

CAMERAS

hyperspectral cameras

General Description

Middleton Research offers a complete line of fully-integrated and calibrated hyperspectral cameras for high-speed hyperspectral imaging. Hyperspectral cameras can be used for many industrial and laboratory-based applications. The cameras, manufactured by Specim Ltd., operate with push-broom technology, collecting full spectral ranges of data simultaneously for each pixel on an imaged line. These cameras scan the whole image, line by line. The push-broom technology is a good fit with on-line process control applications where products are continuously moving. As the target moves past the camera, the spectrum of each point is measured and the results data can be either reported line-by-line or assembled into composition maps or images.



The basic building blocks of push-broom hyperspectral camera systems, as seen above, are: filters (such as spectral flattening filters), imaging lenses, spectrographs, order blocking filters and focal plane array (FPA) sensors. Other important components, such as optical mounting plates, shutters, controllers, housing and electronic components are not shown.

“Cameras” in this chapter refer to fully integrated hyperspectral cameras that are pre-aligned and calibrated.*

Modules contained in hyperspectral cameras require significant expertise to properly integrate them into a complete camera unit. Not all FPA cameras can be integrated with spectrographs, even if they are nominally C-mount compatible.

Fully integrated hyperspectral cameras include:

- Factory alignment and calibration of the spectrograph slit position and focus
- Non-uniformity correction at different camera integration times to account for the possible pixel-to-pixel differences of the actual FPA camera component
- Wavelength calibration to achieve the best wavelength accuracy across entire wavelength range
- Compatibility with optional SpectralDAQ™ camera driver and data collection software

Spectral Cameras	Range (nm)	Sensor	Pixels in full frame (spatial x spectral)	Interface	Frame rate (full frame)
UV	200-400	Frame transfer CCD	1000 x 1000	Base CameraLink	33 Hz / 159 Hz
VIS	380-800	Interline CCD	1392 x 1040 / 1600 x 1200	Firewire / Base CameraLink	11 Hz / 33 Hz
VNIR	400-1000	Interline CCD	1392 x 1040 / 1600 x 1200	Firewire / Base CameraLink	11 Hz / 33 Hz
NIR	900-1700	TE-cooled InGaAs photodiode array	320 x 256 / 640 x 512	USB / Base CameraLink	15-350 Hz
SWIR	970-2500	MCT camera	320 x 256	LVDS	100 Hz
LWIR	8-12 μm	LWIR uncooled microbolometer / MCT	384 x 200 / 384 x 48	LVDS	60 Hz / 100 Hz

*Please note that in some literature the focal plane array (FPA) camera modules are also referred to as “cameras”, because they are used on their own as broadband imaging devices in their respective wavelength regions.

Spectral cameras are available in several wavelength ranges, from UV to LWIR and with multiple data interfaces, allowing for the best optimization for specific application requirements. Please see the chart below and the following pages for more details.

Several spectral cameras are offered as either cased or uncased models. The cased, complete cameras are constructed with an exterior housing to protect the sensitive optical components, and thus are better suited for outdoor or process applications. Data cables, power cables, control cables, and lenses are connected to the exterior of the cased camera.



Visible cased camera (HS V8E / V10E)

The uncased camera models are fully functional hyperspectral cameras without the housing. These models are more economical but lack the protection provided by the exterior casing. Uncased models also lack the computer controlled shutter that is included in cased cameras for the purpose of establishing the dark background levels. The shutter can be added to an uncased model as a separate device. In general, uncased models are suitable for Original Equipment Manufacturer (OEM) applications where the camera is part of a larger system, making the exterior housing unnecessary.



Visible uncased camera (HS V8E / V10E)

Several of the spectral cameras are offered as either a standard series camera or enhanced (E-series) camera. The standard series cameras are lower cost models that are equipped with standard imaging spectrographs (models V8 or V10). The E-series cameras are designed for applications that require higher image quality and spectral purity.

Binning

Some of the spectral cameras allow for the binning of the spatial and/or spectral axis of the detector. This allows for higher acquisition rates as well as improved signal to noise. The figure in the glossary demonstrates how binning can increase the frame rate of a typical camera.

Software

Hyperspectral cameras are matched to the optional SpectralDAQ software for camera control and data acquisition. SpectralDAQ saves datacubes in an ENVI-compatible, user-friendly format for further hyperspectral data processing. For more information on software specifications, see the software chapter of this catalog.

