, and use are described in detail later in this section.

Palette elements can be addressed in any order desired. It is also possible to step through the elements in a palette in sequence. When the last element is reached, the cycle continues with the first element. This is useful when cycling through a sequence repeatedly. Note that the palette commands have been retained more as a legacy feature than for any real performance gain.

VariSpec XNIR-09-20 TTL Sync Port

The VariSpec XNIR-09-20 filter can be controlled using the TTL Sync port on the rear panel of the electronics controller module. This allows the VariSpec filter to respond to signals and synchronization pulses generated by cameras, shutters, and other equipment. The TTL Sync port is a single-trigger detect line. It requires a TTL-level input, and triggers on the downward edge of the pulse. The connection is a standard BNC jack.

Six control modes are possible, listed in the table below. In practice, only Modes 0 or 4 should be used. The Control Mode is selected by using the “M” command.

- Mode 0 cycles the filter sequentially through the palette of wavelengths, triggered by receipt of pulses at the TTL Sync port. When the last palette element is reached, the sequence continues with the first element 0. Before you can use the TTL Sync port in this mode, you must define a palette containing elements (i.e. the wavelengths of interest).
- Mode 4 executes a wavelength step upon receipt of pulses at the TTL/Sync port. This is useful for performing a spectral scan with a fixed step size. Before you can use the TTL Sync port in this mode, you must define the wavelength step increment (in nm) using the “J” command.
- Modes 1, 2, 3, and 5 are reserved. Do not implement these modes as they may cause unexpected results. In all hardware modes, the hardware control ports can be enabled or disabled using the “G” command. This configures the VariSpec hardware so that action is taken only after a specified number of sync or strobe pulses are received. This is useful when integrating a specified number of video frames, for example, at each filter setting. See the description of the “G” command later in this section.

TABLE 1. Control Modes

Mode	Description	Wavelength or Palette Access	Random or Sequential	Trigger Source
0	Cycle palette on sync	Palette	Sequential	Sync
1	Reserved	N/A	N/A	N/A
2	Reserved	N/A	N/A	N/A
3	Reserved	N/A	N/A	N/A
4	Wavelength sweep on sync	Wavelength	Sequential	Sync
5	Reserved	N/A	N/A	N/A

LED Behavior

If the VariSpec filter receives an incorrect communication, the Status LED turns Red and an Error Code is recorded. Error Code can be read out using the “R” command as described later in this section. The LED remains lit Red until the error is cleared, but subsequent commands are processed normally. CRi recommends first retrieving the Error Code and then clearing the error condition before proceeding.

TABLE 2. Status LED Function

State	Meaning
green	no errors; currently not sending or receiving data
blinking green	no errors; data being sent / received
red	an error has occurred; currently not sending or receiving data
blinking red	an error has occurred; data being sent / received

Putting the VariSpec Filter to Sleep

A filter can be put to sleep using the “S” command and awakened using the “A” command. All other commands and queries are ignored when the filter is asleep. Wavelength and other settings are retained upon awakening, if they were previously defined. The TTL Sync port is serviced, if active. Characters are echoed, even if asleep.

Note: Previous-generation VariSpec filters could be daisy-chained using a single RS-232 port, or used with other devices having similar sleep capability.

Escape, Status-Check, and Busy-Check Characters

There are three special characters: the Escape <esc> character “ASCII 27”; the Status-Check character “@”; and the Busy-Check character “!”. These are processed immediately, before all pending commands, provided that the filter is awake. There is no need for a terminator for these characters.

The Escape character stops any command in process, and clears all characters from the USB command queue. This allows you to abort an extended operation or to delay pending commands.

The Status-Check character “@” provides various information on filter status. The VariSpec filter responds with a single, printable ASCII character response. Each bit in the response character indicates something about the filter status, listed in the table below.

The Busy-Check character “!” tests whether the VariSpec filter has completed all pending commands. If done, it responds with the “>” character. If busy with pending commands, it responds with the “<” character.

TABLE 3. Status-Check Characters

Bit	Description	Meaning, if 0 / 1
8 (msb)	Reserved	Always 0
7	Reserved	Always 1
6	Error status	None / Error pending
5	Terminator	Always 0
4	Brief Mode	Normal / Brief or Auto
3	Palette defined	None / Defined
2	Exercised?	No / Yes
1	Initialized?	No / Yes

Command Nomenclature

Several commands are available to control the VariSpec filter. Each command has a one-letter key, and can usually be used as a command or as a query.

In the following descriptions, <arg> can be a number value in fixed or floating-point format, or the query character “?”. The command terminator, <term>, is the carriage-return character, <c/r>. The separator, <sep>, is a comma or any white-space character. Arguments in curly brackets are optional and may not be required for all forms of the command. Error handling is noted for each command.

All wavelengths are specified in nanometers, and need not be integral. Resolution is numerically limited to 0.001 nm, which generally exceeds the filter’s optical tuning resolution.

The standard response format is: the command letter (uppercase), followed by the response value, then the <term> character. The format for wavelengths is xxxx.yyy. Most other response values are integers, xxxxxx. Values are right justified, with leading spaces, rather than leading zeros.

Brief and Auto-Confirm Formats

Each VariSpec electronics controller module can use a Brief Format when replying to queries, to decrease the number of characters sent. When the Brief Format is selected, the command key letter and all leading spaces are omitted.

Another format is provided, called Auto-Confirm format. When this is selected, the VariSpec filter replies to each command with the new value of the parameter that was set. This confirms that the command was received and processed. The Brief Format or the

Auto-Confirm format is selected using the “B” command, described later in this section. Upon power-up the VariSpec filter uses the normal format.

Table of Commands

TABLE 4. Commands

Command	Default Value	Function or Purpose
A(waken)	0 (awake)	Re-activate sleeping filter for USB control
B(rief)	0 (normal)	Select Normal, Brief, or Auto-Confirm Format
C(lear)		Clear palette of all elements (wavelength entries)
D(efine)		Define palette element with specified wavelength
E(xercise)		Exercise filter to prepare for use
G(o)	1 (enabled)	Enable or Disable TTL/Sync port (XNIR-09-20 model only)
I(nitalize)	1 (initialized)	Perform initialization sequence
J(ump)	5.00 nm	Set wavelength increment used in Mode 4
M(ode)	0	Select hardware Control Mode
P(alette)	255 (undefined)	Set filter to transmit selected palette element
R(eset)		Reset Status LED and clear Error condition
S(leep)	0 (awake)	Make filter inactive, unresponsive to commands
V(ersion)		Query the firmware revision and configuration
W(avelength)	Depends on filter type	Set wavelength to transmit specified wavelength (nm)
eX(ecute)		Simulates trigger at TTL port
Y(temperature)		Query temperature of LC elements of optics module

Descriptions of VariSpec Serial Commands

Awaken

A <arg> <term>

Command: awakens filter with ID number given by <arg>. The ID number is the filter’s 5-digit serial number, such as 50527, 50782, etc.

Legal <arg> values: [0 - 65535]

Query reply: 0 if awake, no reply if asleep

Note: It is bad practice to query the awake/sleep status, as a sleeping filter will not reply.



Brief

B <arg> <term>

Command: If <arg> is 0, it selects the VariSpec filter's normal format for replying to queries. If <arg> is 1, it selects the brief format. If <arg> is 2, it selects the auto-confirm format. At power-up, the default is to use the normal format.

In Brief format, the VariSpec filter does not echo the command letter, and omits all leading spaces. Thus the normal reply

M 1<term>

becomes, in brief format,

1<term>

In auto-confirm format, replies are made every time a command is received. This is different from normal and brief mode, which only reply to queries. The auto-confirm mode replies include the command letter and spaces, like the normal format.

Legal <arg> values: [0, 1, 2]

Query reply: 0/normal, 1/brief, 2/auto-confirm

Clear Palette

C <arg> <term>

Command: clears the entire palette if <arg> is nonzero. It is not possible to selectively clear elements using the "C" command.

Legal <arg> values: [0, 1]

Query reply: 0

Define Palette Element

D <arg0> {<sep> <arg1>} <term>

Command: define palette with wavelength given by <arg0>. It is added to the end of the palette, unless <arg1> is given. In that case, palette element <arg1> is assigned a wavelength of <arg0>. Palette elements must be defined sequentially. If <arg1> points past the end of the palette, a fault is generated and no action is taken.

The palette table uses 0-based indexing, so the first palette element is number 0, the next is number 1, and so on.

Legal <arg0> values: set by optics wavelength limit

Legal <arg1> values: [0 - last palette element]

Query reply: The unit responds with the number of elements defined, followed by all palette elements in sequence, separated by end-of-line terminators. So, if three elements were defined as 450 nm, 550 nm and 650 nm, the reply would be:

D 3<term>

D 450<term>

D 550<term>

D 650<term>

In brief format, the response would be:

3<term>
450<term>
550<term>
650<term>

Exercise

E <arg> <term>

Command: exercises the filter <arg> times. This places the liquid crystal elements into a known state. An <arg> of 3 is sufficient to fully exercise the optics at room temperature. If the filter has been powered off for only a few minutes, an <arg> value of 1 can be used. Each cycle takes about 12 seconds.

Legal <arg> values: [0 - 255]

Query reply: number of E cycles pending

Go/Stop TTL Sync Port

G <arg> <term>

Command: this selects whether service of the TTL Sync port is enabled, and selects the dwell time, in trigger pulses, at each setting. If <arg> is 0, service of the TTL Sync port is inhibited (stopped). This means that the wavelength is fixed at its present value, regardless of activity at the TTL Sync port, unless changed explicitly by the “P” or “W” commands.

If <arg> is positive, service is enabled, and the system dwells <arg> pulses at each setting. So, if “G” is set to 4, and the electronics module is in sequential mode 0, it advances to the next palette element every four sync pulses. At power-up, G is enabled and set to a value of 1.

Legal <arg> values: [0 - 255]

Query reply: current hardware service value

Initialize

I <arg> <term>

Command: initializes the VariSpec filter if <arg> is nonzero. The electronics module needs to perform an initialization sequence, which takes less than 1 second before it is ready to tune properly. Note that older RS-232 units and USB units may take 30 seconds or longer for the sequence to complete its cycle.

This is performed as part of the automatic power-on sequence, so it is not necessary to request another initialization when the filter is operating, unless it has been more than 8 hours since the last initialization, or if the filter module’s temperature has changed more than 3-degrees Centigrade.

Legal <arg> value: [1]

Query reply: 1 if initialized, 0 otherwise

Jump

J <arg> <term>

Command: defines the wavelength jump size. The jump can be positive (jump towards the red) or negative (jump towards the blue). The controller jumps this

amount from its present wavelength, upon receipt of an eXecute command or an external hardware trigger pulse in mode 4. At power-up Jump is set to 5.00. The jump step can be any value consistent with the tuning range of the filter, given the specifications.

Legal <arg> values: determined by filter optics

Query reply: present jump size in nm

Mode Select

M <arg> <term>

Command: set the Control Mode. Legal modes are 0 (sequential on sync) and 4 (move wavelength step on sync).

Mode 0 is sequential. The filter changes wavelength upon receipt of the sync pulse. In Mode 4, the filter steps in wavelength as set by the “J” command, triggered by the sync signal.

Legal <arg> values: [0, 4]

Query reply: present mode

Palette Select

P <arg> <term>

Command: go to palette element <arg>. If that element is undefined, an error is generated and the Status LED is lit Red. The palette uses 0-based indexing, so the first element is element 0.

You may also use the “>” character as <arg>, to request the next palette element; or the “<” character, to request the previous palette element.

Legal <arg> values: [0 - 127], “<”, “>”

Query reply: present palette element number; 255 if palette element undefined

Reset

R <arg> <term>

Command: resets any pending fault conditions if <arg> is nonzero. This also resets (to green) the Status LED if it is lit Red on the front panel. It is a good idea to send an <esc> before sending the “R” command, if previous commands were garbled in transmission. The <esc> clears the VariSpec communications buffer and insures the “R” command is received properly.

Legal <arg> values: [0 or 1]

Query reply: 0 if no fault, error code otherwise

Sleep

S <arg> <term>

Command: puts filter to sleep with ID number given by <arg>. The ID number is the filter’s 5-digit serial number, such as 50527, 50782, etc.

Legal <arg> values: [0 - 65535]

Query reply: 0 if awake, no reply if asleep

Note: it is bad practice to query the awake/sleep status, as a sleeping filter will not reply.

Version

V <arg> <term>

This can be issued only as a query. It returns the VariSpec firmware revision number and other configuration data, in the following format:

v_ _ _ rrr_ _ bbbb.bb_ _ tttt.tt_ sssss

where rrr is the firmware revision level; bbbb.bb (no leading spaces or leading zeroes) is the shortest wavelength the filter can tune to, in nm; tttt.tt is the longest wavelength the filter can tune to, in nm; and sssss is the serial number.

Note: each underscore represents one space between characters.

Legal <arg> values: Query only

Query reply: revision and configuration data as described above

Wavelength Select

W <arg> <term>

Command: tunes the filter to wavelength <arg>. The legal range of <arg> is determined by the optics module's construction and electronics module's configuration. If <arg> is out of range, it causes an error and lights the Status LED Red.

You can send ">" as the <arg>. This causes the filter to step to a wavelength longer than the one to which it is presently tuned. The step size is set by the "J" command. Similarly, if the "<" character is given as <arg>, the filter steps to a wavelength shorter than the one it is presently tuned to.

