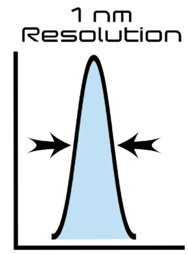
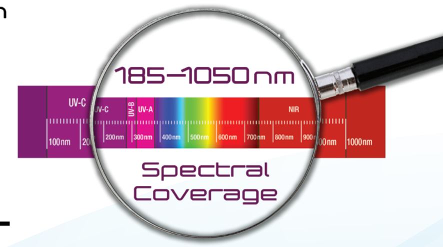
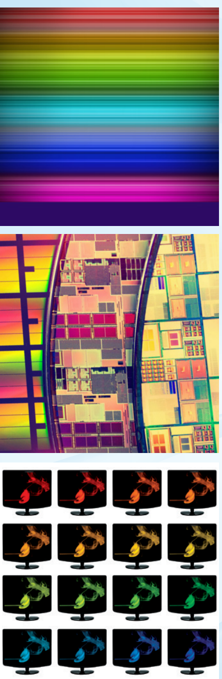
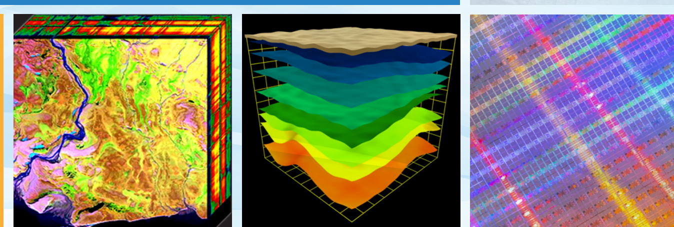
HORIBA





PoliSpectra® 135 Multichannel Spectrometer and Hyperspectral Line Imager





For OEM Industrial Applications

horiba.com/oem

PoliSpectra® 135 Spectrometers

Overview

HORIBA has developed a high-performance rugged spectroscopy platform that is factory-configurable for use in a multichannel or hyperspectral imaging system. This system can be configured with our Sylent® 2D sCMOS camera, low-cost cameras, or even customer-supplied sensors.

In hyperspectral imaging applications, this system can be used as a line-scanning instrument (push-broom) that collects full spectral data simultaneously across the input slit height.

Variations

- Multichannel (M135) vs. lens-based or bare slit (H135)
- Two gratings to choose from: UV-NIR or VIS-NIR
- Default sensors are the Sylent sCMOS cameras (cooled to -25° C or uncooled), or any customer preferred sensor.

Applications

- Optical Emission Spectroscopy (OES)
- Fluorescence
- Hyperspectral Line Imaging
- Semiconductor Inspection and Metrology
- Semiconductor Process Monitoring
- Aerial Reconnaissance

Features

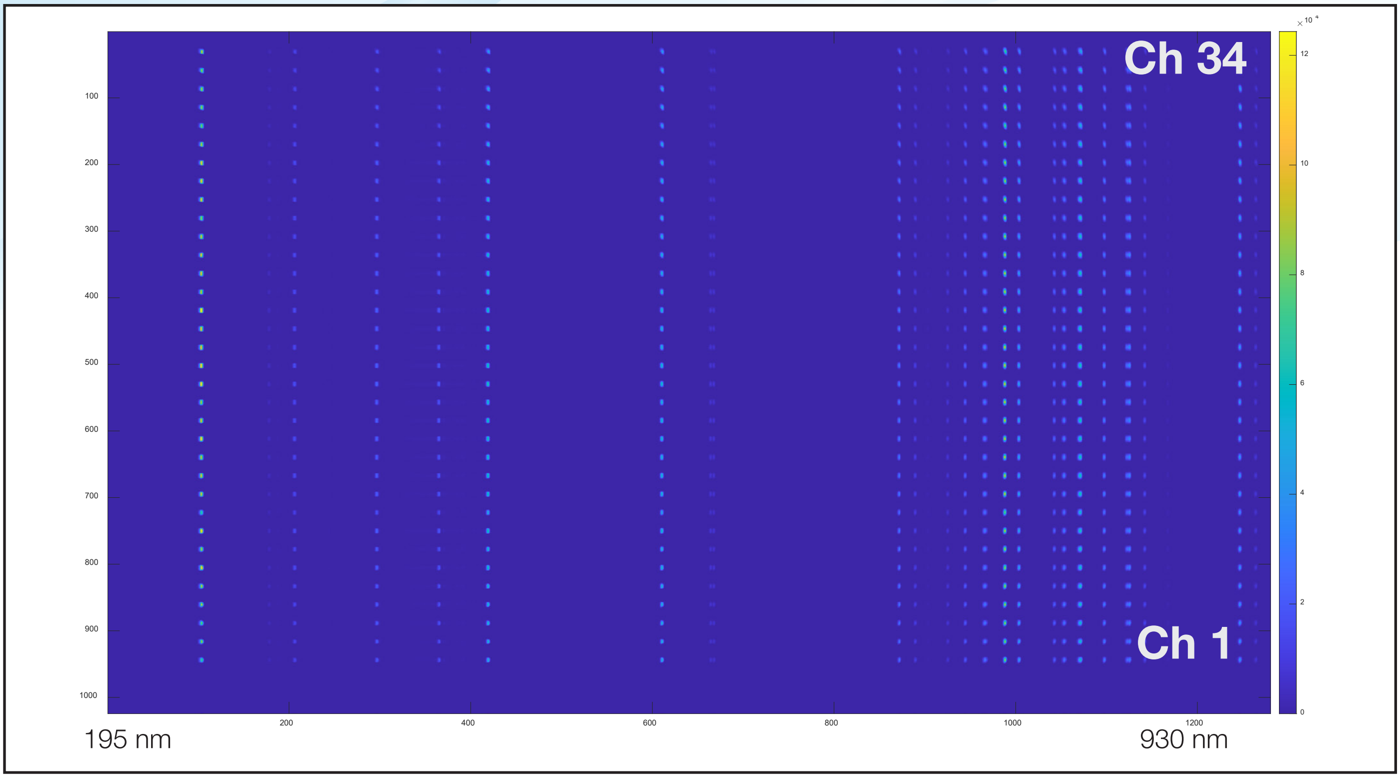
Up to 96 fiber channels with simultaneous readout (factory configurable)

Ultraviolet hyperspectral line imaging (180-1050 nm)

High throughput combined with low stray light

2D scientific CMOS with high quantum efficiency and low noise

Simultaneous Multispectra



34 fibers acquired simultaneous spectra across the UV-VIS-NIR range.

General Spectrometer Specifications

PoliSpectra 135	VIS-NIR Grating	UV-NIR Grating
Grating Efficiency Range (nm)	300-1050	185-900
Configurable Range	Sensor dependent; see spectral range table	
F/#	F/2.3	
Focal Length (nm)	135.0	
Spectral Resolution (20 µm slit) (nm)[1]	1.0	2.0
Grating Dispersion (nm/mm)	34.7	58.2
Grating Blaze (nm)	575	280
Grating Groove Density (lines/mm)	401	239
Weight (no camera) (lbs.)	4.7	
Weight (with uncooled camera) (lbs.)	6.0	
Weight (with cooled camera) (lbs.)	10.4	
Max Keystone (µm)	<15	
Spectral Tilt (µm)[2]	<15	
Crosstalk (%)[3]	<1.5	<1.7
Stray Light (%)[4]	<0.2	<0.3
Multichannel Fiber Configuration		
Multichannel Fibers	up to 96	
Wavelength Accuracy (nm)	<0.1	
Smile (µm)[5]	NA	
Line Imaging Configuration		
Lens Option	c-mount	
Max Spatial Image Height (mm)	20.0	
Magnification	1:1	
Wavelength Accuracy (nm)	<0.4	
Spatial Resolution (µm)	6.0	9.0
Smile (µm) (line imaging)	<15	

[1] Max spectral line width (FWHM) for all peaks in the image.
[2] Versus a sensor row.
[3] The Crosstalk % can be further reduced with more dead space between channels.
Measured on one channel (off), with all other channels illuminated. See Cross Talk Calculation figure on pages following.
[4] Stray light measured using a BP filter: Baseline light level (outside the band) divided by the BP peak (unsaturated).
[5] Smile is eliminated by using channel calibration coefficients.