Accessories

There are several accessories available to complement the hyperspectral cameras, including:

- Fore objective lenses optimized for each spectral range
- Fiber optics that are used to create a multiple-point spectrometer
- Mirror scanners or rotating stages for stationary targets or scenes
- Moving sample stages for microscopes and other laboratory applications

Three different sizes of rugged transport cases can be provided with the cameras for shipping and portability. These cases are optional but recommended to protect the cameras.

UV 200 – 400 nm HYPERSPPECTRAL CAMERA

Middleton Research offers a hyperspectral camera in the ultra-violet range (200-400 nm) from Specim Ltd. The UV camera is designed for ultraviolet applications that require high spatial and spectral resolution and the best imaging optics. The camera consists of an imaging spectrograph (ImSpector UV4E), a UV-sensitive monochrome camera (frame transfer CCD) and a base CameraLink interface.

The UV camera is currently offered as an uncased model and comes with the frame grabber, cables and full wavelength and non-uniformity calibrations. This UV camera can be used for many applications where the UV spectral region is of interest, including forensics, semiconductors, biomedical and other applications.



UV Image of currency

UV Camera Specifications

Optical Characteristics	UV-CL-30-UV4E-OEM
Range (nm)	200-400
Resolution (spatial x spectral)	1000 x 1000 (430 active)
Spectrograph	ImSpector UV4E
Spectral Resolution	2 nm (30 μ m slit)
Spectral Sampling	0.46 nm/pixel
Spatial Resolution	RMS spot diameter < 60 μ m
Aberrations	Smile < 3 μ m (0.025%)
Numerical Aperture	F/2.8
Slit Width, default	80 μ m (50 μ m available on request)
Effective Slit Length	8 mm
Total Efficiency (typical)	> 50%, independent of polarization
Stray Light	< 1%

Electrical Characteristics

Sensor	Frame transfer CCD
Interface	Base CameraLink
Camera Output	Digital 12-bit
Frame rate (full / binning)	33 Hz / 159 Hz (8 x 8 binning)
Frame Grabber	NI-PCI 1428
Pixel Size	8 μ m x 8 μ m
Camera Control	CameraLink
Exposure Time Range	500 μ s - 1 s (10 s for C8800-21C)
Power Consumption	10 W (20 W for C8800-21C)
Input Voltage	12 V

Environmental Characteristics

Storage	-10 C to 50 C
Operating	0 C to 40 C non-condensing

Mechanical Characteristics

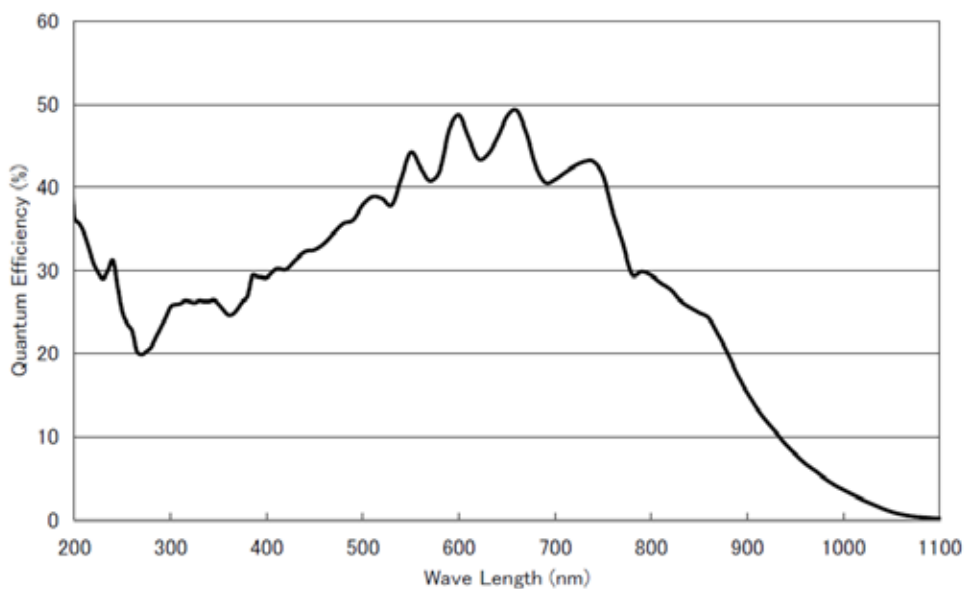
Size (LxWxH)	50 x 55 x 165 mm
Weight	320 g
Body	Anodized Al
Lens Mount	Standard C-mount adapter
User Adjustments	Rotating image axis relative to detector rows, adjustable back focal length \pm 1 mm
Shutter	No

One of the best illumination sources is the sun, which produces a strong UV emission. Indoor UV sources, such as deuterium or xenon lamps and others can be used with the UV camera. Depending on the application, size of the illuminated objects and other factors, UV absorption is a very sensitive method for establishing the thickness of UV absorbing layers and low concentration chromophores. Most natural materials show strong fluorescence under UV radiation. In some applications, the visible spectrum is also an important source of information.