Legal <arg> values: [set by optics], ">", "<"

Query reply: present wavelength in nm

eXecute

X <arg> <term>

Command: issuing this command with <arg> nonzero is equivalent to sending a trigger pulse to the TTL Sync port, which is available on the electronics controller box of the XNIR-09-20 model. See "VariSpec XNIR-09-20 TTL Sync Port" on page 19 for details on setting the appropriate control mode. It causes the filter to jump to the next palette element, or shift the pass wavelength by an amount set by the Jump command, depending on the mode selected. (See the M command, "Mode Select" on page 25.)

Legal <arg> values: [0-255]

Query: 0

Temperature of LC elements in optics module

Y <arg> <term>

This can be issued only as a query. It returns the temperature of the liquid crystal elements of the VariSpec optics module in centigrade.

Legal <arg> values: Query only

Query reply: temperature of LC elements in
optics module in centigrade

Escape

<esc> (ASCII character code 27)

This character is processed immediately, with no need for a <term> character. The VariSpec filter stops processing all pending commands immediately. All characters in the communications buffer are erased, and the input buffer is reset. There is a latency of up to 20 milliseconds before the unit returns to the “idle” state.

There is no response if the unit is asleep, but the <esc> character is echoed like any other.

Status Check

@

This character is processed immediately, with no need for a <term> character. The VariSpec filter responds with a status character, whose bits indicate various status information about the filter. The table of character bits is located at the beginning of this section, Table 3 on page 21, (Escape, Status-Check, and Busy-Check Characters).

There is no response if the unit is asleep, but the “@” character is echoed like any other.

Busy Check

!

This character is processed immediately, with no need for a <term> character. The VariSpec filter responds with “<” if it is busy (processing other commands), or with “>” if it is idle (no pending commands).

There is no response if the unit is asleep, but the “!” character is echoed like any other.

Error Codes

When an error occurs, the VariSpec filter records an error code. This code is stored until the error is cleared using the “R” command, or until another error occurs. At that point, the error code changes to reflect the new error condition. The code can be read by querying the “R” parameter.

Errors can be caused by syntax errors, impossible argument values, or issuing commands before other, supporting commands have been performed. An example of this last type would be an attempt to tune to a palette element when no palette element has been defined.

Many of these errors do not interfere with the processing of subsequent commands, and the VariSpec filter continues to process commands even while an error is pending. Those errors listed as (internal) are usually caused by problems internal to the VariSpec filter, rather than commands sent to it.

TABLE 5. Error Codes

Code	Meaning
0	No errors pending
1	Syntax error
2	Attempt was made to set a read-only parameter
3	“E” (exercise) command was issued with illegal <arg> value
4	Attempt to set wavelength or palette while filter is uninitialized
5	“I” (initialize) command issued with illegal <arg> value
6	Mode error
7	“M” (mode) command issued with illegal <arg> value
8	Error calculating liquid crystal drive levels (internal)
9	Palette not defined
10	Palette not prepared (internal)
11	Palette element out of range
12	Wavelength out of range
13	Liquid crystal drive level out of range (internal)
14	Jump wavelength step too large
17	“G” (go) command issued with illegal <arg> value
*	Appears when the filter is set out of bounds, when initialization has not occurred, or when the filter cannot tune to a specified wavelength (not necessarily out of range)

Programming Examples

Here are several examples of how the VariSpec filter may be programmed, using the USB port and the command set described in the previous section. In the examples, commands sent to the VariSpec are shown in **bold text** and replies from the VariSpec are shown in normal text. Comments are placed within braces.

Example 1. Tuning by wavelength

In this example, a VIS-model VariSpec filter is controlled by a host computer using the USB port. This presumes that the proper USB driver files have been installed. The optics in this case can tune from 400 nm to 720 nm.

	{plug VariSpec filter into USB port and wait until initialization is complete}
W ?	{wait for reply}
W 550.000	{VariSpec filter is tuned to the default 550 nm for this particular model}

W 500 <c/r>	{tune filter to 500 nm}
W 600 <c/r>	{tune filter to 600 nm}
W 488 <c/r>	{tune filter to 488 nm, altered spacing is okay}
W 900 <c/r>	{wavelength out of range, Status LED lights Red}
W ? <c/r>	{what wavelength is the filter currently set at?}
W 488.00 <c/r>	{filter stays at the last legal wavelength given}
R 1 <c/r>	{clear the Status LED and reset the error condition}

Example 2. Tuning with a palette

In this example, we set up a palette of wavelengths and then tune using the palette. The preamble is the same as the previous example.

	{plug VariSpec filter into USB port and wait until initialization is complete}
W ? <c/r>	{wait for reply}
W 550.000 <c/r>	{VariSpec filter is tuned to the default 550 nm for this particular model}
D 460 <c/r>	{define first palette element 0}
D 540 <c/r>	{define second palette element 1}
D 640 <c/r>	{define third palette element 2}
D ? <c/r>	{query what palette elements are}
D 3 <c/r>	{number of elements}
D 460.000 <c/r>	{wavelength of element 0}
D 540.000 <c/r>	{wavelength of element 1}
D 640.000 <c/r>	{wavelength of element 2}
P 0 <c/r>	{tune to element 0}
W ? <c/r>	{query pass wavelength}
W 460.000 <c/r>	{wavelength is 460 nm}
P 2 <c/r>	{tune to element 2}
W ? <c/r>	{query pass wavelength}
W 640.00 <c/r>	{wavelength is 640 nm}
D 550 1 <c/r>	{change element 1 wavelength to 550 nm}
W ? <c/r>	{query pass wavelength}
W 640.000 <c/r>	{filter is still at old 640 nm wavelength}
P 1 <c/r>	{tune to element 1}
W ? <c/r>	{query pass wavelength}
W 550.000 <c/r>	{wavelength is 550 nm}

Example 3. Cycling through various wavelengths using the TTL Sync port on the XNIR-09-20

Here we define a palette and then use a 10 Hz TTL signal generator at the TTL Sync port to cycle through the palette elements in sequence.

	{plug VariSpec filter into USB port and wait until initialization is complete}
W ? <c/r>	{wait for reply}
W 550.000 <c/r>	{VariSpec filter is tuned to the default 550 nm for this particular model}
G 0 <c/r>	{disable sync}
D 460 <c/r>	{define first palette element 0}
D 540 <c/r>	{define second paletteelement 1}
D 640 <c/r>	{define third palette element 2}
P ? <c/r>	{query present element}
P 255 <c/r>	{palette code for “palette element undefined”}
	{attach TTL signal generator to TTL Sync port, set rep rate at 10 Hz}
M 0 <c/r>	{select mode 0, sequential on sync port signal}
P ? <c/r>	{query present element}
P 255 <c/r>	{palette code for “palette element undefined”}
G 1 <c/r>	{enable sync port service for every pulse}
	{filter cycles through the palette at 10 Hz}
G 2 <c/r>	{enable sync port service for every second pulse}
	{filter cycles through the palette at 5 Hz}
P ? <c/r>	{query present element}
P 1 <c/r>	{element will be 0, 1, or 2, depending on timing}
	{filter continues to cycle through the palette at 5 Hz}

Controlling VariSpec Filters with Other Operating Systems

CRi does not directly support the use of VariSpec filters on operating systems other than Windows XP Professional or Windows 7. However, VariSpec filters can be controlled using other operating systems when the appropriate drivers are used. USB drivers are available for Apple Mac OS X and Linux. Contact CRi for further information.

Chapter 4

Frequently Asked Questions & Troubleshooting

FAQs

I want to clean the glass surface of the VariSpec optics module from fingerprints and other debris. How do I clean it?

Use a compressed air can to clean surface dust off the glass surfaces. Hold the can upright so that no freezing-temperature liquid comes out. If the glass surface has fingerprints or other residue, use isopropyl alcohol or commercial lens cleaner. You may also try distilled water or spectroscopic-grade methanol. Minimize the use of commercial glass cleaners containing ammonia, since the anti-reflective (AR) coatings may be damaged over time.

Use gloves and apply the cleaning solution to lint-less lens tissue. Drag-wipe over the surface and discard the tissue. Repeat if necessary. Do not press down on or rub the glass surface, since the AR coatings may be damaged.

How large an aperture can I buy?

VIS filters come in 22 mm and 35 mm apertures. All others come in 22 mm apertures. See the current Configuration List for a full list of available filter models.

What is your definition of bandwidth?

The Full-Width at Half-Maximum (FWHM), measured as the spectral separation between the two points where the filter's transmission attains 50% of the peak value. The passband center wavelength is the wavelength midway between these two points. VariSpec filters come in a variety of bandwidths, which are set during the design and manufacturing process and are not adjustable by the customer.

Nominal bandwidth is measured at a wavelength about halfway within the wavelength range of the particular filter: e.g. 550 nm for VIS models and 850 nm for SNIR

models. The actual width of the passband is constant in terms of center wavenumber, but varies in terms of center wavelength such that a center wavelength selected closer to the blue will have a narrower passband width than a center wavelength selected closer to the red.

What is the transmission of the filters?

The percentage of linearly polarized light, oriented so that maximum transmission is attained, passing through the filter relative to the amount that entered. Since the entrance element of the VariSpec filter is a linear polarizer, transmission of randomly polarized light is half that of linearly polarized light in the correct orientation. VariSpec transmission is wavelength dependent. Typical spectral curves taken across the wavelength range of each type of filter are available from CRi in graphical form. Contact CRi for more information.

What is the tuning speed of the filters?

Several factors affect this number, including the liquid crystal relaxation time from “charge” to “no charge” states under various ambient temperatures and the calculation time of the electronics, which must send the correct voltages to each liquid crystal element for each change. Typically, this time is 50 ms to 150 ms.

Current filters utilize a USB serial interface. These filters also utilize a fast microprocessor to calculate the necessary voltages in order to control the liquid crystal (LC) elements inside the optics module. Older filters with an RS-232 interface used a previous-generation microprocessor that required much longer times to calculate these voltages-sometimes hundreds of milliseconds. Therefore, in order to minimize tuning time, users would typically store wavelengths of interest (up to 128) in a palette using the “D” commands. These commands remain, as a legacy feature, in the current command set, but no longer result in significantly faster tuning speeds.

CRi has performed tests at various ambient temperatures to determine the typical transition times of each model. Contact CRi for more detail.

What is the damage threshold of the filters?

The damage threshold for reasonably long-term exposure of the filters to VIS and NIR energy is 500 mW/cm². Note that the filters absorb light that you do not want to see or otherwise detect. VIS filters have a near-infrared hot mirror to reflect some unwanted near-infrared light, but longer wavelength near-infrared light, such as thermal energy, can damage the filters. Keep in mind that many detectors, such as CCD or CMOS sensors, may not be able to detect this energy. It is good practice to check the temperature of the filter optics to make sure the tuning elements are not subjected to excess heat.

Typically the epoxy and polarizing material will be damaged first, followed by the coatings, glass, and the liquid crystal material itself.

The enclosure has been designed to withstand moderate impacts, but a major component by weight of most VariSpec filter models is glass, so inadvertent impacts can damage the filter. Nevertheless it is quite rare for a VariSpec filter to break in the field.

Tests (such as CE testing) have shown the enclosure to be resistant to EMI. Nevertheless, exposing the electronics to voltage spikes or sags or a large static discharge can render the filter inoperable or, worse, damage the electronics.

I have two XNIR-09-20 filters, can I interchange the optics and electronics?

No. VariSpec Optics and electronics controller modules are a matched set with configuration data unique to a particular optics module loaded into the memory of the electronics module.

Can I use a longer 26-pin cable between the optics and electronics modules of the XNIR-09-20 filter? Can I use a longer USB cable?

CRi does not recommend using a longer 26-pin cable, since the added length may cause excessive signal loss, and hence transmission loss, in some models. Regarding longer USB cables, the official USB specification limits the length to 3 meters.

What are the differences in LCTF and AOTF technology?

As described earlier, CRi VariSpec filters are Liquid Crystal Tunable Filter (LCTF) designs. The liquid crystal (LC) material is a so-called *nematic* LC. Nematic LC is used in many imaging applications such as liquid crystal display (LCD) monitors and screens. Nematic material can be easily controlled using relatively low voltages and responds consistently to repeated signals. Image quality is very high and the field-of-view is relatively wide (from 3.5-degrees to 7.5-degrees, depending on the model). Although tunable filters can be manufactured using other designs to enable wavelength tuning, CRi's Lyot designs are among the most widely recognized and, thus, the term LCTF is usually associated with VariSpec filters.

Acousto-Optic Tunable Filters (AOTF) use a crystal in which vibrational waves at radio frequencies allow a single wavelength of light to pass. The wavelength of light is a function of the frequency of the radio waves applied to the crystal. Transmission can be high, but without the superior out-of-band transmittance performance of an LCTF. There is also a so-called *blur* effect that can compromise the spatial imaging quality of the filter in many applications. Very narrow bandwidth filters can be built—some as narrow as CRi's VISR or NIRR designs. Field-of-view is narrower than with VariSpec LCTFs because of the requirements of the AOTF design. Tuning speeds can be as fast as 20 microseconds because all that is required is that the radio waves penetrate the crystal.

Do VariSpec filters polarize the light that passes through them?

Yes. Unpolarized light that enters the filter becomes linearly polarized, and the light that exits the filter is linearly polarized. Of course, if the light entering the filter is linearly polarized in the same orientation as the filter, efficiency is doubled as compared with unpolarized light. Contact CRi if you would like to know the axis of polarization for the entrance and exit apertures for a particular filter model.