Spectral Resolution vs. Slit Size

Best Spectral Resolution (nm)*					
Slit Width (µm)	22	35	45	100	200
UV-NIR Grating (280 nm blaze)	2.0	2.7	5.3	6.5	12.3
VIS-NIR Grating (575 nm blaze)	1.0	1.5	1.9	3.8	7.2

* Ignoring pixel limitations, which are sensor-dependent. Specification is the maximum width (FWHM) of all spectral lines on all channels (or rows) on the image. Any size slit is orderable (for OEM quantities).

Spectral Range vs. Grating and Sensor Choice

	VIS-NIR				UV-NIR			
Sensor	Digital Resolution (nm/px)*	Range (nm)	Low Example (nm)	High Example (nm)	Digital Resolution (nm/px)*	Range (nm)	Low Example (nm)	High Example (nm)
1.3 MP-XX-9.76-BI	0.3	434	300-734	616-1050	0.6	727	200-927	323-1050
4.2 MP-XX-6.5-BI	0.2	462	300-762	588-1050	0.4	775	200-975	275-1050
4.2 MP-XX-11-BI	0.4	782	300-1050		0.6	1311	200-1050	
IMX174	0.2	394	400-794		0.3	660	TBD	

* Average digital resolution AKA digital dispersion

Sensor Options

						Read Noise (median)							
Name	Sensor Type	Effective Pixels	Pixel Size (µm)	Active Pixels	Active Photosensitive Area (mm)	STD (e-)	CMS (e-)	ADC (bits)	Shutter	Full Well	Dynamic/ Range (dB)	QE	Cooling
1.3 MP-XX-9.76-BI	Back-illuminated sCMOS	1.3 MP	9.76 x 9.76	1024 x 1280	9.994 x 12.493	1.6	0.9	12, 16 (HDR-mode), 32 [1]	Rolling	48 ke-	90.0	Up to 90%	Uncooled or -25° C
4.2 MP-XX-6.5-BI	Back-illuminated sCMOS	4.2 MP	6.5 x 6.5	2048 x 2048	13.312 x 13.312	1.6	1.2	12, 16 (HDR-mode), 32 [2]	Rolling	53 ke-	89.5	Up to 95%	Uncooled or -20° C
4.2 MP-XX-11-BI	Back-illuminated sCMOS	4.2 MP	11 x 11	2048 x 2048	22.528 x 22.528	1.6	N/A	12, 16 (HDR-mode), 32 [2]	Rolling	80 ke-	93.9	Up to 95%	Uncooled or -20° C
IMX174	CMOS	2.3 MP	5.86 x 5.86	1216 x 1936	7.126 x 11.345	7.4		10, 12	Global	30 ke-	71.7	Up to 78%	Uncooled

[1] In binned spectra mode.
[2] In binned spectra mode (roadmap).

Other sensor options:
EMCCD
CCD (eshutter)
Customer sensors (factory installed only)

Input Options

			Speed (FPS)				
Input Examples Other configurations available upon request	Fiber Type	Throughput	1.3 MP-XX-9.76-BI[1]	4.2 MP-XX-6.5-BI[1]	4.2 MP-XX-11-BI[1]	Sony IMX174[2]	Notes
Single Channel	Round-to-Line	Extreme	20	36	23	664	
4-Channels	200 µm	Good	198	155	164	322	
4-Channel High Throughput (OES Multitrack)	Bundle	Very Good	64	58	62	165	
8-Channels	200 µm	Good	107	132	`141	284	
18-Channels	100 µm	Low	41	96	106	212	
34-Channels	70 µm	Low	23	53	58	N/A	
34-Channels	100 µm	Low	24	57	62	N/A	
Imaging Fiber	4 µm x 100 k fibers	Medium	134	332	358	586	VIS Only (365 nm +)
Full Chip Hyperspectral Line Imaging (Lens or Bare Slit)	N/A	Depends on # of rows binned	20	36	23	164	Slit to camera imaging is 1:1

[1] HDR mode
[2] 12-bit mode

PoliSpectra 135 Naming Guide

UV-NIR Spectral range:
200-900 nm

VIS-NIR Spectral range:
300-700, 400-800 nm

A Axial input
L Lateral input

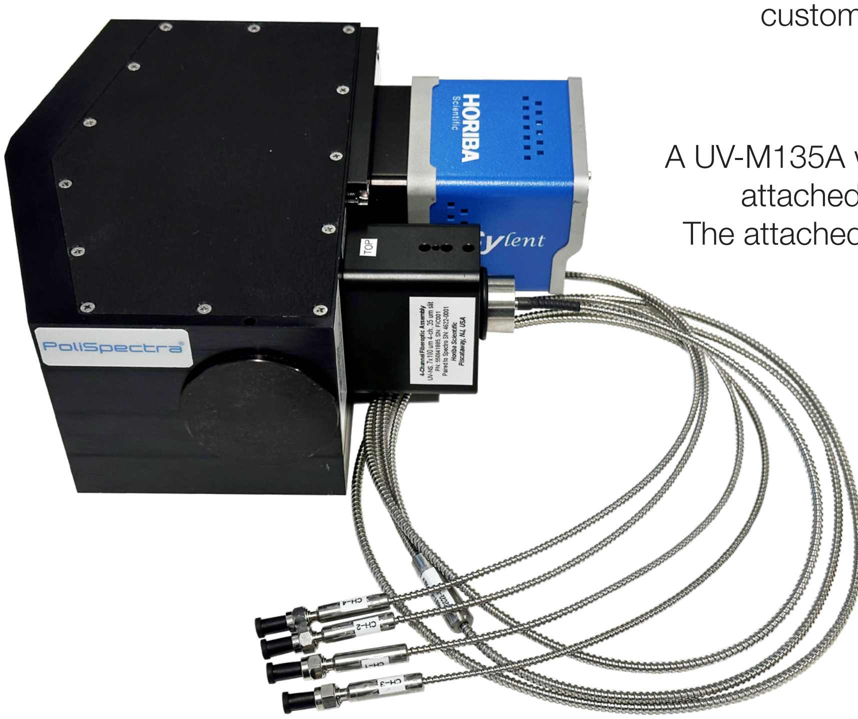
UV-M135A

M
Multichannel Input
(Up to 96 simultaneous fiber channels)

H
Hyperspectral Input
(c-mount, lens, or free-space)

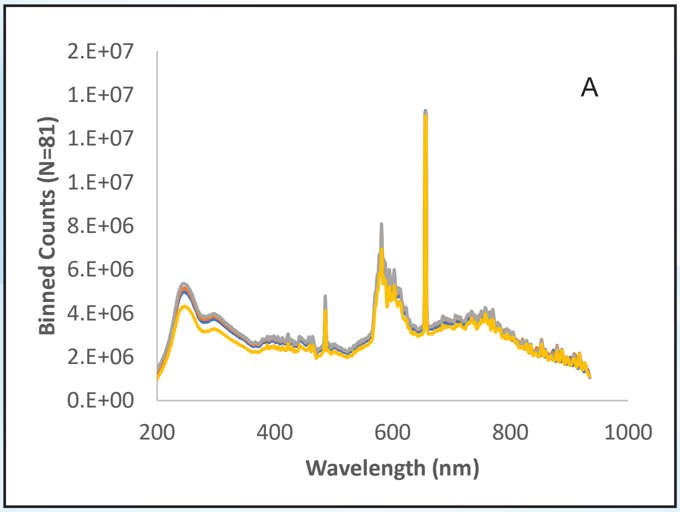
HTS
High Throughput Single channel
(Round-to-line converter)

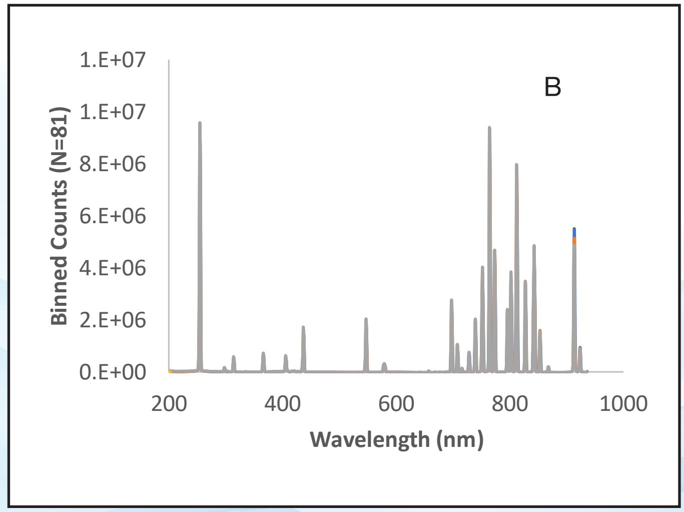
A VIS-H135L with a
Sylent BLUE camera and
custom interface on the lateral input.