Applications

- Semiconductors
- Forensics
- Life Sciences
- Mineralogy



Spectral response of UV camera

UV Camera Ordering Information		
Part Number	Description	Product Name
MRC-302-004-01	OEM UV Spectral Camera, with Enhanced Spectrograph. 30 fps, 1000x1000 CCD, Cameralink frame grabber + cables	UV-CL-30-UV4E-OEM

VISIBLE 380 – 800 nm HYPERSPSCTRAL CAMERAS

Middleton Research offers several hyperspectral cameras in the visible wavelength range from 380 – 800 nm (HS, PS, and PFD Series) from Specim Ltd.



The HS Series hyperspectral cameras are designed for visible applications that require a high throughput, high spatial and spectral resolutions and the best imaging optics. The camera consists of an imaging spectrograph (ImSpector V8E), a monochrome camera (sensitive high speed interline CCD sensor), and a base CameraLink interface. With its solid structure and exceptional performance, the HS hyperspectral camera is suited for industry, laboratory and field applications.

The Visible cased camera package includes: control unit, power supply, USB cable, Firewire cable (Firewire camera only), National Instruments CameraLink frame grabber and data cable (CameraLink cameras only), control cable, power cord set, and software CD.

Cased Camera Specifications

Optical Characteristics	HS-CL-30-V8E	PS-FW-11-V8E	PFD-CL-65-V8E
Range (nm)	380-800	380-800	380-800
Resolution (spatial x spectral)	1600 x 1200 (840 active)	1392 x 1040 (870 active)	1312 x 1024
Spectrograph	ImSpector V8E	ImSpector V8E	ImSpector V8E
Spectral Resolution	2 nm (30 µm slit)	6 nm (30 µm slit)	2 nm (30 µm slit)
Spectral Sampling	0.55 - 4.4 nm/pixel	0.48 - 3.86 nm/pixel	0.59 - 4.75 nm/pixel
Spatial Resolution	RMS spot diameter < 9 µm	RMS spot diameter < 18 µm	RMS spot diameter < 9 µm
Aberrations	Insignificant astigmatism, keystone or smile (for all)		
Numerical Aperture	F/2.4	F/2.4	F/2.4
Slit Width, default	30 µm (18, 50, 80, 150 µm)	30 µm (18, 50, 80, 150 µm)	30 µm (18, 50, 80, 150 µm)
Effective Slit Length	11.84 mm	8.98 mm	10.50 mm
Total Efficiency (typical)	> 50%, independent of polarization (for all)		
Stray Light	< 0.5% (halogen lamp, 590 nm low-pass filter) for all		

Electrical Characteristics

Sensor	Interline CCD	Interline CCD	CMOS
Interface	Base CameraLink	Firewire	Base CameraLink
Camera Output	Digital 12-bit	Digital 12-bit	Digital 12-bit
Frame rate (full / binning)	33 Hz / 120 Hz	11 Hz / 62 Hz (1 x 8 binning)	65 Hz / (180 Hz w/binning)
Cooling	N/A	N/A	N/A
Frame Grabber	NI-PCI 1428*	N/A	NI-1429
Pixel Size	7.4 µm x 7.4 µm	6.45 µm x 6.45 µm	
Camera Control	Base CameraLink	Firewire	CameraLink
Exposure Time Range	0.1 - 100 ms	1 µm - 120 s	0.1 - 100 ms
Power Consumption	< 5 W	< 5W	< 5W
Input Voltage	24 V	24 V	24 V

Environmental Characteristics

Storage	-20 to 50 C	-20 to 50 C	-20 to 50 C
Operating	5 to 40 C non-condensing	5 to 40 C non-condensing	5 to 40 C non-condensing

Mechanical Characteristics

Size (LxWxH)	330 x 85 x 90 mm	330 x 85 x 90 mm	330 x 85 x 90 mm
Weight	5.0 kg	5.0 kg	2.7 kg
Body	Anodized Al w/mounting screw holes (for all)		
Lens Mount	Standard C-mount	Standard C-mount	Standard C-mount
User Adjustments	None	None	None
Shutter	Yes, w/USB control	Yes, w/USB control	Yes, w/USB control