When I connect the USB cable from the VariSpec filter's Electronics Controller module to my computer, Windows asks me where 'ftdibus.sys' and 'ftser2k.sys' are. What can I do? The filter does not seem to be recognized by the Windows operating system.

Sometimes the Windows operating system's Plug and Play feature for new devices does not work entirely seamlessly. If you followed the directions to install the SDK onto your computer and received no error messages during or after the installation, those files should be located in: C:\Program Files\Cri\VariSpec\USB. Use the Detect New Hardware wizard to browse to that location and select the appropriate file. After the Detect New Hardware wizard is finished, the VariSpec filter should operate normally as a new USB serial device.

I need a multispectral imaging system, and your VariSpec filter technology looks ideal. But I don't want to do any system integration. Do you have a turnkey solution?

Yes. We also manufacture and sell the Nuance™ Multispectral Imaging System, the R&D 100 Award-winning Maestro™ In-Vivo Fluorescence Imaging System, and the Vectra™ microscope slide analysis system. Contact CRi for more information (sales@cri-inc.com).

- Nuance systems can be used for a wide variety of brightfield and fluorescence applications, including FISH and FRET experiments, multicolor immunohistochemistry, general fluorescence or brightfield microscopy, tissue microarray investigation, and high-content screening research. The Nuance optics module is compact and robust, with standard C-mount coupling for easy integration onto existing microscopes. A tripod socket is supplied for remote-sensing, forensic, machine vision, or other macroscopic applications. A workstation computer with Windows-compatible multispectral imaging software is also included.
- Maestro systems are affordable, breakthrough instruments for fluorescence-based *in-vivo* molecular imaging. Using multispectral acquisition and analysis, they provide dramatically improved sensitivity, multicolor flexibility and quantitative accuracy for both visible and near-infrared labels. The systems virtually eliminate contrast-robbing autofluorescence, revealing otherwise invisible targets that appear bright against a near-black background. This dramatic improvement in the signal-to-noise ratio can increase sensitivity many fold, allowing much smaller or fainter targets to be detected. A workstation computer with Windows-compatible multispectral imaging software is also included.
- Vectra™ is the world's only multispectral fluorescence- and brightfield-capable microscope slide analysis system. Vectra's pattern recognition-based scanning rapidly acquires high-resolution multispectral images of samples on microscope slides. Samples can be cultured cells, cell spreads, tissue sections or tissue microarrays, stained with standard stains such as H&E or trichrome, or immunofluorescence and immunohistochemical techniques. CRi's intelligent scanning approach, based on multispectral imaging, pattern recognition and machine learning, provides a more quantitative, more efficient and faster

approach to harness reliable data from slides, compared to approaches that use color images acquired on whole-slide digital scanners. The Vectra system incorporates CRI's powerful image analysis software, called inForm™, and CRI's proprietary autofluorescence removal methodology. With this system, you can separate up to five fluorophores from one another and autofluorescence without cross-talk. The system is designed to perform batch processing of slides, up to 200 at a time, or for tissue microarrays.

Appendix A. System Specifications & Dimensions

Operating Specifications

Note that these specifications represent typical VariSpec filters as of August 2010 and are subject to change.

Parameter	VariSpec VIS	VariSpec SNIR	VariSpec LNIR	VariSpec XNIR	VariSpec VISR	VariSpec NIRr
Wavelength range (nm)	400-720	650-1100	850-1800	1200-2450	480-720	650-1100
Bandwidth FWHM (nm)	7, 10, or 20	7 or 10	6 or 20	9	0.25 (best effort)	0.75 (best effort)
Working aperture (mm)	22 or 35	22	22	22	22	22
Angle-of-acceptance (half-angle)	7.5 degrees	7.5 degrees	3.5 degrees	3.5 degrees	3.5 degrees	3.5 degrees
Optics response time (ms) ¹	50	150	150	50	150	150
Single or dual-housing design ²	Single	Single	Single: 20-nm Dual: 06-nm	Dual	Dual	Dual
Wavelength accuracy	Bandwidth/8 +/- 0.5 nm		Bandwidth/8 +/- 0.5 nm		Bandwidth/8 +/- 0.5 nm	
Maximum optical input	500 mW/cm ²		500 mW/cm ²		500 mW/cm ²	
Operating temperature	10-40 °C		10-40 °C		10-40 °C	
Storage temperature	-15-55 °C		-15-55 °C		-15-55 °C	
Computer interface	USB 1.1		USB 1.1		USB 1.1	
Power supply	USB bus-powered		USB bus-powered		USB bus-powered	
Weight (excluding USB cable)	small aperture: 375 g large aperture: 460 g	375 g	6 nm: 800 g 20 nm: TBD	optics: 1015 g electronics: 2 x 450 g cable: 2 x 190 g	800 g	800 g
<i>some weights are approximate</i>						

1. Optics response time depends on a number of factors including ambient temperature (colder temperatures cause the liquid crystal material to become more viscous and slower to respond) and model (NIR models are slower to respond than VIS models). Older filters (with electronics designed with a RS-232 serial interface) used a microprocessor than was not as fast as newer versions and, unless the palette function was utilized, might respond in 300 ms or more.
2. Dual-housing filters use two sets of optics. They must both be sent identical commands, but do not need to be addressed simultaneously. The XNIR-09-20 model uses two matched sets of Optics and Electronics modules.

Mechanical Dimensions (Optics Module)