A UV-M135A with 4-channel fiber optics
attached in the axial position.
The attached camera is a Sylent Mini.

Spectral Examples

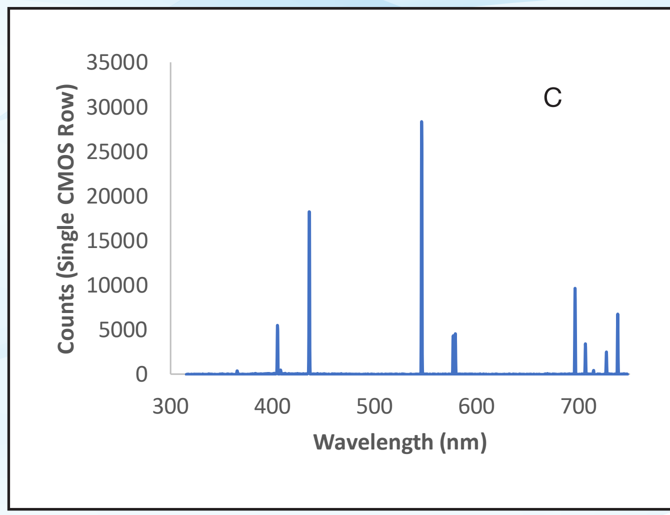




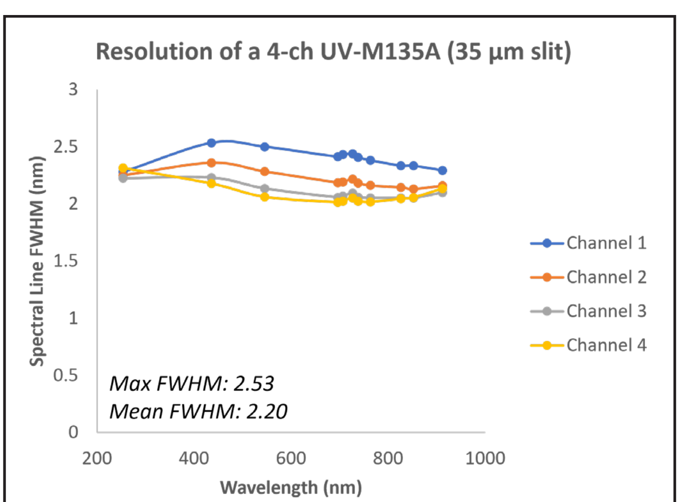
A. Tungsten-deuterium illumination of a fiber-based 4-Ch UV-M135A with 35 µm slit and 1.3MP-U-9.76-BI Sylent Mini sCMOS camera. The system is configured for on-board binning and can export up to 8 spectra with 32-bit depth. Fiber-to-fiber transmission is +/-20%.

B. Corresponding mercury-argon spectrum for subfig A.

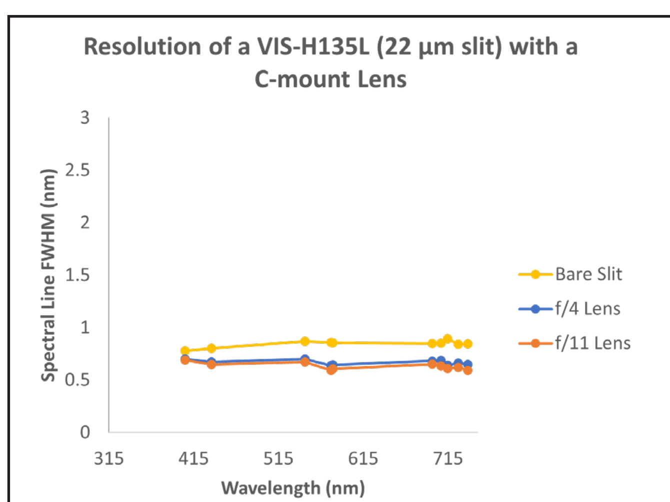
C. Mercury-argon spectrum on a lens-based VIS-H135L, with a 22 µm slit and 1.3MP-U-9.76-BI Sylent Mini sCMOS Camera.



Spectral Line Width Graphs

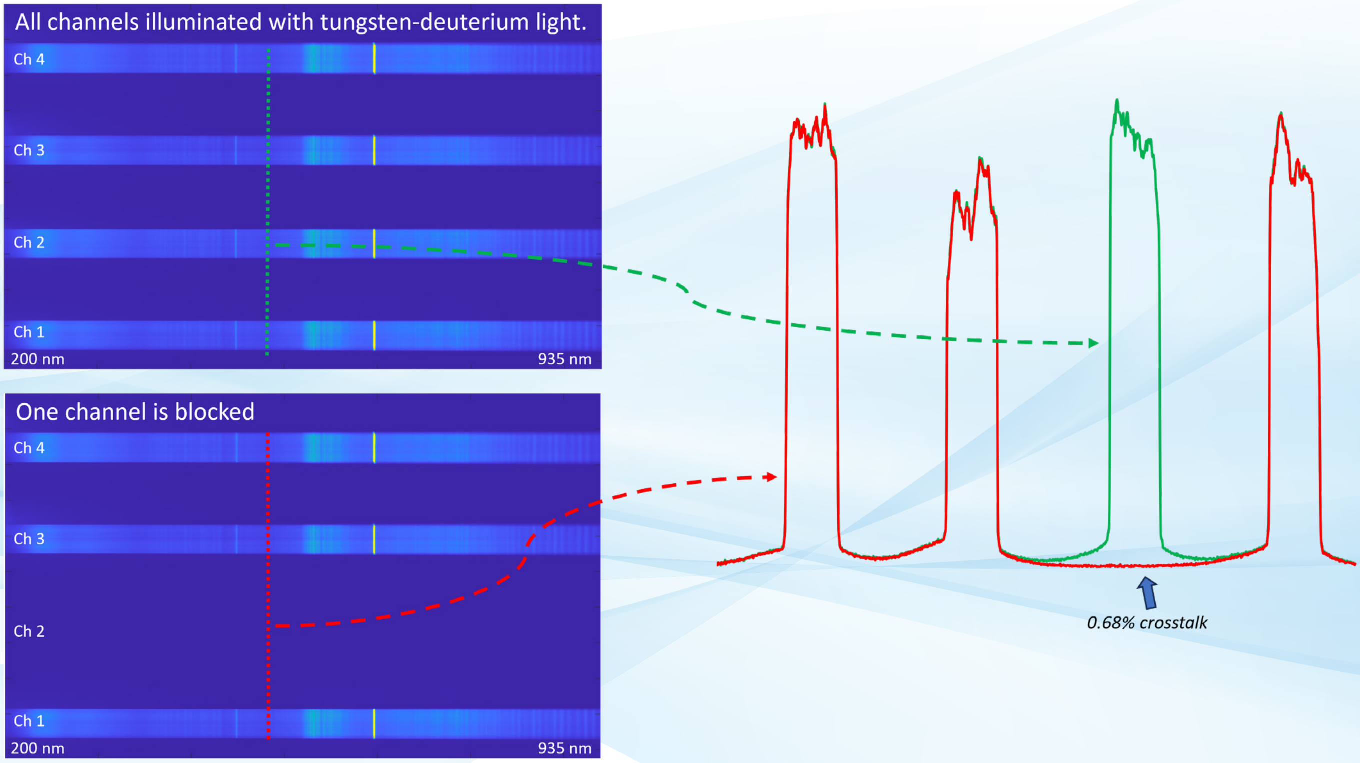


The wavelength resolution specification establishes the maximum width (FWHM) of all spectral lines on all channels. This is a more stringent requirement than using the mean as the specification.