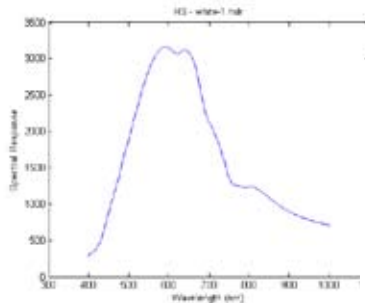


The PS Series hyperspectral cameras provide high spatial and spectral resolution, low noise, and a rugged structure for visible applications in the laboratory or the field. Each camera is an integration of an imaging spectrograph and a monochrome area camera (sensitive high speed interline CCD sensor) and includes a Firewire interface.

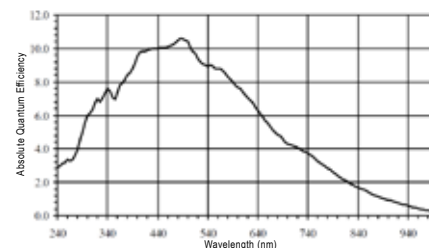
The PFD Series is a new family of visible and VNIR hyperspectral cameras that are based on a CMOS sensor and include a CameraLink interface.

Applications

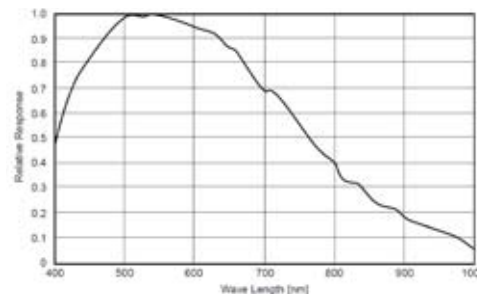
- Color control and sorting of textiles, cosmetics, and other manufactured products
- Forensics
- Scanning of art works
- Flat panel display measurement
- Color print testing
- Counterfeit detection
- Fruit and vegetable inspection and sorting
- Life science applications including fluorescence monitoring
- Plant and vegetation research
- Environmental monitoring
- Hyperspectral microscopy



Spectral response of HS camera with spectral flattening filter

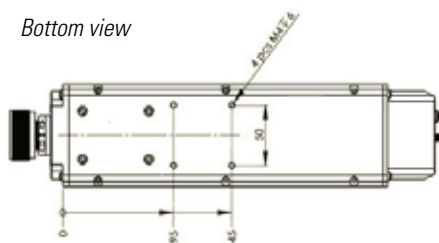


Spectral response of HS camera without flattening filter

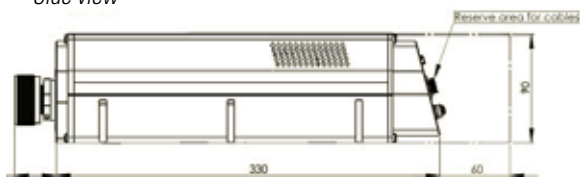


Spectral response of PS camera without flattening filter

Bottom view

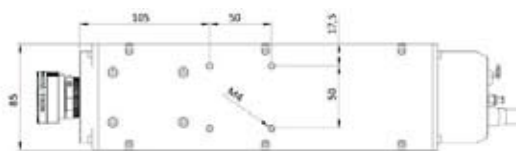


Side view



PS V8E and HS V8E Cased cameras

Bottom view



Side view



PFD V8E Cased cameras

CAMERAS visible 380 – 800 nm

Visible Cased Cameras Ordering Information		
Part Number	Description	Product Name
MRC-303-001-01	Visible Spectral Camera with Enhanced Spectrograph. 11 fps, 1392x1040 IT CCD, Firewire, cables included	PS-FW-11-V8E
MRC-303-001-02	Visible Spectral Camera with Enhanced Spectrograph. 30 fps, 1600x1200 IT CCD, CameraLink frame grabber + cables	HS-CL-30-V8E
MRC-303-001-05	Visible Spectral Camera with Enhanced Spectrograph. 65 fps, 1312x1024 CMOS, CameraLink frame grabber + cables	PFD-CL-65-V8E

VISIBLE 380 – 800 nm, continued

HYPERSPETRAL CAMERAS

The uncased camera models are fully functional hyperspectral cameras without the housing. These models are more economical but lack the protection provided by the exterior casing. Uncased models also lack the computer controlled shutter that is included in complete cameras for the purpose of establishing the dark background levels. The user may choose a camera with a lower-cost Standard Series spectrograph (ImSpector V8), or an Enhanced Series spectrograph (ImSpector V8E), the latter providing higher quality images and enhanced spectral fidelity.