VariSpec 22 mm Aperture Standard Enclosure

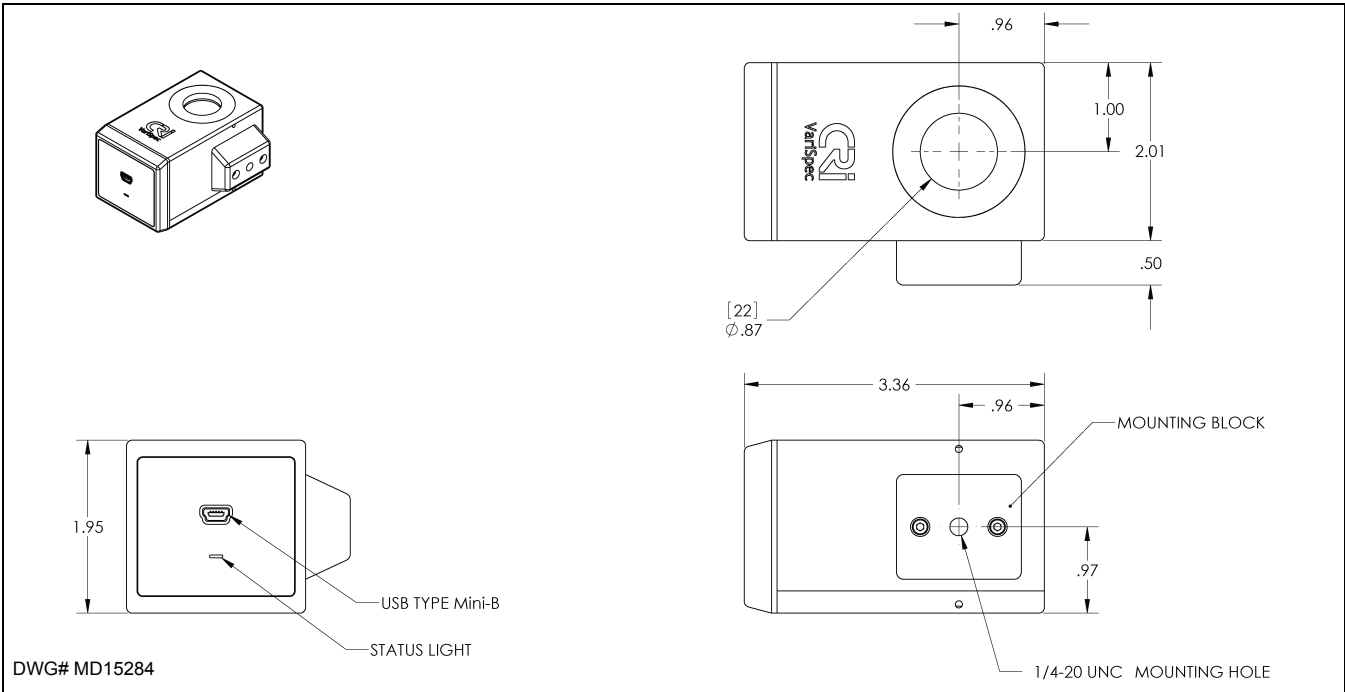


Figure 12. Exterior of a 22 mm Aperture Enclosure

VariSpec 22 mm Aperture Dual-Housing Enclosure

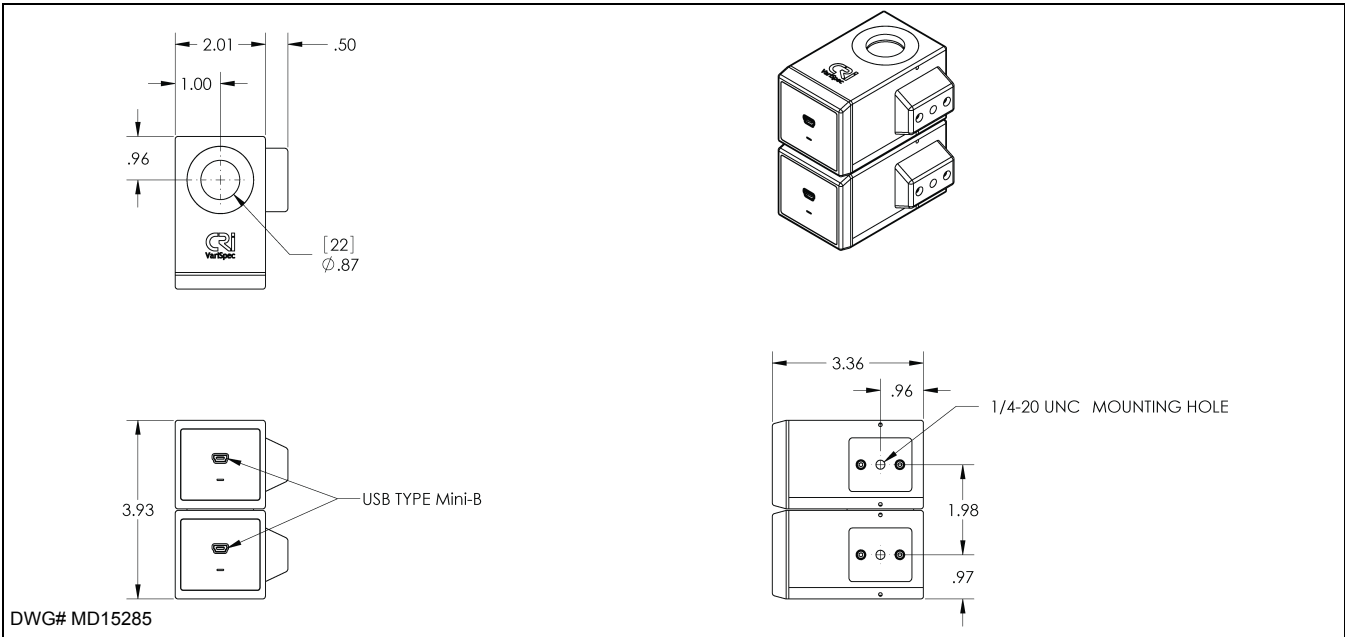


Figure 13. Exterior of a 22 mm Dual-Aperture Enclosure

VariSpec 22 mm Aperture Enclosure for the XNIR-09-20 Model

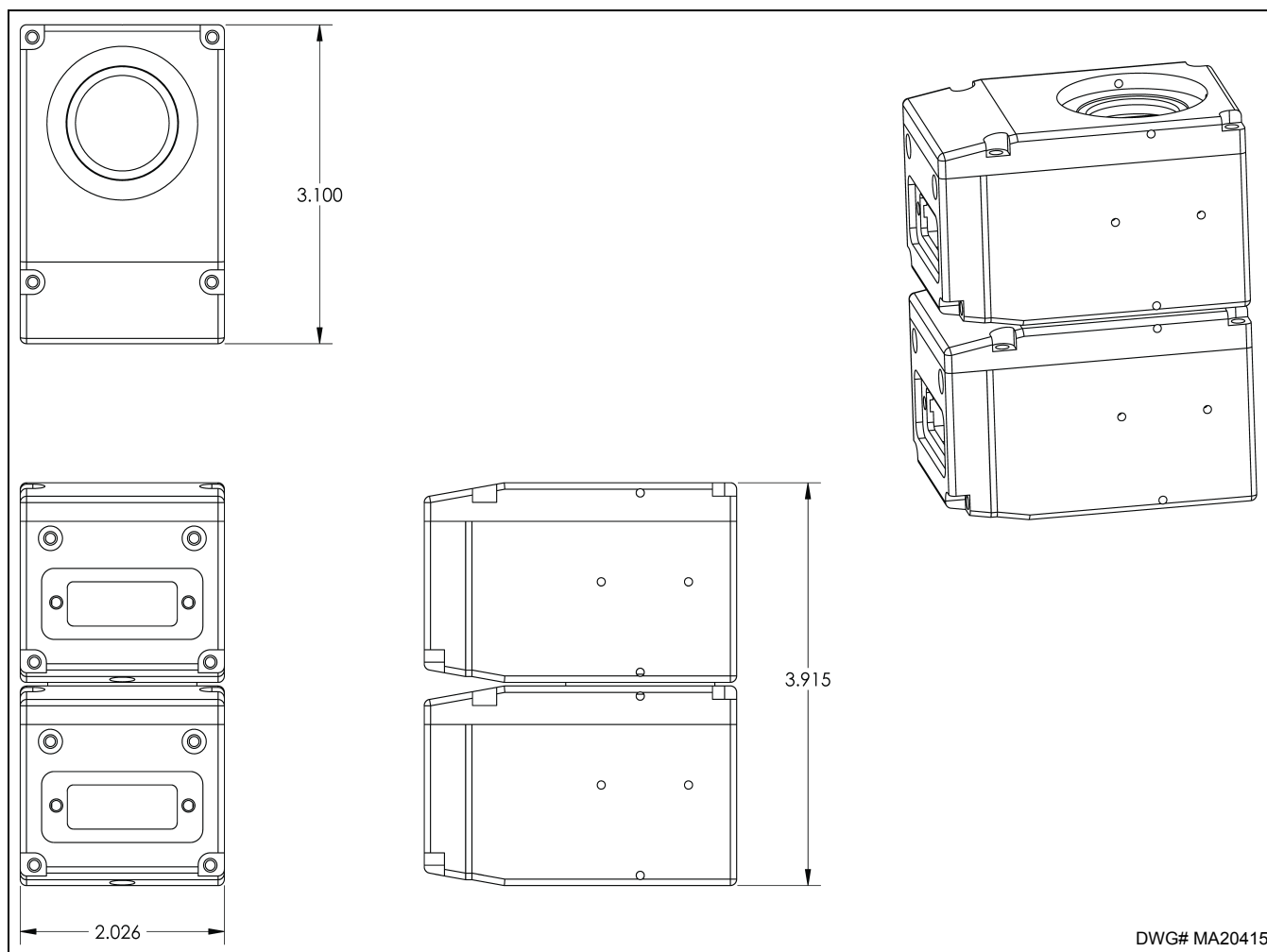


Figure 14. Exterior of the Unique XNIR-09-20 Dual-Aperture Enclosure

VariSpec Mounting Adapters for 22 mm Aperture Models

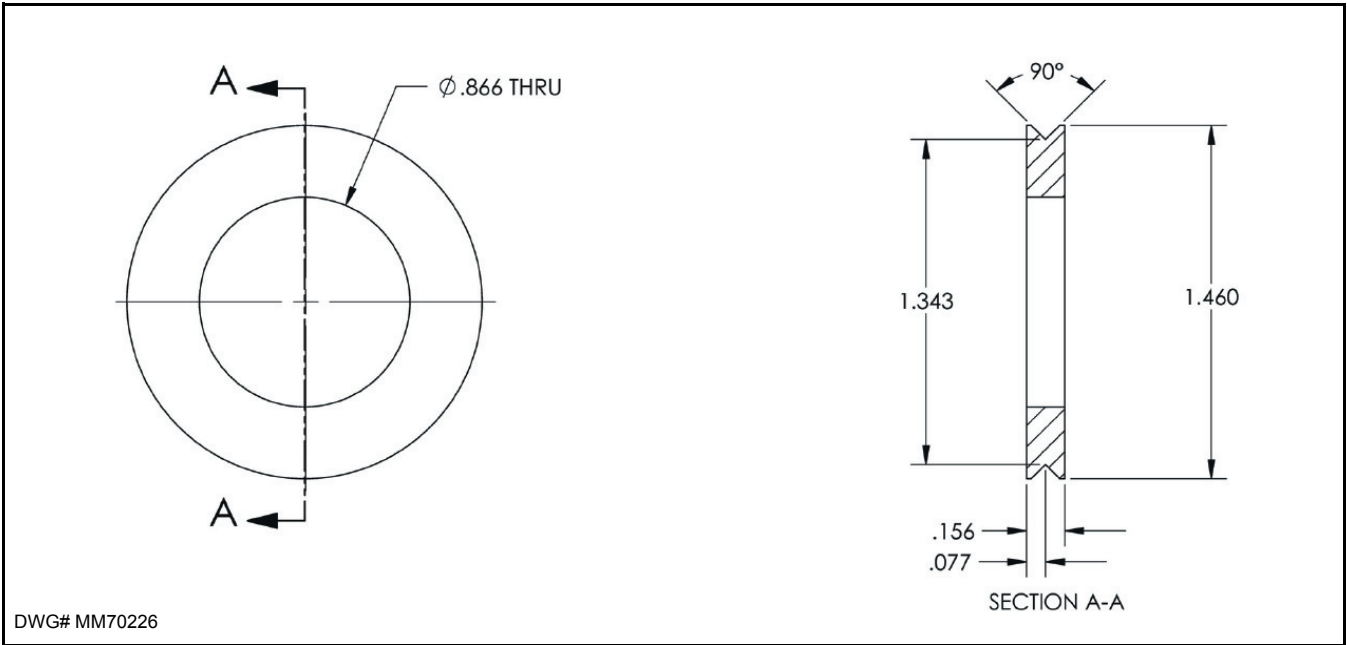


Figure 15. Stainless Steel Insert — Default, Blank

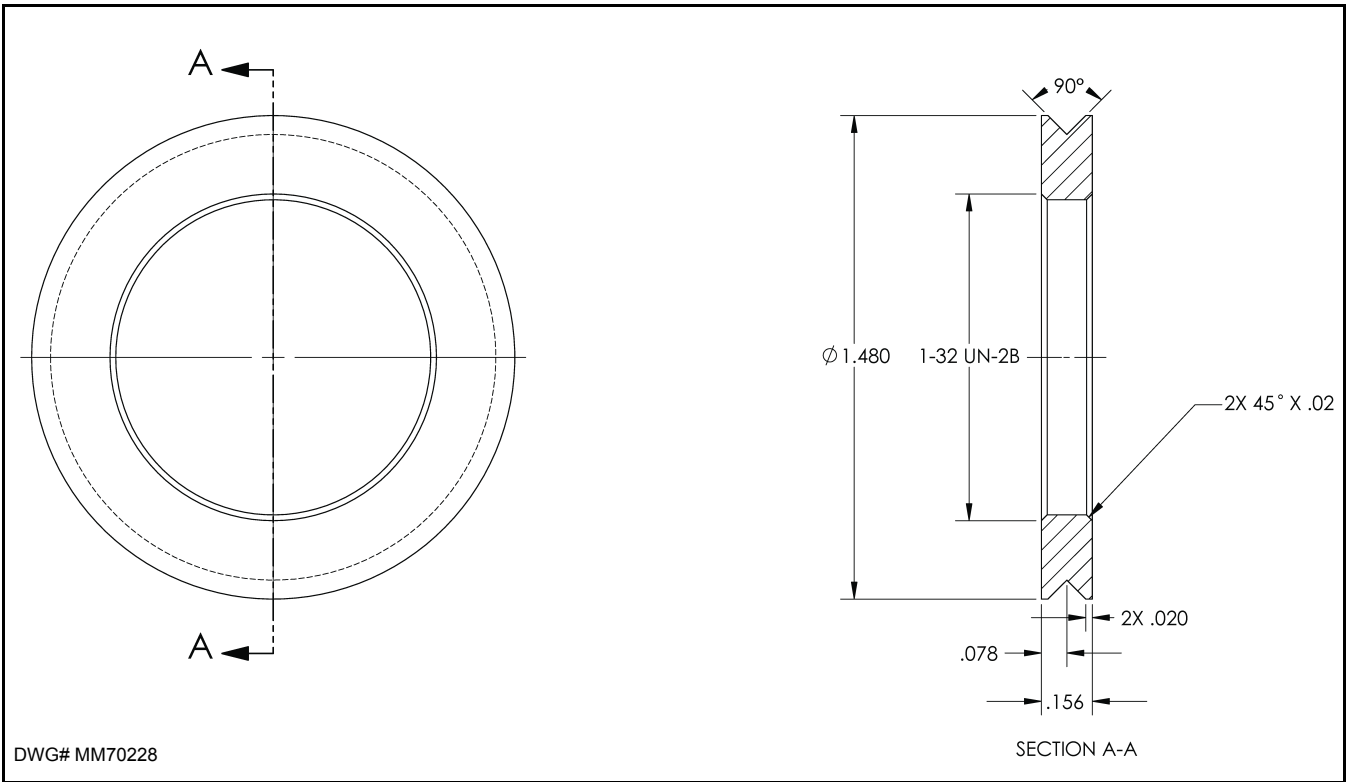


Figure 16. Stainless Steel Insert — Female C-mount

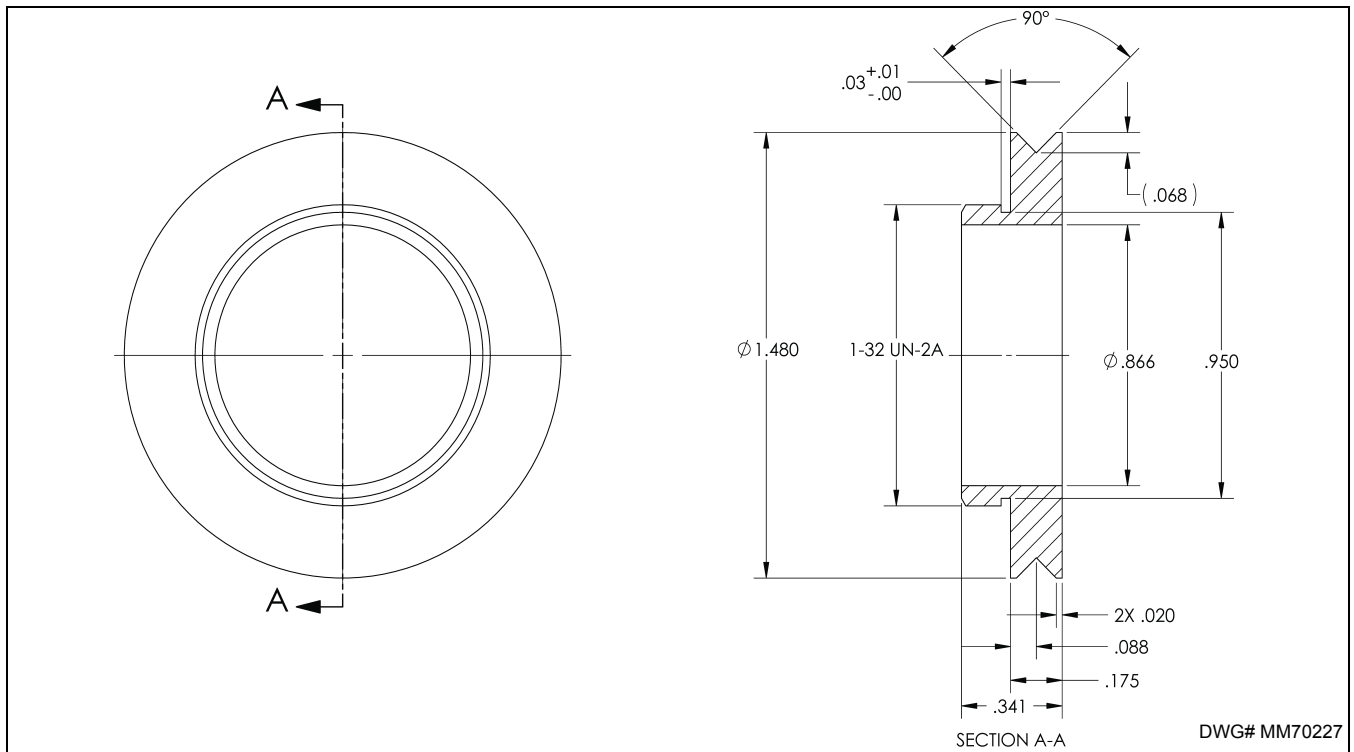


Figure 17. Stainless Steel Insert — Male C-mount

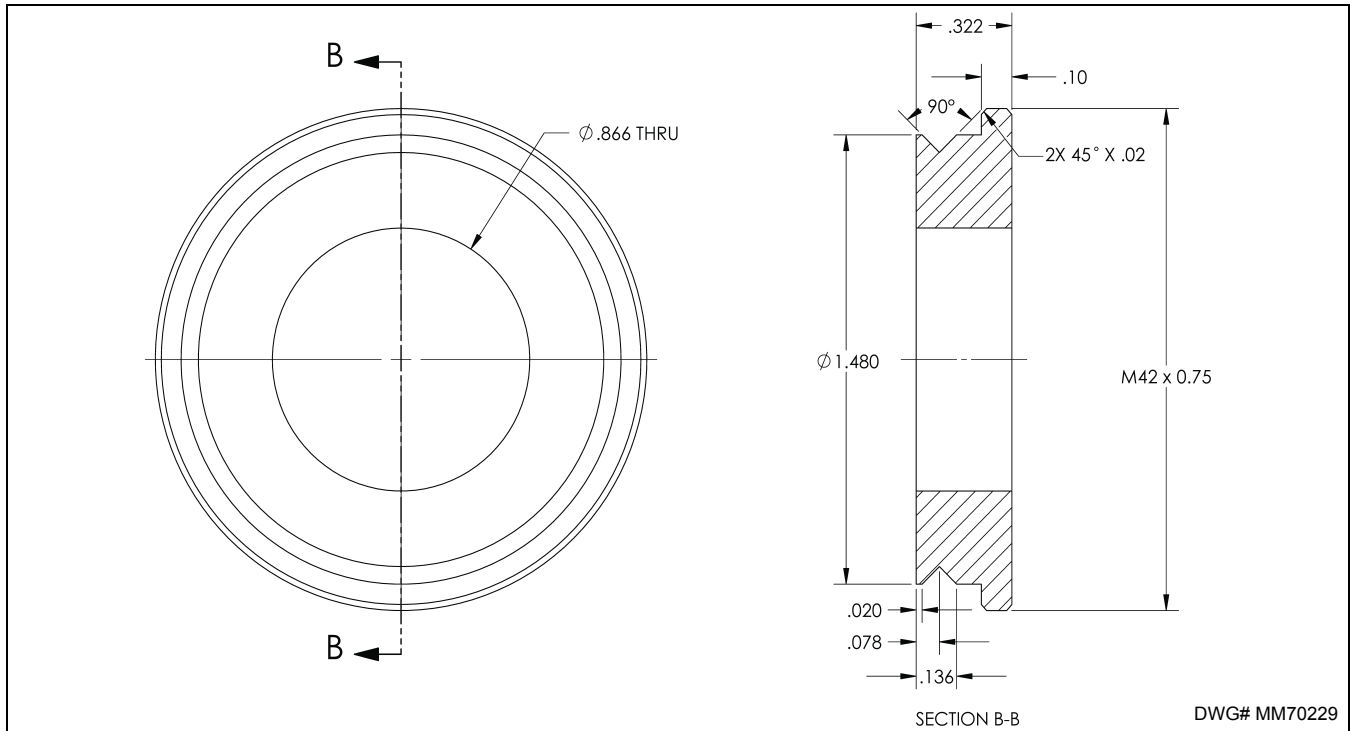


Figure 18. Stainless Steel Insert — Male T-mount

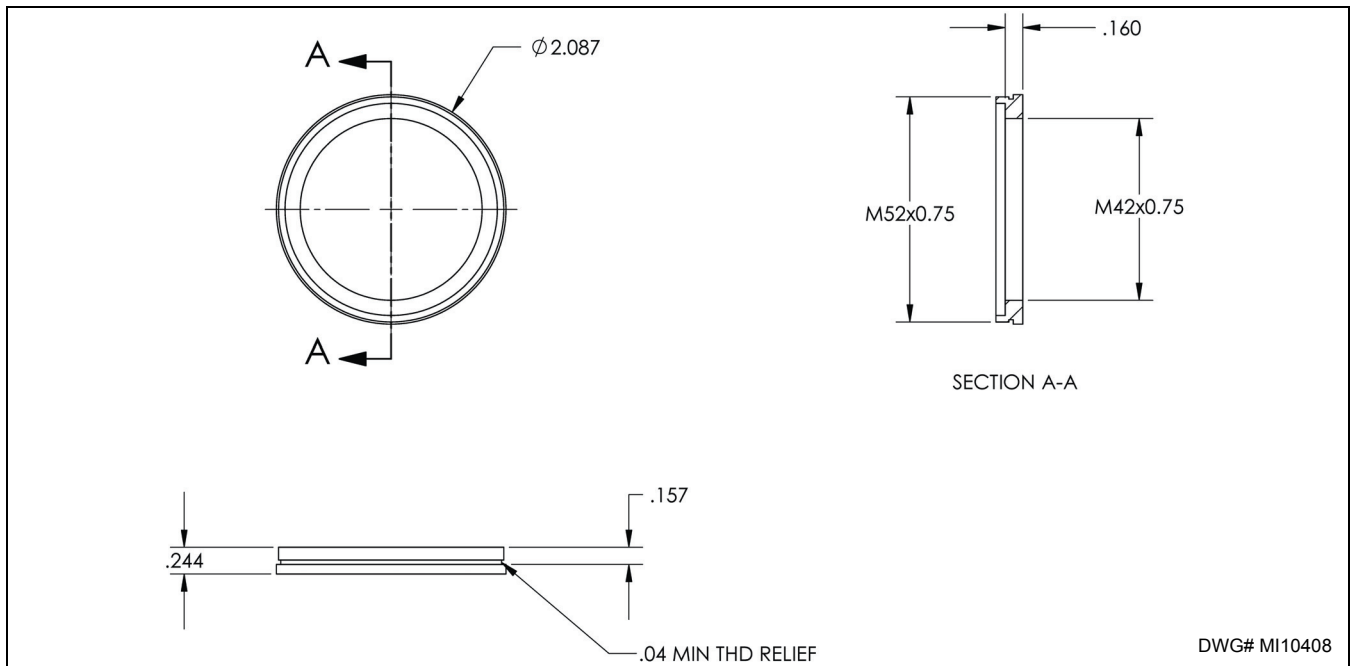


Figure 19. 52 mm Camera Lens Thread Adapter

Standard 22 mm Aperture Filter Mounting Block

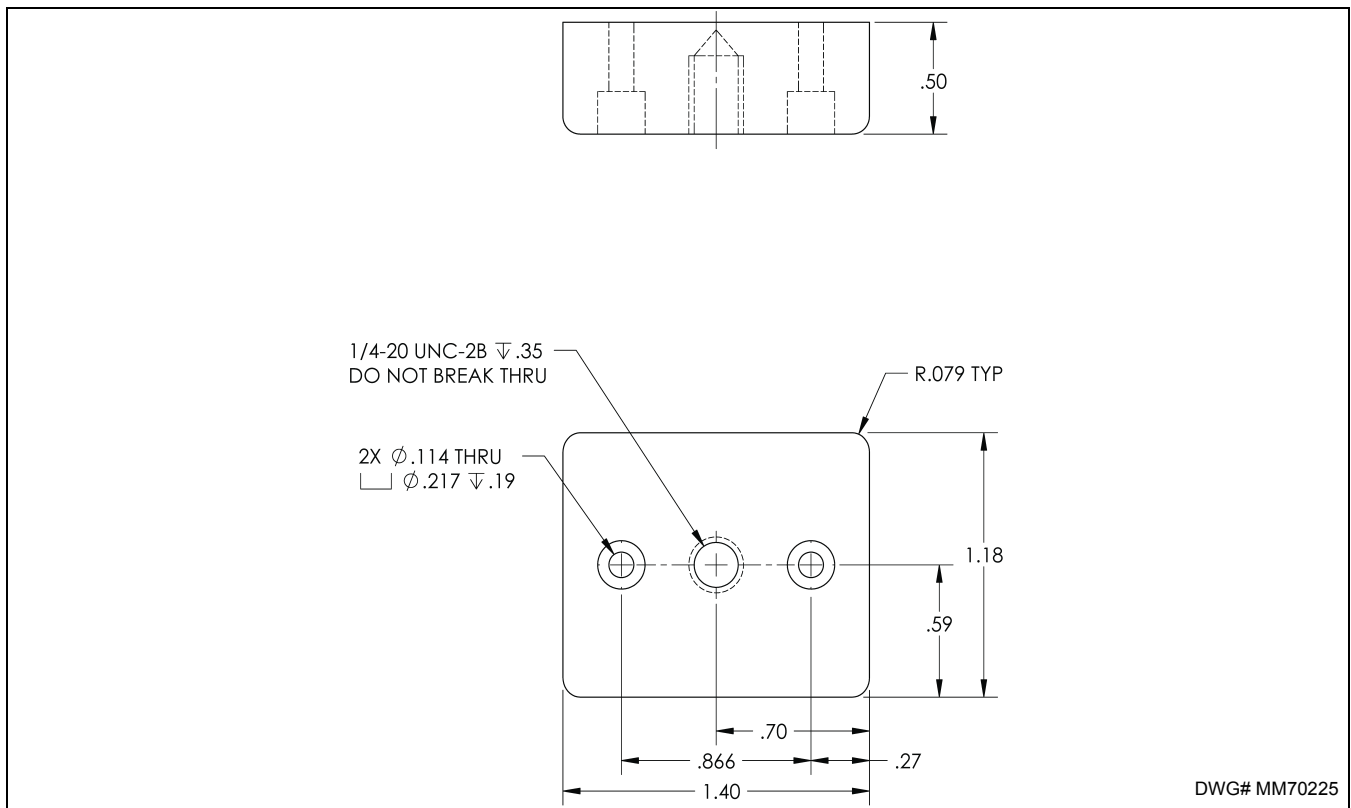


Figure 20. VariSpec Mounting Block for 20 mm Aperture Filters

VariSpec 22 mm Aperture Enclosure for the LNIR-20-20 Model

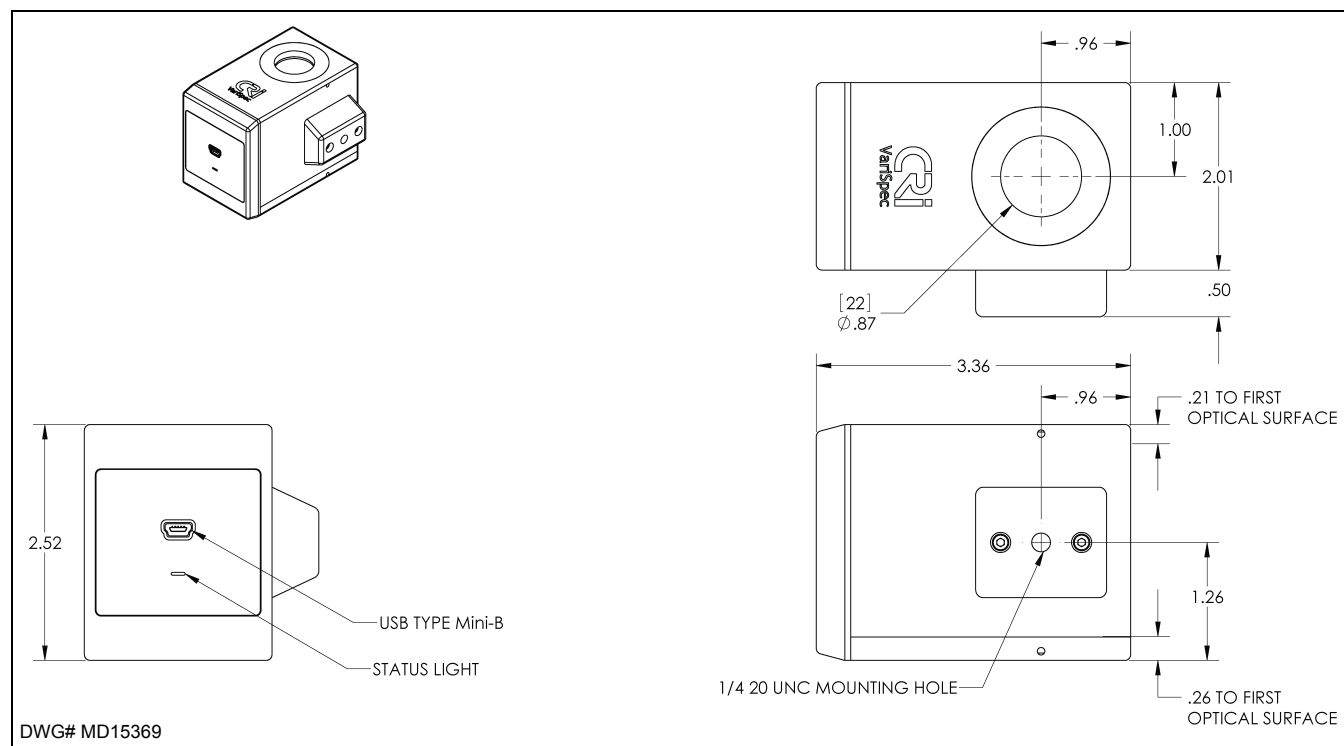


Figure 21. Exterior of the Unique LNIR-20-20 Enclosure

VariSpec 35 mm Aperture Enclosure

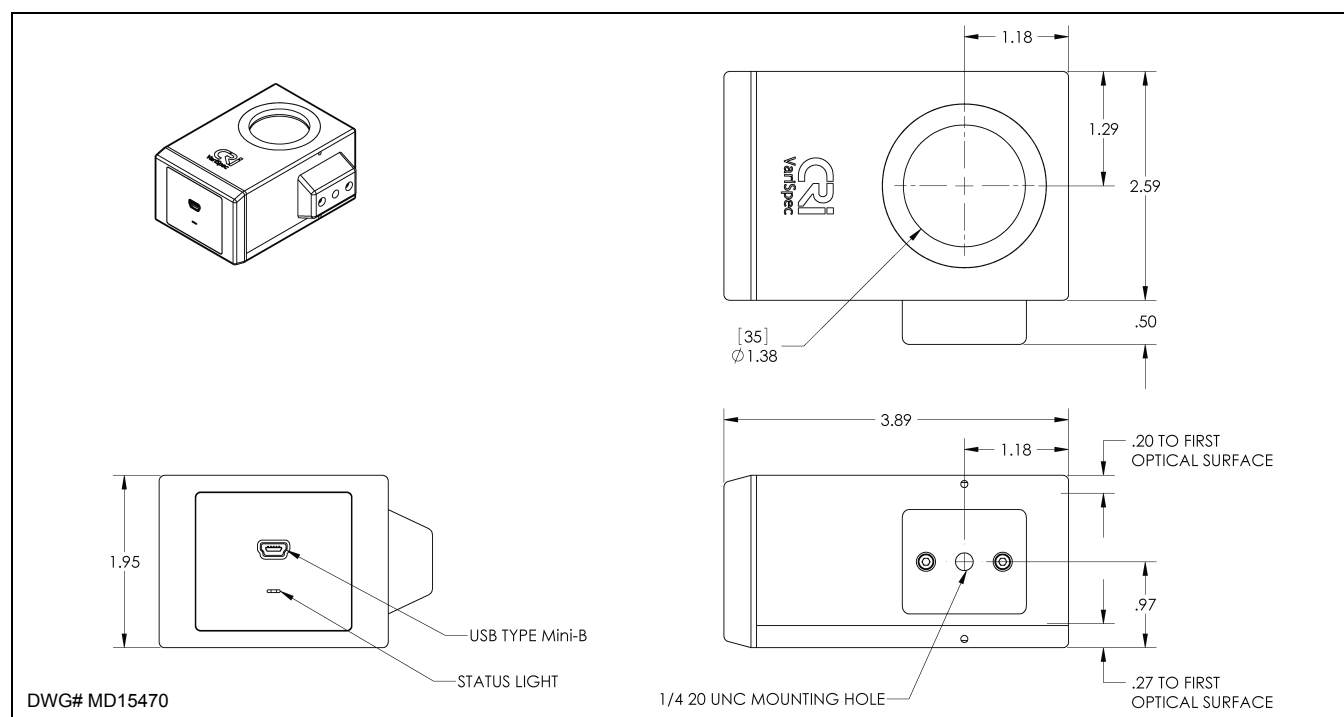


Figure 22. Exterior of a 35 mm Aperture Enclosure

Dovetail Spacer

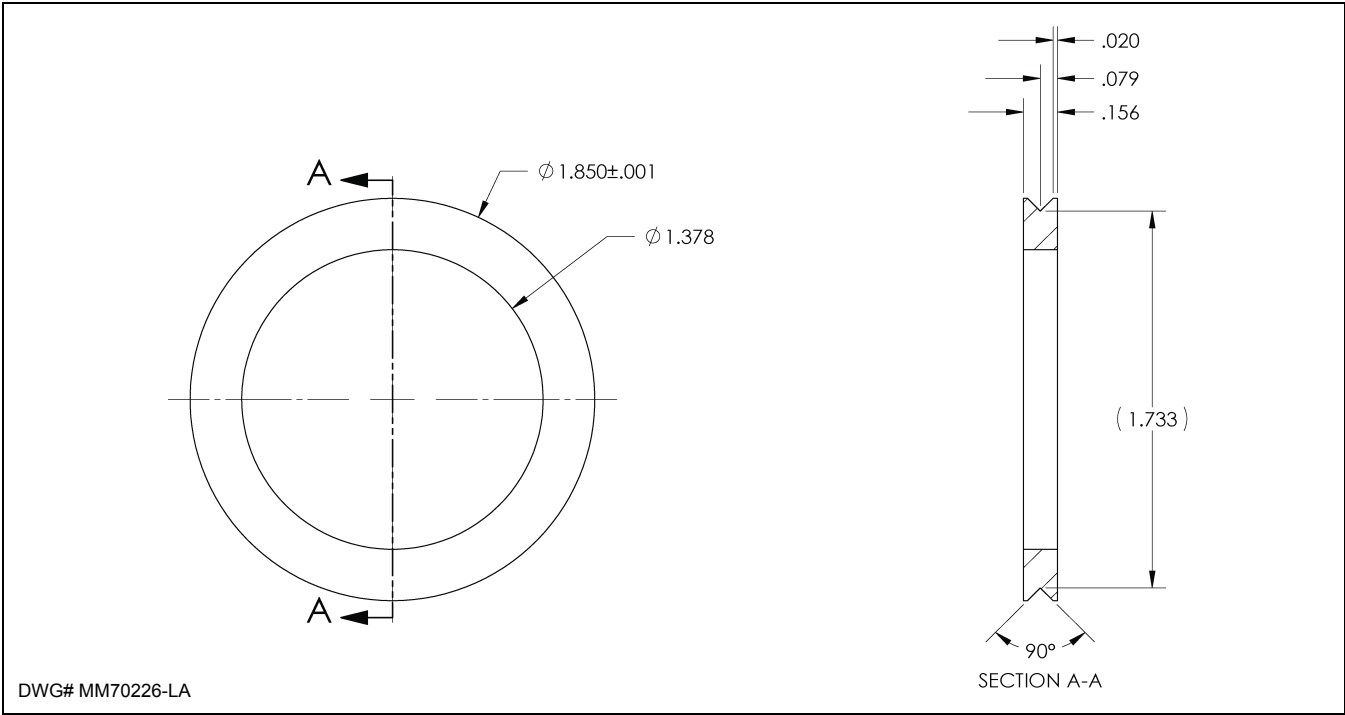


Figure 23. Dovetail Spacer, Large Aperture

Dovetail C-Mounts

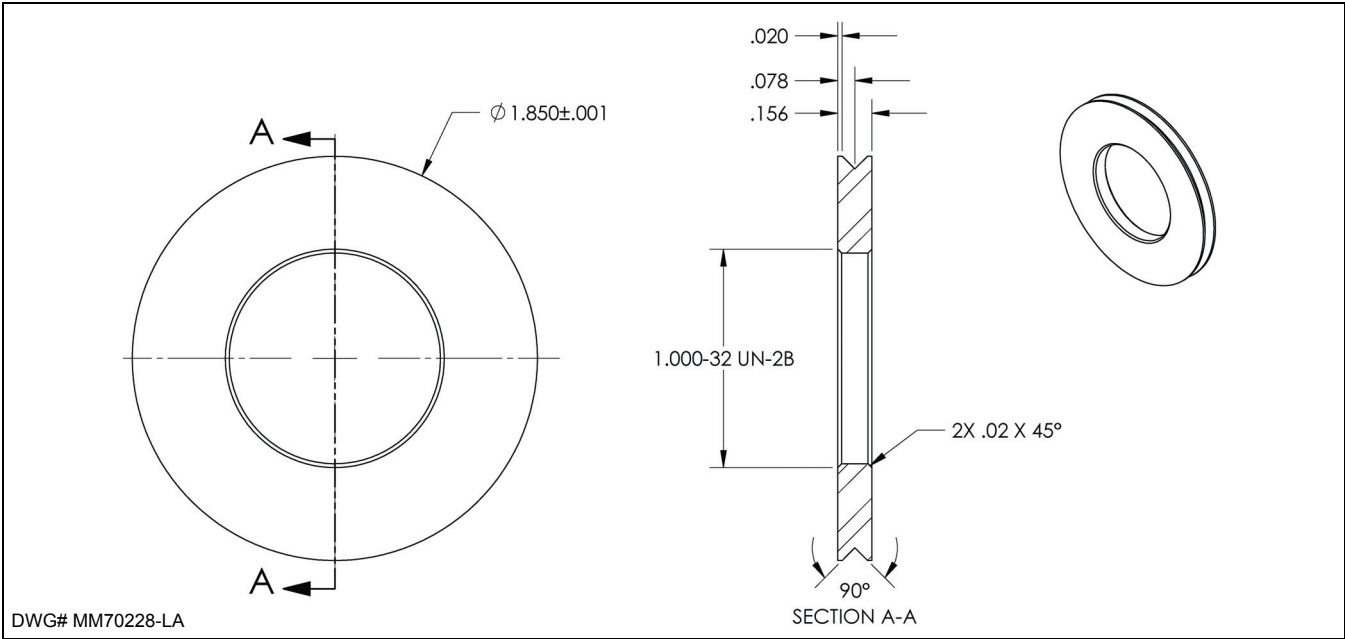


Figure 24. Dovetail, Female C-Mount, Large Aperture

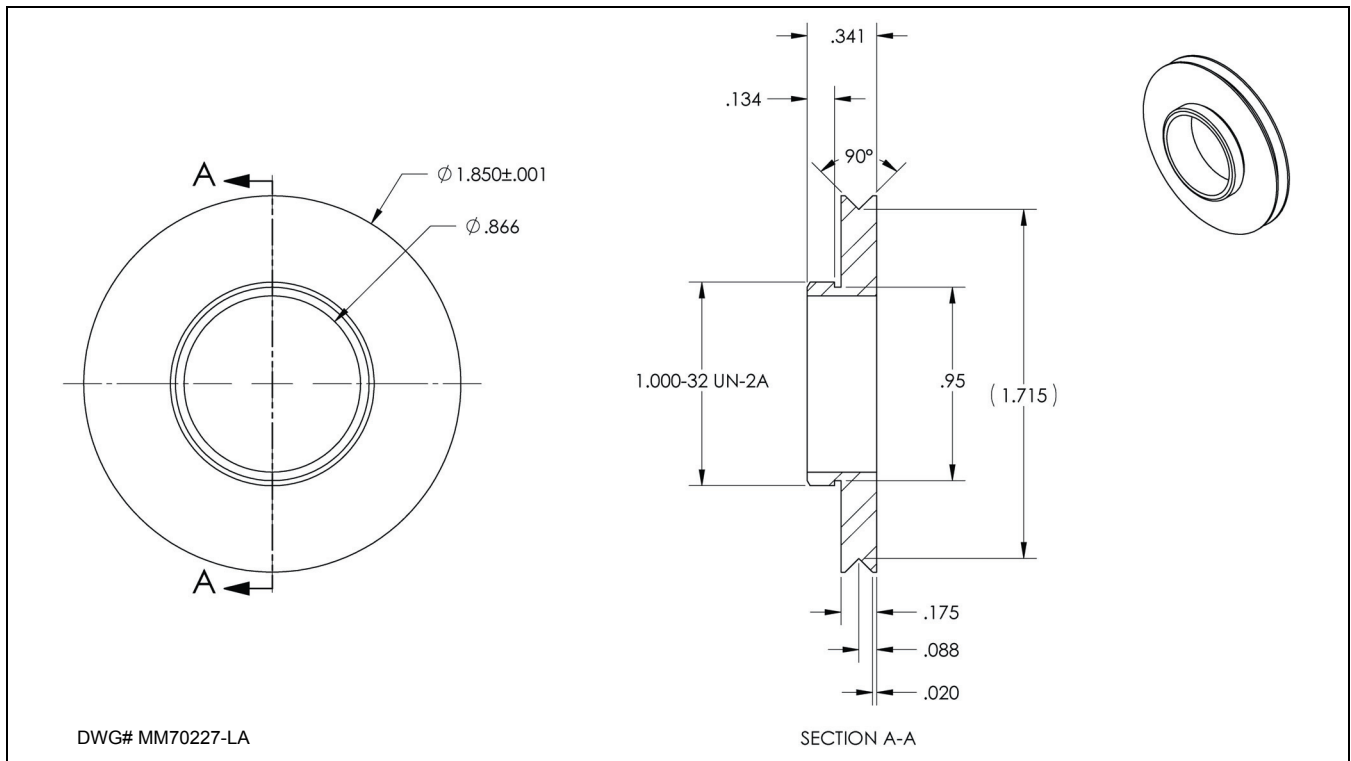


Figure 25. Dovetail, Male C-Mount, Large Aperture

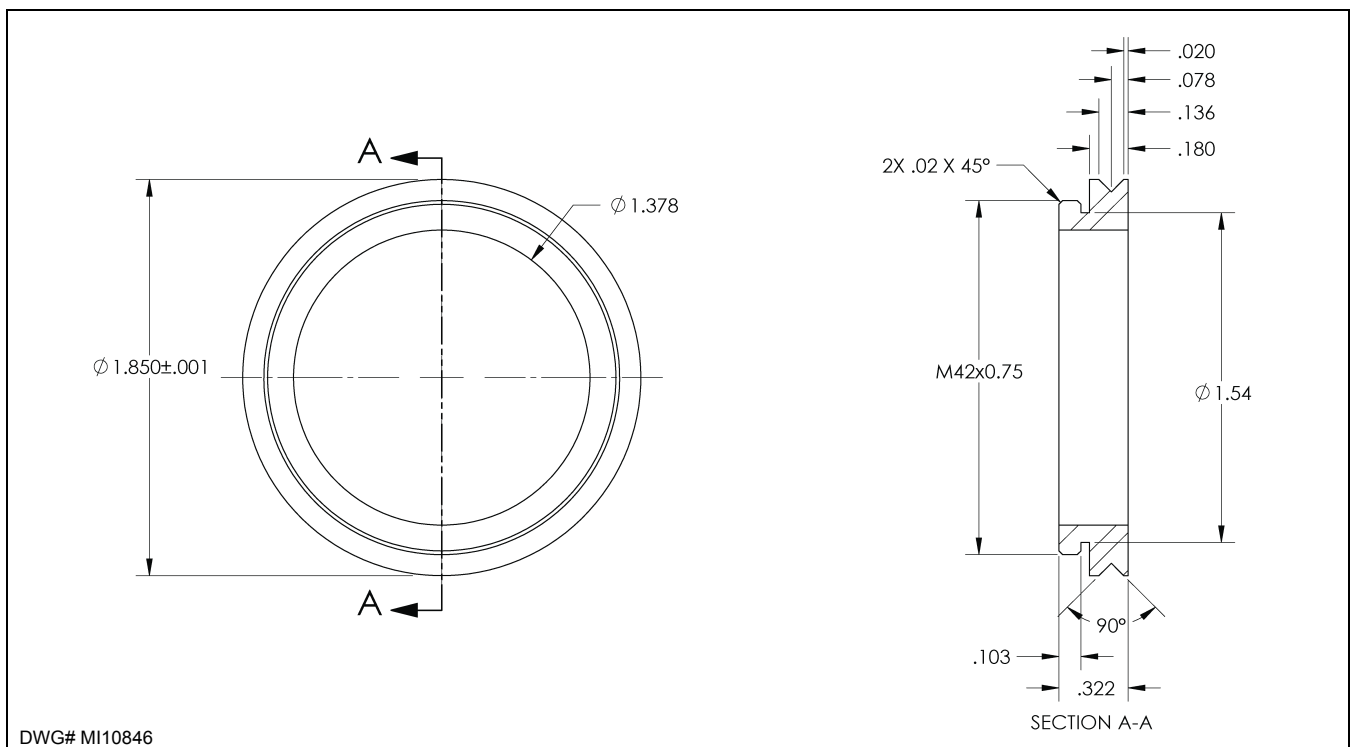


Figure 26. Dovetail, T-mount

Electronics Controller Module

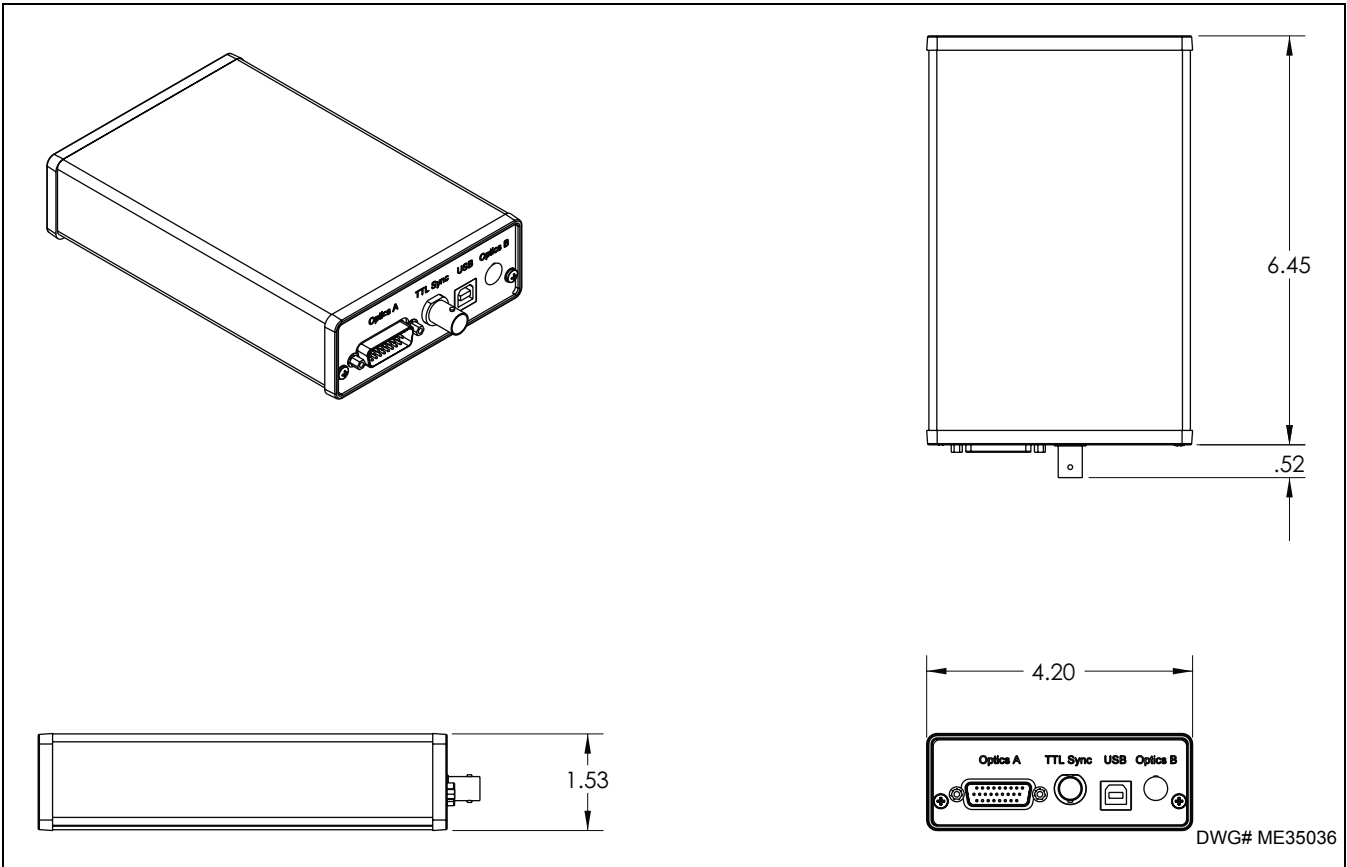


Figure 27. Electronics Controller Module (for the XNIR-09-20 model only)

Optics-to-Electronics Cable

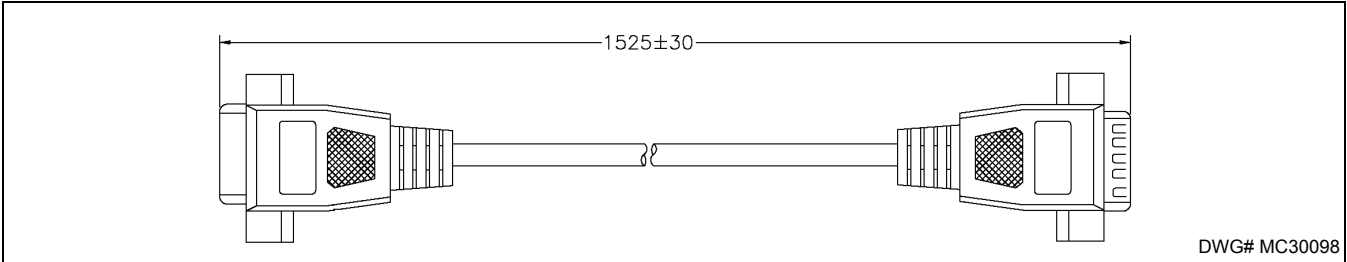


Figure 28. End Connectors of the 26-pin HD Cable with Specified Length (for the XNIR-09-20 model only)

Appendix B. Operating Considerations

This section supplies operating considerations with which you should be familiar to maximize the operation of your VariSpec filter.

Variation of FWHM with Pass Wavelength