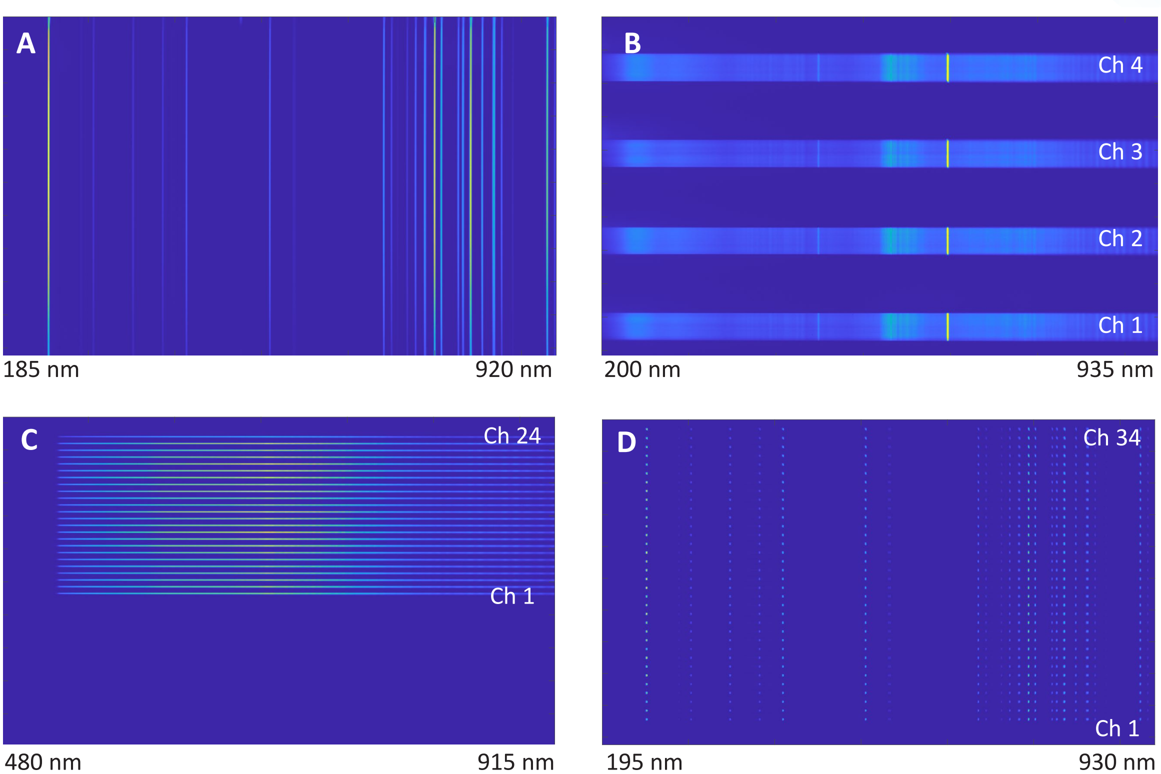
A lens-based hyperspectral H135's resolution is dependent on the grating, slit, and f/# of the lens used.

Cross Talk Calculation



Crosstalk is measured with one channel off. Stray light from all the illuminated channels contribute to the total cross talk.

Image Examples



A. Hyperspectral line image from a UV-H135L with 10 mm tall slit using a UV-VIS-NIR lens.

B. 4-channel UV-M135A illuminated with balanced tungsten-deuterium light.

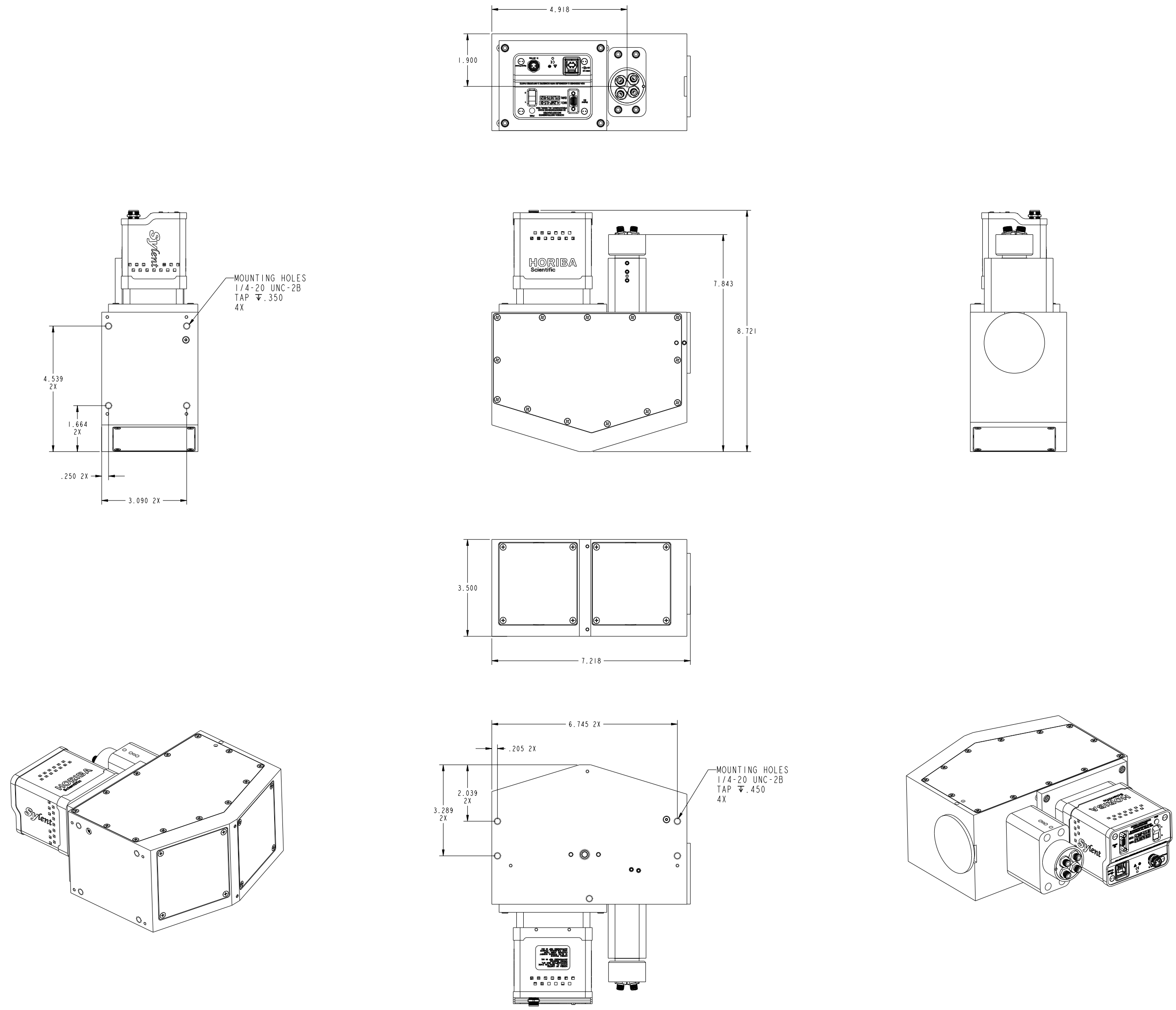
C. 24-channel VIS-M135L illuminated with tungsten light.

D. 34-channel UV-M135A illuminated with a mercury-argon lamp.

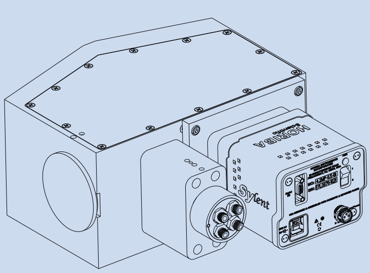
System Mechanical Drawings

PoliSpectra 135 with Sylent Mini sCMOS Camera

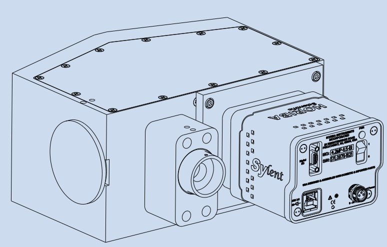
UV-M135A with Integrated 4-channel Fiber Optic Input



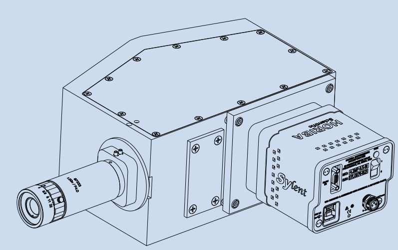
Alternative Configurations



4-ch fiber optic input
(Also available: Direct fiber attachment for up to 96-channels)