The Visible uncased camera package includes: power supply (CameraLink cameras only), Firewire cable (Firewire cameras only), National Instruments CameraLink frame grabber and data cable (CameraLink cameras only), power cord set, and software CD.

Uncased Camera Specifications

Optical Characteristics	PS-FW-11-V8-OEM	PS-FW-11-V8E-OEM	HS-CL-30-V8E-OEM	PFD-CL-65-V8E-OEM
Range (nm)	380-800	380-800	380-800	380-800
Resolution (spatial x spectral)	1392 x 1040 (990 active)	1392 x 1040 (870 active)	1600 x 1200 (840 active)	1312 x 1024
Spectrograph	ImSpector V8	ImSpector V8E	ImSpector V8E	ImSpector V8E
Spectral Resolution	6 nm (30 μ m slit)	2 nm (30 μ m slit)	2 nm (30 μ m slit)	2 nm (30 μ m slit)
Spectral Sampling	0.43 - 3.4 nm/pixel	0.48 - 3.86 nm/pixel	0.55 - 4.4 nm/pixel	0.59 - 4.75 nm/pixel
Spatial Resolution	RMS spot diam. < 60 μ m	RMS spot diam. < 18 μ m	RMS spot diam. < 9 μ m	RMS spot diam. < 9 μ m
Aberrations	Smile < 45 μ m, keystone < 40 μ m	Insignificant astigmatism, keystone or smile	Insignificant astigmatism, keystone or smile	Insignificant astigmatism, keystone or smile
Numerical Aperture	F/2.8	F/2.4	F/2.4	F/2.4
Slit Width, default	50 μ m (25, 80, 150 μ m)	30 μ m (18, 50, 80, 150 μ m)	30 μ m (18, 50, 80, 150 μ m)	30 μ m (18, 50, 80, 150 μ m)
Effective Slit Length	8.98 mm	8.98 mm	11.84 mm	10.50 mm
Total Efficiency (typical)	> 50%, independent of polarization	> 50%, independent of polarization	> 50%, independent of polarization	> 50%, independent of polarization
Stray Light	< 0.5% (halogen lamp, 590 nm low-pass filter)	< 0.5% (halogen lamp, 590 nm low-pass filter)	< 0.5% (halogen lamp, 590 nm low-pass filter)	< 0.5% (halogen lamp, 590 nm low-pass filter)

Electrical Characteristics

Sensor	Interline CCD	Interline CCD	Interline CCD	CMOS
Interface	Firewire	Firewire	Base CameraLink	Base CameraLink
Camera Output	Digital 12-bit	Digital 12-bit	Digital 12-bit	Digital 12-bit
Frame rate (full / binning)	11 Hz / 62 Hz (1 x 8 binning)	11 Hz / 62 Hz (1 x 8 binning)	33 Hz / 120 Hz	65 Hz / (180 Hz w/binning)
Cooling	N/A	N/A	N/A	N/A
Frame Grabber	N/A	N/A	NI-PCI 1428*	NI-1429
Pixel Size	6.45 μ m x 6.45 μ m	6.45 μ m x 6.45 μ m	7.4 μ m x 7.4 μ m	
Camera Control	Firewire	Firewire	Base CameraLink	CameraLink
Exposure Time Range	1 μ s - 120 s	1 μ s - 120 s	0.1 - 100 ms	0.1 - 100 ms
Power Consumption	< 5W	< 5W	< 5 W	< 5 W
Input Voltage	12 V	12 V	12 V	12 V

Environmental Characteristics

Storage	-20 to 50 C	-20 to 50 C	-20 to 50 C	-20 to 50 C
Operating	5 to 40 C non-condensing	5 to 40 C non-condensing	5 to 40 C non-condensing	5 to 40 C non-condensing

Mechanical Characteristics

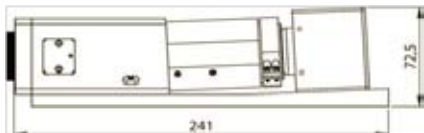
Size (LxWxH)	220 x 60 x 70	241 x 73 x 79 mm	260 x 70 x 79 mm	231 x 80.5 x 78 mm
Weight	1.8 kg	1.8 kg	1.8 kg	1.8 kg
Body	Anodized Al w/mounting screw holes	Anodized Al w/mounting screw holes	Anodized Al w/mounting screw holes	Anodized Al w/mounting screw holes
Lens Mount	Standard C-mount	Standard C-mount	Standard C-mount	Standard C-mount
User Adjustments	None	None	None	None
Shutter	No	Optional	Optional	Optional