The bandwidth of the VariSpec filter is defined as the full-width at half-maximum (FWHM) of the transmission curve. As with all Lyot filters, its bandwidth is constant in wavenumber as the filter is tuned. That means that the FWHM varies with wavelength as λ^2 . This property is intrinsic to all types of Lyot filters. Except for this inherent bandwidth variation, the bandwidth of the VariSpec filter is fixed and cannot be adjusted in the field.

Bandwidth Center Across Angle-of-Acceptance

For standard, single-housing models, the bandwidth uniformity is specified over a 7.5-degree (half-angle) viewing cone, to the normal of the optical surface, and within this cone the passband center does not deviate more than the specified amount. For dual-housing models, the bandwidth uniformity is specified over a 3.5-degree (half-angle) viewing cone. The shift is not the same as for interference filters, where there is a blueshift with increasing angle off-axis.

For the VariSpec filter, the deviation of the curve has a saddle shape. Maximum chromatic shift to the blue occurs for shifts in altitude, maximum chromatic shift to the red occurs for shifts in azimuth, while isochromatic contours are found along the lines at $\pm 45^\circ$ where altitude = $\pm$ azimuth.

Response Time versus Tuning Wavelength

There is no simple relationship between the response time to change from one wavelength to another wavelength. Because of the way the filter is tuned, some wavelengths request tuning of more LC elements than others, resulting in shorter or longer tuning speeds.

Thermal Drift and Re-Initialization

The VariSpec filter has a slight drift when the optics module temperature changes. This results in a slight wavelength error, in absolute terms. If the ambient temperature has changed by more than 3 °C, you can issue the “I 1” or retune the filter to force it to recalculate the drive levels.

Response Time versus Temperature

The liquid crystal variable retarders set the response time of the filter, and their viscosity varies with the temperature. At 35 °C, the viscosity is only half its 20 °C value, allowing faster operation in a warm environment. Elevated temperature use is the single easiest way to improve the response speed. Similarly, if the optics is cooler than 20 °C, the response time is longer than that given in the Specifications.

Fringing in Coherent Light