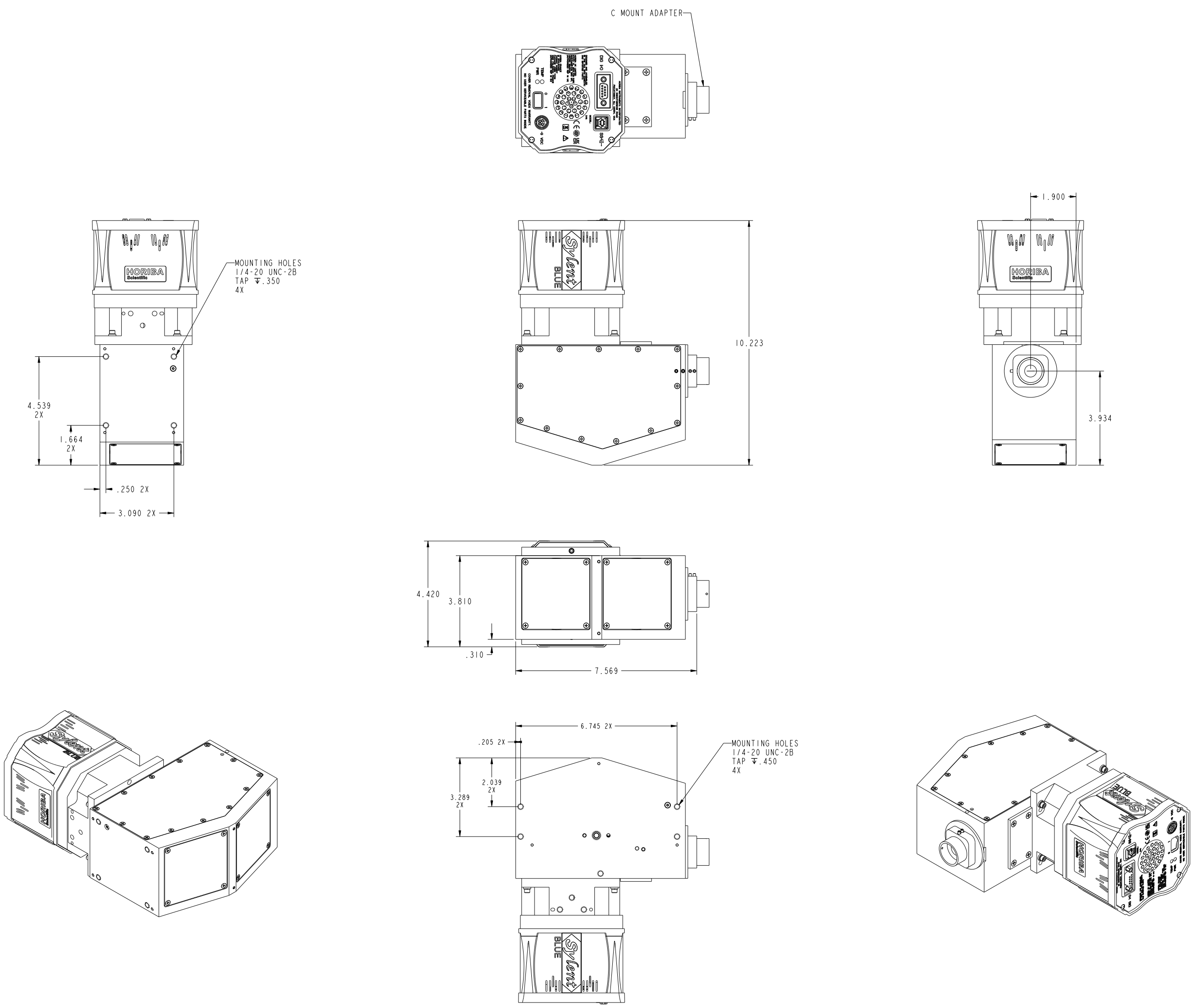
C-mount thread for lens in the axial input position



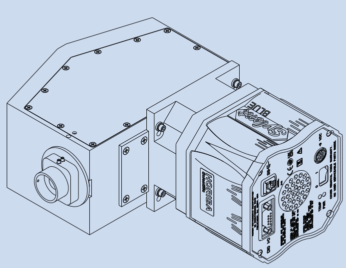
C-mount thread for large lens in the lateral input position (with lens shown)

PoliSpectra 135 with Sylent Blue sCMOS Camera

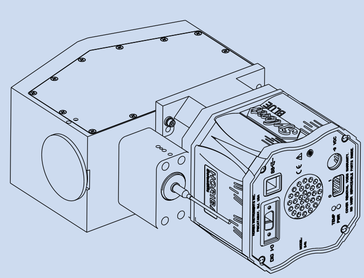
VIS-H135L with C-mount Thread for Large External Lens



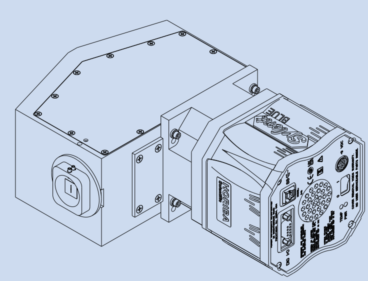
Alternative Configurations



C-mount thread for lens in the lateral input position



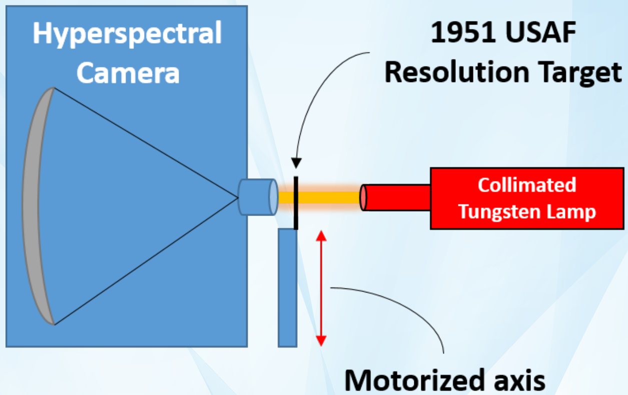
Direct fiber attachment (up to 96-ch) in the axial or lateral position

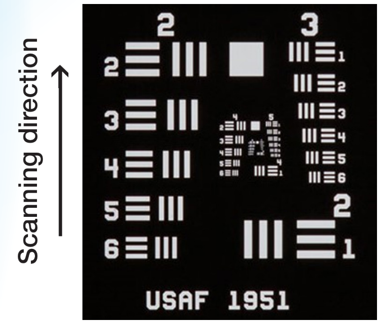


Bare slit for customer-specific focusing optics

Features

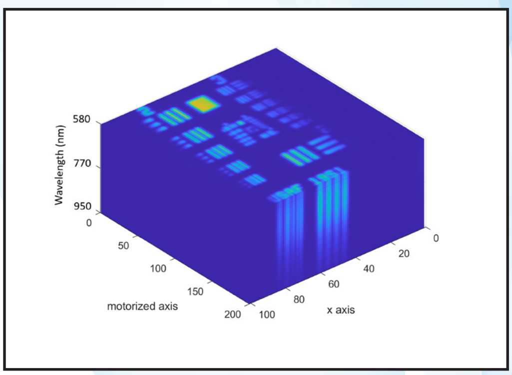
Push Broom Hyperspectral Imaging Configuration



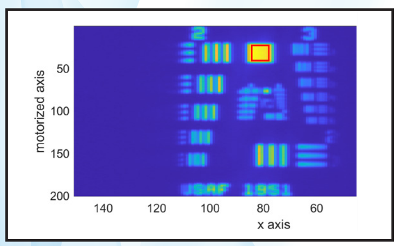


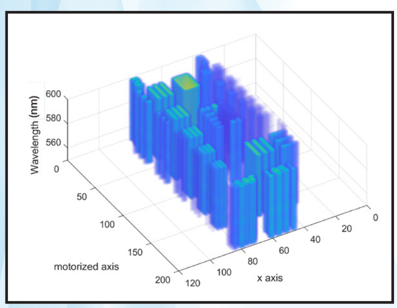
USAF 1951 transmission resolution target.

Resolution test configuration using the H135 hyperspectral camera and a 1951 USAF transmission resolution target via the push broom method. A lens focuses the image on the slit, which is oriented horizontally. A motorized stage moves the target vertically to assemble the hyperspectral cube. A collimated tungsten light provides illumination.



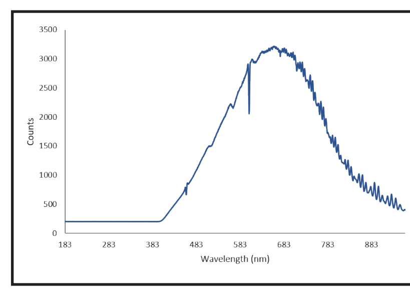
A hyperspectral cube of the 1951 USAF target stitched together from 200 images illuminated by a tungsten lamp. The hyperspectral camera acquired this image in XZ-plane slices (corresponding to real space horizontal axis and wavelength, respectively) and assembled the hyperspectral cube by stitching XZ images along the y-axis (the motorized scan axis). The intensity at each point is in units of electron counts.





A hyperspectral cube with the background subtracted

(Left) A slice of the hyperspectral cube showing the 1951 USAF resolution target at 808 nm. Pixels from the sliced hyperspectral cube were spatially averaged (within the red box at left) to produce a spectrum for that area (shown below). No sample transmission below 400 nm.



Over the last 25 years, HORIBA has been a pioneer in the field of holographic gratings and imaging spectrographs, and has been awarded many patents.

Our first patent on an Offner design, coupled with a CCD and multiple fibers at the input, was filed in 1989, and published in 1992.

Examples of key patents:
1971: First aberration-corrected grating
1972: Concave grating spectrograph with flat field
1989: Aberration-corrected grating in a Czerny-Turner spectrometer
1992: Concentric (Offner) spectrograph with holographic grating and 2D detector
1999: Concentric (Dyson) spectrograph

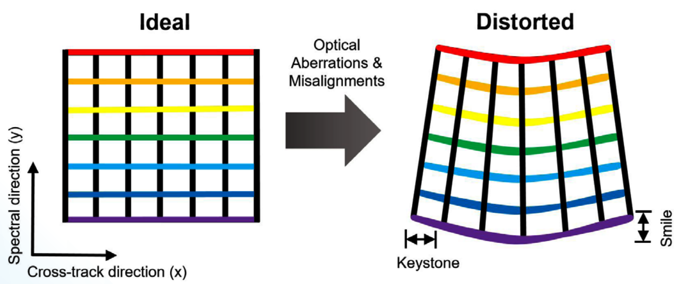
The PoliSpectra H116, M116, H135, and M135 all use a new proprietary concentric layout combined with a Type-I holographic grating. Such Type-I gratings feature equidistant and parallel grooves, and are optimized for very broad spectral range.

Hyperspectral Imaging Distortions: Keystone and Smile

Definitions:

The **KEYSTONE** property is a band-to-band magnification that changes with wavelength. This involves mixing of spectra from adjacent field positions.

The **SMILE** property is a wavelength shift caused by a change in dispersion with field position [1].



Schematic showing an ideal image compared to a real image with optical distortions [2]

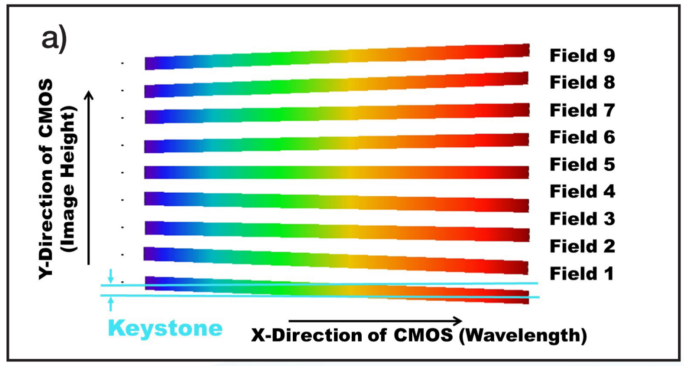
$L\lambda$= Pixel center location of each field identifier slit at a given wavelength

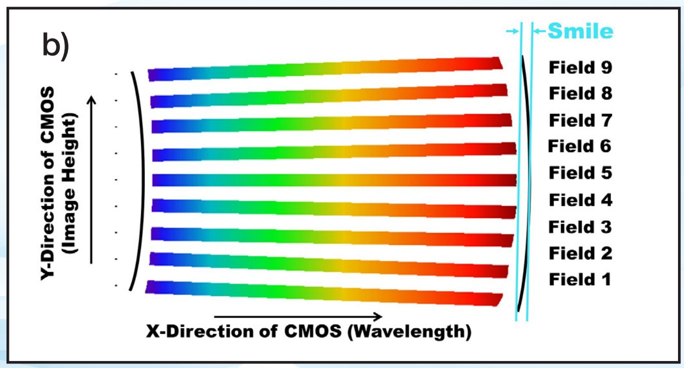
Keystone = $(L_{\lambda max} - L_{\lambda min})$

$C\lambda$= Center pixel location of a given wavelength at each field identifier location

Smile = $(C_{\lambda max} - C_{\lambda min})$

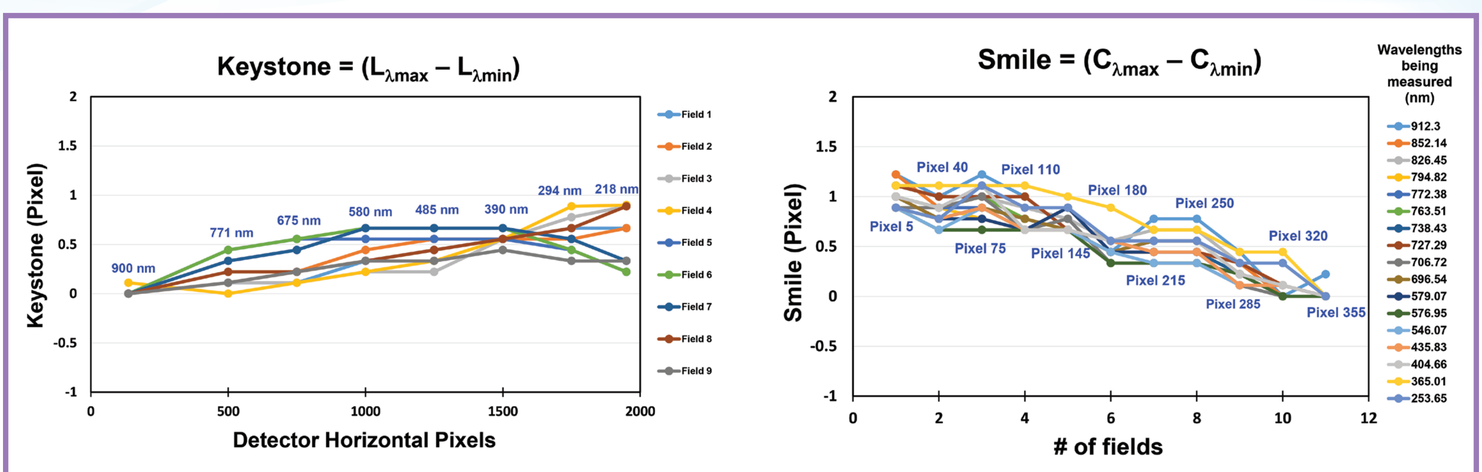
KEYSTONE is measured by calculating the maximum displacement a field slit makes as it moves across the entire spectrum and the **SMILE** is measured by calculating the maximum displacement a wavelength makes as it moves across the entire height of the region of interest.





The method HORIBA uses to measure a) Keystone and b) Smile

Excellent optical performance for PoliSpectra system showing keystone and smile smaller than 1.5 pixels



An example of the production testing for HORIBA's hyperspectral/multichannel spectroscopy systems based on the method described above.

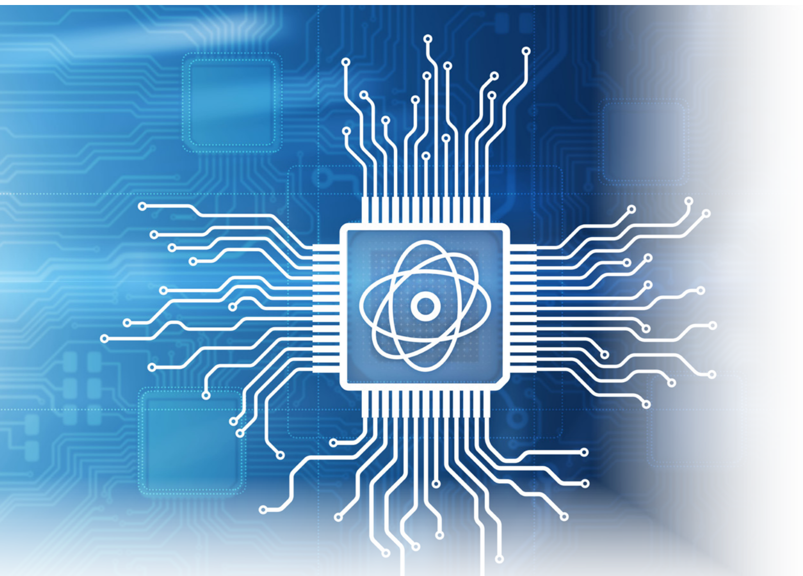
[1] J. Fischer, M. Baumback, J. Bowles, J. Grossmann, and J. Antoniades, "Comparison of low-cost hyperspectral sensors," Proc SPIE, Vol. 3438, pp. 23-30, 1998.