The optical module contains several dozen optical elements, cemented together with index-matching epoxies, and in many cases, coated with thin film coatings. As a result, there is spatial fringing when the light being sent through the filter has a coherence length greater than 75 microns. Generally, this is not a problem except when using laser sources, atomic (mercury) lamps, or inorganic fluorescence phosphors. In these cases, the light can be intrinsically monochromatic enough to produce fringes.

Tuning Latency

When the VariSpec tuning is synchronized with an external signal via the TTL/Sync port on the XNIR-09-20 model, there is a slight delay, or latency, before the electronics module actually issues the signals to tune the filter. This latency comes about because of the need to synchronize tuning operations with other processes being performed.

Latency delay does not materially affect the tuning speed. However, because the latency depends on the exact task the electronics is performing when a tuning request is made, the latency has some fluctuation or “jitter”. This jitter causes slight variations in the time to tune to the desired wavelength.

Near-Infrared Warning

Visible-wavelength and a near-infrared wavelength filters do not respond the same to infrared light. Infrared light causes heat. The great majority of energy in halogen lamps, for example, is in the infrared band (perhaps 90% or more of the total output). VariSpec VIS filters contain a dielectric hot-mirror that reflects this infrared energy away. So the VIS filter is not heated by the infrared light. However, SNIR, LNIR, and XNIR filters do not utilize a hot mirror and they receive all of this infrared energy and are heated by it.

There are two concerns when using an infrared light source: heat at the filter and heat at the sample. For example, the LNIR-06-20 filter has a 6 nm bandwidth (FWHM) and transmission of 30%. The total bandwidth for infrared light is 1200 nm. So the fraction of light that passes to the sample is:

transmitted energy function = $0.30 * 6 \text{ nm} / 1200 \text{ nm} = 0.0015$ or 0.15%.

That means the filter receives 6600 times more energy than the sample! This is one reason why the filter may get hot, even though the sample may not.

Given sufficient heat, delamination may occur. To cause delamination, two factors must be present: heat and stress. Mechanical stress may be produced by the thermal expansion of the LC cells and other components.