[2] N. Yokoya, N. Miyamura, and A. Iwasaki, " Detection and correction of spectral and spatial misregistrations for hyperspectral data using phase correlation method ," Applied Optics, vol. 49, no. 24, pp.4568-4575, 2010.

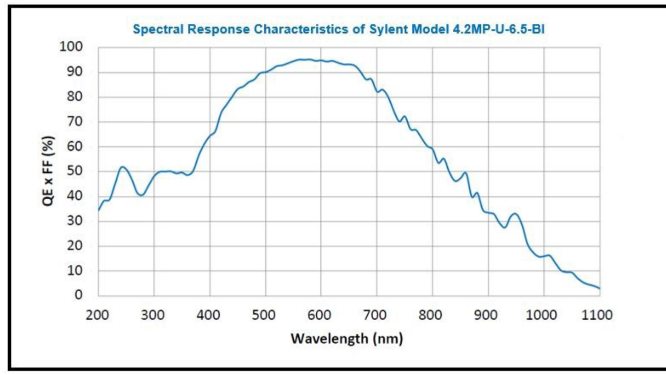
Sylent sCMOS Camera Features

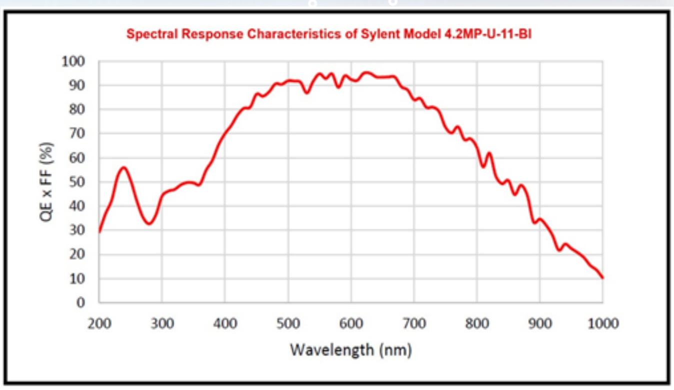
Scientific CMOS Sensor

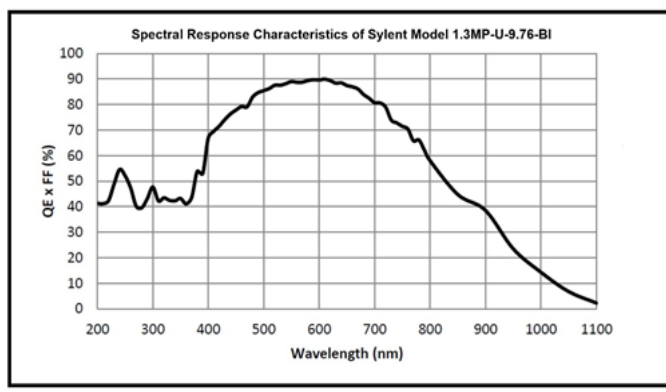
At the heart of all HORIBA's new Sylent scientific CMOS camera offerings (BLUE or Mini) lies a novel back-illuminated sensor architecture providing UV to NIR responsivity with quantum efficiencies (QE) of up to 95%, as shown in the graphs below … without the use of performance limiting micro-lenses.



Sylent Quantum Efficiency







Outstanding High Dynamic Range

In addition to the user-selectable 12-bit high and low gain operating modes, all Sylent camera models feature an unprecedented 16-bit High Dynamic Range (HDR) mode (> 89.5 dB) allowing for the accurate capture of weak and bright signal regions simultaneously on a per image basis.

Here, Sylent's HDR mode leverages its sensor's Dual Amplifier/ADC structure to simultaneously sample each pixel's high gain (low noise) and low gain (high capacity) path and merge the appropriate digitized value (on a pixel-by-pixel basis) to extend the captured image's dynamic range to a 16-bit level, without compromising sensitivity or linearity. As illustrated in the image collage opposite, trade-offs traditionally made by scientists and engineers to choose between the limitations of high gain (sensitivity) or low gain (capacity) acquisitions are overcome with this novel feature to meet the challenges of today's imaging and spectroscopic quantitative applications.

USB 3.0 Interface

From a host communication standpoint, all Sylent camera models incorporate a USB 3.0 interface to handle the high data rates and full resolution images associated with its mega pixel scientific CMOS sensor offerings, as shown in the table below. For the most demanding applications that require enhanced temporal resolution, increased frame rates are achieved by user-selectable smaller ROI sizes.

Uncooled Sylent Model	Effective Pixels	Pixel Size (µm)	Full Image Size	Frame Rate (FPS)
1.3MP-XX-9.76-BI	1.3 MP	9.76	1280 x 1024	30
4.2MP-XX-6.5-BI	4.2 MP	6.50	2048 x 2048	43
4.2MP-XX-11-BI	4.2 MP	11	2048 x 2048	23

Note: “XX” Definition to complete the appropriate Sylent model number is as follows: BLUE (TE) and Mini (U).

Timestamp Feature

All camera models for HORIBA’s new Sylent sCMOS camera product line provide a user selectable coarse or fine “Timestamp” function per image that is accurate to 1 µSec and 20 nSec respectively. This “Timestamp” feature allows the user to have precise knowledge of acquired frametimes as they relate to an application’s temporal dynamics and is especially important for fast events to eliminate the ill effects of computer and interface latencies.

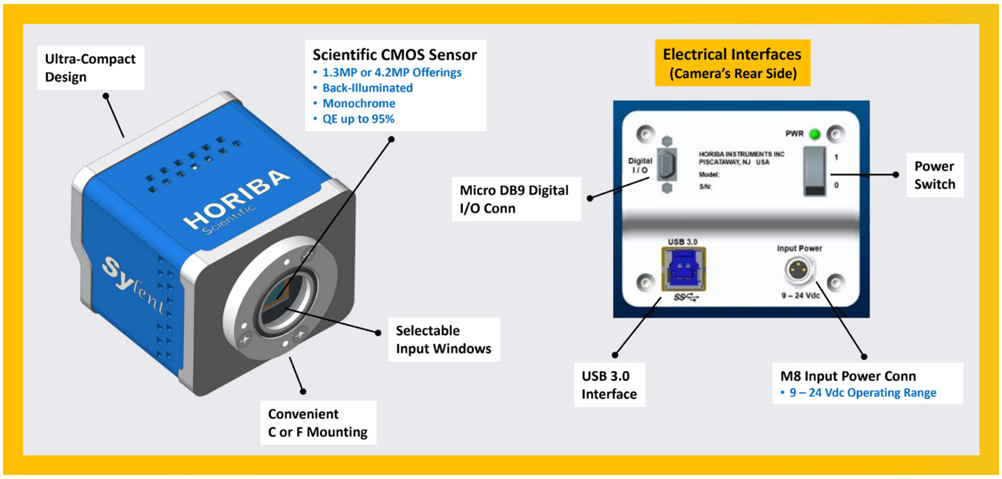
Low Noise Mode

Sylent BLUE or Mini camera offerings that employ a 1.3 MP / 9.76µm or 4.2 MP / 6.5 µm sCMOS sensor provide for a Low Noise Mode of operation that utilizes the two-gain channel structure of their respective novel sCMOS back-illuminated sensors to significantly reduce the typical / normal 1.6 e- read noise of these cameras in High Sensitivity / HDR modes. In this Low Noise camera operating mode, also referred to as Two Times Correlated Multisampling Mode (2-CMS), simultaneous sampling is performed on both sensor gain channels set for “High Gain”, which effectively cuts the read noise level down to 0.85 e- and 1.2 e- respectively for the noted 1.3 MP and 4.2 MP Sylent camera models, without sacrificing high frame rate capability.

This Low Noise Mode is especially valuable to end-user applications that require the highest sensitivity and lowest possible noise floor for imaging the weakest of signals.