It seems remarkable, but heat can travel through an entire filter. We must distinguish between heat transmission and optical transmission. The filter acts to stop light passing through it, except for the desired wavelength. Energy is absorbed by the filter's optics. Heat can then easily travel through the filter by conduction. Note that the filter is enclosed in an aluminum housing, and aluminum is an excellent conductor of heat.

Using HyperTerminal™ for Manual Control

The filters can be controlled using the HyperTerminal program (written by Hilgraeve and distributed by Microsoft) that is included with many computers running Windows operating systems.

1. Connect the filter to the computer and wait for it to finish initializing.
2. Launch the **HyperTerminal** program (usually located in Start > Program Files > Accessories > Communications > HyperTerminal). If it is not present on your computer, you can install it from your original Windows installation CD-ROM using the Add/Remove Programs feature in the Windows Control Panel.
3. The **Connection Description** window (Figure 29) will appear. Enter a name and click **OK**.

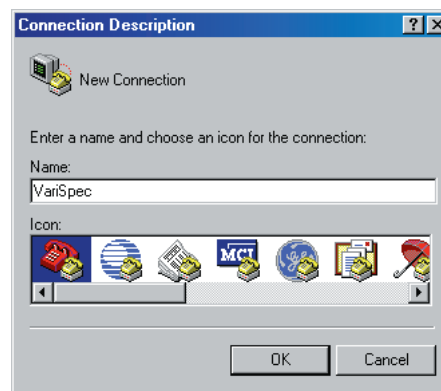


Figure 29. Connection Description

4. In the **Connect To** window (Figure 30), choose a COM port that corresponds to the virtual COM port assigned to the filter.

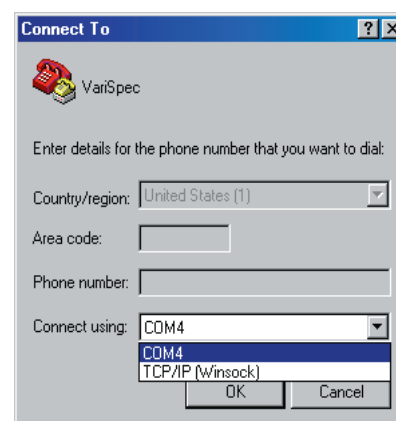


Figure 30. Connect To

5. In the **COMx Properties** window (Figure 31), select the following settings:
Bits per second: 115,200 (9600 for the XNIR-09-20),
Data bits: 8,
Parity: None,
Stop bits: 1,
Flow control: None.

Click the **OK** button.

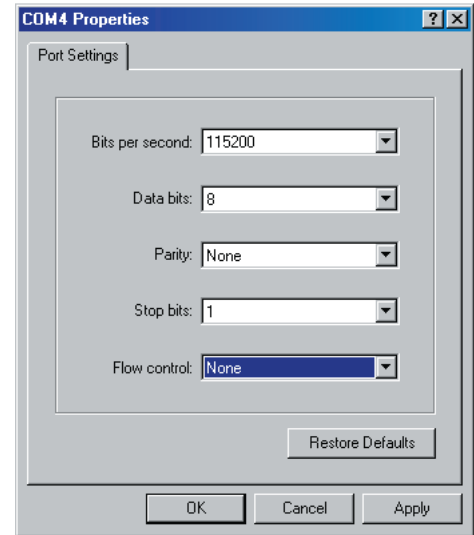


Figure 31. COMx Properties

6. Select the **Properties** item from the **File** menu drop-down list. Click on the **Settings** tab then the **ASCII Setup...** button
7. In the **ASCII Setup** window (Figure 32), select the following settings:
“Append line feeds to incoming line ends” and
“Wrap lines that exceed terminal width”
8. Click the **OK** button to close the **ASCII Setup...** window. Click the **OK** button to close the **Properties** window. These settings make it easier to see the commands and responses in the **HyperTerminal** window.
9. You may now type characters that will be sent to the VariSpec filter each time the Enter or Return key is pressed.
10. If you have a dual-mode filter, repeat steps 2 thru 6 for the second module. In order to tune a dual-mode filter, “W” commands should be sent to each module. The commands do not have to be sent simultaneously.

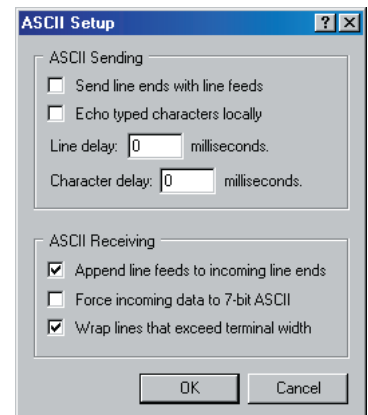


Figure 32. ASCII Setup

Appendix C. Legacy Hardware and Software Considerations

Optics and Electronics Controller Modules

Previous-generation VariSpec filters utilize an RS-232 serial interface. The rear panel of the VariSpec electronics module features an RJ-12 connector and 18VAC 50/60 Hz AC jack. Each filter requires an appropriate power transformer for the country it is to be used in. The US and Japan transformer is an 18V, 880 mA model.

An RJ-12 straight-through modular data cable is plugged into the RS-232 connector. The other end is plugged into an RJ-12 to DB-9 adapter for the host computer's serial (COM) port. COM port settings for legacy filters are identical to the COM port settings for current USB filters: Bits per second: 9600, Data bits: 8, Parity: None, Stop bits: 1, Flow control: None.

The form-factor of the optics modules for legacy filters may differ from the mechanical drawings included in this publication.

Previous-generation filters utilized a much slower microprocessor for wavelength tuning calculations. The use of palette functions is encouraged as a way to tune as fast as possible, given a set of wavelengths of interest. Random tuning using the 'W' command can result in transition times in the hundreds of milliseconds. Accessing a stored wavelength using the palette commands results in much faster transition times from 50 ms to 150 ms. Current filters with USB electronics always tune as fast as they are capable (at a given ambient temperature). See the Specifications section.

Handheld Controller

A handheld controller that interfaces with the previous-generation filters using the RS-232 connector is available. Current filters that use the USB interface do not need this accessory, since they can be installed and tested more easily using more recent software releases and host computers with available USB ports.

Legacy Software

Software available from CRi prior to the release of filters with USB control consisted of the following:

- CRiS3: an obsolete standalone program compiled using the LabVIEW programming environment. Older LabVIEW sub-VIs were also available and are no longer supported. Current, updated sub-VIs are available from CRi for those who wish to use LabVIEW.

- VSGui Software Developer's Kit and demonstration executable (revisions prior to 1.2): an obsolete standalone program that will allow a programmer to use a CRi-written Windows dynamically-linked library (DLL) to control the filter from the CRi-written demonstration program or a user-written program. Current versions will work with both present USB and most legacy RS-232 serial hardware.

Contact CRi if you have legacy hardware and/or software and wish to upgrade or purchase new software or hardware.

Appendix D. CRi Software End-User License Agreement

The following is an agreement (the “Agreement”) between you and Cambridge Research & Instrumentation Inc., 35-B Cabot Road, Woburn, MA 01801 (“CRi”) for software known as the VariSpec Software Developer’s Kit (SDK) and its accompanying documentation (collectively, the “Software”). By installing and/or using the Software, you agree to the following terms and conditions. If you do not agree to all of the terms and conditions in this Agreement, you may not install or use the Software.

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10. Miscellaneous. This Agreement contains the entire agreement of the parties with respect to the subject matter hereof and supersedes any proposal or prior agreement, written or oral, and any other communications between the parties relating to the subject matter hereof. No modification or waiver of any provision of this Agreement shall be effective unless in writing and signed by the parties. No delay or failure on the part of any party in exercising any right under this Agreement shall impair any such right or any remedy of such party, nor shall it be construed to be a waiver of any continuing breach or default under this Agreement. In the event any provision of this Agreement is held to be unenforceable, the remaining provisions of this Agreement will remain in full force and effect. This Agreement shall be governed by the laws of the State of New York without regard to principles of conflicts of laws. Any disputes relating hereto shall be adjudicated

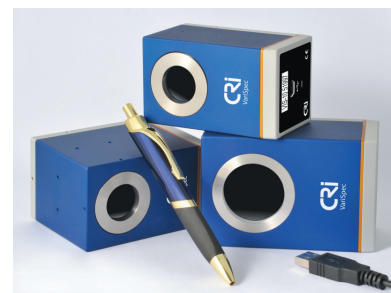
only in the state or federal courts in New York County, New York State, and you hereby consent to the exclusive jurisdiction of those courts. This Agreement shall not be governed by the United Nations Convention on Contracts for the International Sale of Goods, the application of which is expressly excluded. You may not assign or otherwise transfer this Agreement or any of your rights or obligations therein without the prior written consent of CRi. You may not use the Software for any unlawful purpose nor export or re-export the Software except as authorized by law.

Should you have any question concerning this Agreement, you may contact CRi by writing to CRi, 35-B Cabot Road, Woburn, MA 01801. You may also call 1-800-383-7924 in the US or +1-781-935-9099 elsewhere.

! CRI supplies a Windows-compatible SDK installation CD-ROM with each VariSpec filter. Included hardware drivers are specific to the Windows operating system. However, you may contact CRI if you are interested in drivers for other operating systems.

! These Quick Start instructions apply to standard single-housing filter designs. Dual-housing designs have to VariSpec modules. The demonstration software does not support dual module filters. But the existing drivers or LabVIEW sub-VIs can be used to write programs fully capable of controlling these dual models. You can also use HyperTerminal or similar terminal emulators to send the appropriate serial (ASCII character-based) commands to each VariSpec module.

! Your host computer needs to be running Windows XP or Windows 7. Log in as an Administrator to install the software. You must have a USB port available and the port must be able to provide the standard USB power load. If you have multiple USB devices connected to the same port through an unpowered USB hub, you may need to utilize a powered hub.



Installing VariSpec Software

1. Unpack the VariSpec filter. Make sure that all components are present. Be careful with the glass surfaces of the optics module, since they have anti-reflective (AR) coatings that might be scratched if not handled carefully.
2. DO NOT attach the VariSpec filter to your host computer until after you have installed the appropriate USB drivers. Turn on the computer and allow it to boot into the Windows operating system.
3. Insert the CD-ROM containing the VariSpec demonstration and SDK software into the computer's CD-ROM drive. Or if you downloaded the installer, open the zip file.
4. Locate the Microsoft installer file, most likely named something similar to "VsRev1p37.msi" or "VsRev1p35.exe." Double-click the executable to launch the Installation Wizard.
5. Choose the "Full" installation type. Continue with the Wizard until you can click on the **Finish** button to complete the installation.



Connecting the VariSpec Filter (except XNIR-09-20 models)

Reference the VariSpec User's Manual if you are setting up an XNIR-09-20 model VariSpec.

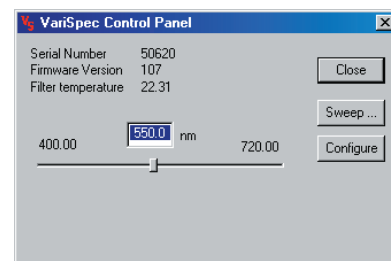
1. Connect the VariSpec filter to the computer using the included USB Type-A to Mini-B cable.
2. The blinking LED indicates that the filter is initializing and exercising the liquid crystal (LC) elements in the optics module and bringing the filter to a known state. For example, 550 nm in the case of a visible-wavelength (VIS) model.
3. If this is a first time installation, the computer should launch a *Found New Hardware Wizard*. Click the **Next** button to proceed. (If the wizard did not start automatically, launch the *New Hardware Wizard* from the Windows Control Panel.)
4. Choose to "Search for a suitable driver for my device" and click the **Next** button. A **Files Needed** window may appear. Windows may ask if it can install the software automatically or from a list or special location. Choose "automatically or the CDROM/ installation folder" as the search location. Windows should find a file on the CD-ROM named "ftdibus.inf." Click **Next**. Windows should then find a file named "ftdiport.inf." Click **Next** and then click **Finish**. If Windows cannot find the files, go back and manually locate the files.
5. After the *Add New Hardware Wizard* has finished, you will see a new program group icon appear: **Start > Programs > CRI**. This program group includes the demonstration software "VsGui.exe" and a PDF copy of the User's Manual.



VsGui Program for Windows XP and Windows 7

The VsGui demonstration program on the host can be used to verify correct filter operation and demonstrate the filter's capabilities.

1. When launched (select **Start > Programs > CRI > VsGui.exe**), the **VariSpec Control Panel** will appear (see figure).



2. You may initially receive an error message saying that software cannot connect to a COM port (Error Code 104). If this occurs, click **OK**. Then click the **Configure** button to open the **VariSpec Configuration** window (see figure).
3. Click the **Auto-detect** button to search for the correct virtual COM port. If not found, you can manually select it; choose COM3, COM4, or COM5.
4. Click the **Close** button when finished to return to the **VariSpec Control Panel**.
5. The **VariSpec Control Panel** lets you select a wavelength by manually entering a wavelength in nm or by dragging the slider along a linear scale representing your filter's wavelength range. Your filter's **Serial Number** and **Firmware Version** are displayed and cannot be edited.
6. Click the **Sweep** button to open the **Sweep** window (see figure). This window lets you set a **Wavelength Range** and **Step Size** (in nanometers) for the filter to cycle through. You can also set the amount of time you want the filter to remain at each wavelength and whether or not you want the filter to cycle once or repeat indefinitely.
7. The VsGui program does not interface with commercial image-capture hardware, but the underlying DLL can be used, along with the SDK, to create your own application. If you want to write software to control the VariSpec filter using CRI's DLL driver, refer to the publication "*Programmer's Guide to VsDrv*". The most recent revision of this installer program can be downloaded from CRI's web site at <http://www.crii-inc.com>.

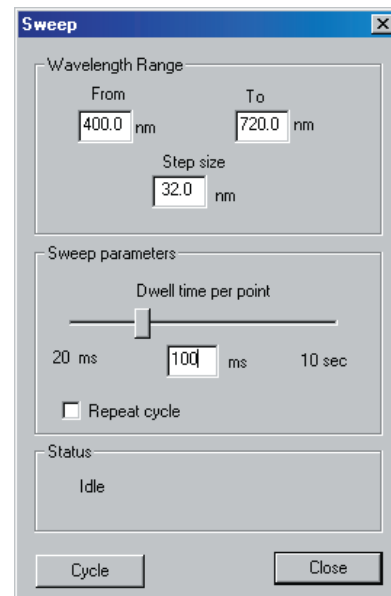
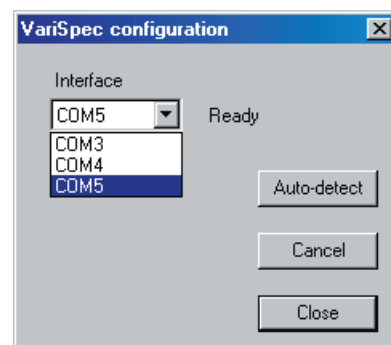
Congratulations! You may now use the demonstration software to tune the VariSpec filter. The software makes a great troubleshooting tool if you are writing your own software, or if you simply wish to manually tune the filter.

Operational Notes:

- Unplugging the VariSpec filter from the physical USB connection will not harm it under normal circumstances. But plugging it back into the USB port will require another initialization cycle (about 30 seconds) in order for the filter to begin accepting and processing commands. While the filter is initializing, a communications buffer will store commands sent to it, for immediate processing once initialization has completed.
- The VariSpec filter has a transition time of approximately 50 ms for VIS models and 150 ms for near-infrared (SNIR, LNIR, or XNIR) models. Selecting a faster interval between selected wavelengths will result in the filter being placed into unknown and uncharacterized transitional states. Transition time is affected by the ambient temperature: higher temperatures allow the LC to become less viscous and faster. Nevertheless, always stay within the recommended operating temperature and maximum input flux (500 mW/cm² to prevent damage to the LC).
- Longer or extended 26-pin cables may allow the VariSpec filter to function correctly, but if the drive impulses utilized by the electronics controller box are too weak, you will see an error condition of "Drive levels out of range."

Older-model serial (RS-232) interface filters:

- You may utilize the software and SDK, as long as you remember that you must manually select the COM port in the **VariSpec Configuration** window in the VsGui.exe program.



Technical Assistance:

Having difficulty setting up, operating, or maintaining your VariSpec LCTF? Contact your local CRI representative.

CRI's main US office hours are from 8:00 a.m. to 6:00 p.m. (Eastern Standard/Daylight Time), Monday through Friday.

- Telephone (US Toll-Free): 1-800-383-7924
- Telephone (Worldwide): +1-781-935-9099
- Facsimile (Worldwide): +1-781-935-3388
- E-mail: techsupport@cri-inc.com

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