Input Power: Sylent Mini

All Sylent Mini “Fan Only” cooled camera models provide end-users with a wide input DC voltage operating range of +9 to +24 Vdc via a 3-pin M8 style female connector (MFG Part 2-2172089-2) and typically utilize 7.5 watts of input power. All Sylent Mini variants utilize the M8 input voltage pin assignment specified in the table below:



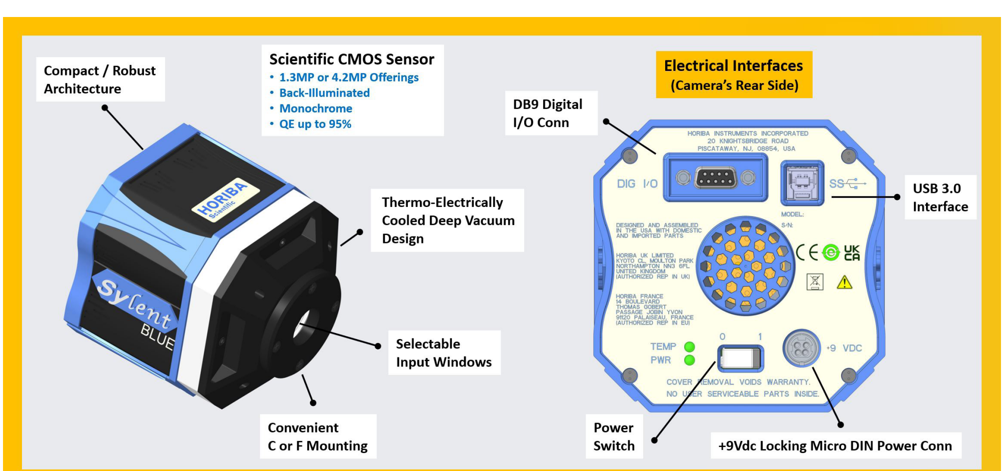
M8 Input Power Connector	Input Power Signal Description
Pin 1	+Vin_Return
Pin 2	+Vin_Return
Pin 3	+Vin

Input Power: Sylent BLUE

All Sylent BLUE camera variants operate from a DC input voltage of +9 volts and utilize a maximum of 58 watts for proper operation and thermo-electric cooling of the incorporated scientific CMOS sensor. Required attributes for Sylent BLUE’s +9V power are noted below:

Input Power Attribute	Value
Voltage Regulation	+9 Vdc ± 5%
Voltage Ripple and Noise	200 mVpp Maximum
Current Capability	6.44 A Maximum
Power Source Switching Mode	Fixed Frequency Operation

Said +9V power is provided via a female 4-pin Micro DIN connector (MFG Part PS-40S) on the Sylent BLUE camera’s rear side with the following pin assignment:



Micro DIN Input Power Connector	Input Power Signal Description
Pin 1	+9 Vdc IN
Pin 2	+9 Vdc IN
Pin 3	+9 Vdc RETURN
Pin 4	+9 Vdc RETURN

Best Selling Miniature Spectrometers for OEM Industrial Applications

Fiber-coupled USB Spectrometers:

MiniVS20 Spectrometer with Linear UV-VIS CMOS or NIR InGaAs Sensor

OEM hand-held spectrometer covering 190 to 1,700 nm for various low stray light applications
- Aberration-corrected concave holographic grating options
- VIS configuration featuring a 1.7” x 1.9” x 2” size combined with full F/2.3 optics for high signal-to-noise
- High throughput, compactness and long term reliability

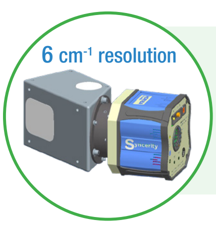
MiniVS70 VIS Spectrometer with FI CMOS or BI CCD

NEW miniaturized VS70 configuration
- Based on high performance aberration-corrected concave gratings fitted with a custom order-sorting filter to eliminate higher orders
- Low cost combined with high performance and low stray light
- Long term opto-mechanical stability and choice of front-illuminated linear CMOS or back-illuminated CCD sensors

VS70 UV-VIS-NIR Spectrometer with Uncooled / TE-cooled CCD

Compact, versatile most popular VS70 OEM spectrometer and OES configurations
- Based on high performance aberration-corrected concave gratings with full F/2.3 aperture
- Affordable, high throughput, robust and stable
- Electronics drivers ranging from **USB-2 to Ethernet and EtherCAT**

CiCi-Raman-NIR with Scientific Camera Optimized for 785 nm



Most compact OEM Raman spectrometer with aberration-corrected holographic grating
- Covers 150-3,300 cm^{-1}
- High efficiency and low stray light
- Available in F/2.3 and in compact F/5 configurations
- -50° C deep-cooled scientific CCD camera with minimized etaloning and high NIR QE

PoliSpectra® Quad Spectrometer for Simultaneous Acquisition of 4 VIS Spectra

CCD spectrometer for simultaneous acquisition from 4 fiber inputs (470-730 nm)
- High-speed electronics (as fast as <1.5 msec readout time for 4 spectra)
- QUAD-channel high throughput system (f/2.3) and ultra-low stray light
- Industrial low-light applications from low light fluorescence to reflectance

PoliSpectra® M116 8-32 Channel Multitrack UV-VIS-NIR CMOS Spectrometer

Fiber-coupled multi-spectra system with 8- to 32-channel simultaneous measurements
- Concentric optical design with UV extended spectral range provides minimized crosstalk
- High throughput USB-3 system featuring a fast 2D scientific BI CMOS running at 94 to 188 frames per second, acquiring 8, 16 or 32 simultaneous spectra (2048 pixels per spectrum)

PoliSpectra® 135 Multichannel or Hyperspectral Line Imager from UV to NIR

Ultra-high performance rugged spectrometer for hyperspectral imaging with a 2D sCMOS Camera
- For line-image scanning, in a push-broom hyperspectral configuration
- High throughput, USB-3 system featuring a fast 2D scientific BI CMOS with rolling shutter, running at 94 (HDR) to 188 (Standard Mode) frames per second (2048 pixels per spectrum)

OEM Philosophy and Mission

3 Centers of Excellence Dedicated to OEM Spectroscopy and Camera Solutions in US, EU, and Asia

Our mission is to provide a complete development and manufacturing experience, from optical simulations to opto-mechanical design and prototyping of spectroscopic and camera systems extending to and including electronics, firmware, software design and first articles.

Our products provide superior performance, reliability and stability combined with robust cost reduction. Capable of flexible high volume production capacity in quantities of hundreds to thousands per year, we offer full confidentiality providing "Black Boxes" or private labelling using your logo or graphics.

Unmatched customer service is provided by our exceptionally experienced workforce featuring on-time delivery and flexibility allowing scheduling modifications.

Adhering to Copy Exactly! Processes (CE!) our fully trained staff from engineering to manufacturing form a dedicated OEM engineering force that supports you over the lifetime of the product.

Scientific Segment - OEM Products and Capabilities:

- Custom master optical diffraction gratings
- Diffraction grating replicas (concave, convex and flat)
- Spectrometers, optical assemblies with pre-aligned sensors (CCD, PDA, CMOS, InGaAs) using either customers' or HORIBA's OEM electronics
- OES spectrometers
- Spectroscopy systems or modular engines such as mini fluorometers and mini Raman systems
- Single and double scanning monochromators
- Imaging spectrographs and spectrometers with CCD or CMOS cameras
- Multispectra spectrometers with multiple fiber input / MultiTrack spectroscopy
- Hyperspectral system with HORIBA camera or customer provided (Push-broom configurations)
- Cameras: Spectroscopic deep-cooled scientific cameras (1D and 2D CCD & InGaAS – FI and BI)
- OEM electronics for optosensors ranging from PD and PDA to CCD and CMOS sensors
- Imaging cameras: Uncooled and cooled with FI and BI high-end scientific CMOS
- VUV/FUV spectrometers and CCD vacuum and N2-purged cameras

Scientific Deep Cooled CCD and sCMOS cameras

Syncerity®

Low Cost -50º C
Air-cooled OEM Camera

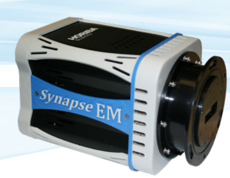
Sylent Mini

Ultra-compact 4.2 MP
Monochrome sCMOS Sensor

Sylent BLUE

TE-cooled to -25˚ C
4.2 MP sCMOS Sensor

Synapse® EM



EM CCD
Deep-cooled Camera

VUV Syncerity®

TE-cooled to -50˚ C (Vacuum)
or -30˚ C with N2 purge

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