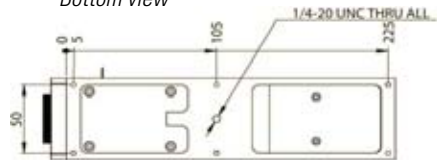
PS V8E OEM



Side view



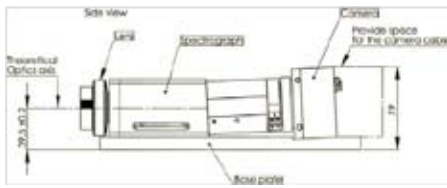
Bottom view



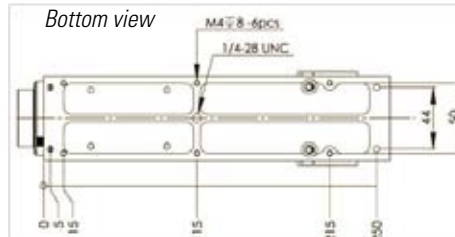
HS V8E OEM



Side view



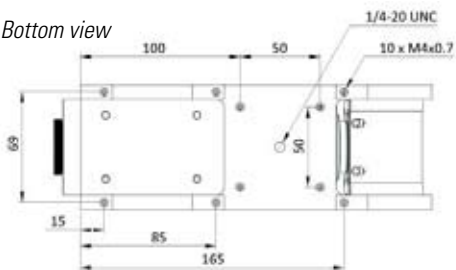
Bottom view



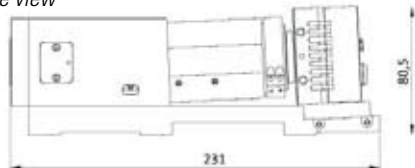
PFD V8E OEM



Bottom view



Side view



PS V8 OEM



Visible Uncased Cameras Ordering Information

Part Number	Description	Product Name
MRC-301-001-01	OEM Visible Spectral Camera, with Standard Spectrograph. 11 fps, 1392x1040 IT CCD, Firewire, cables included.	PS-FW-11-V8-OEM
MRC-302-001-01	OEM Visible Spectral Camera, with Enhanced Spectrograph. 11 fps, 1392x1040 IT CCD, Firewire, cables included	PS-FW-11-V8E-OEM
MRC-302-001-03	OEM Visible Spectral Camera, with Enhanced Spectrograph. 30 fps, 1600x1200 IT CCD, CameraLink frame grabber + cables	HS-CL-30-V8E-OEM
MRC-302-001-06	OEM Visible Spectral Camera, with Enhanced Spectrograph. 65 fps, 1312x1024 CMOS, CameraLink frame grabber + cables	PFD-CL-65-V8E-OEM

VNIR 400 – 1000 nm HYPERSPECTRAL CAMERAS

Middleton Research offers several choices of hyperspectral cameras in the VNIR wavelength range from 400 – 1000 nm (HS, PS, and PFD Series) from Specim Ltd.



The HS Series hyperspectral cameras are designed for VNIR applications which require a high throughput, high spatial and spectral resolutions, and the best imaging optics. The camera consists of an imaging spectrograph (ImSpector V10E), a monochrome camera (sensitive high speed interline CCD sensor) and has a base CameraLink interface. With its solid structure and exceptional performance, the HS hyperspectral camera is suited for industry, laboratory and field applications.

The VNIR cased camera package includes: control unit, power supply, USB cable, Firewire cable (Firewire camera only), National Instruments CameraLink frame grabber and data cable (CameraLink cameras only), control cable, power cord set, and software CD.

Cased Camera Specifications

Optical Characteristics	HS-CL-30-V10E	PS-FW-11-V10E	PFD-CL-65-V10E
Range (nm)	400-1000	400-1000	400-1000
Resolution (spatial x spectral)	1600 x 1200 (840 active)	1392 x 1040 (950 active)	1312 x 1024
Spectrograph	ImSpector V10E	ImSpector V10E	ImSpector V10E
Spectral Resolution	2.8 nm (30 µm slit)	6.8 nm (30 µm slit)	2.8 nm (30 µm slit)
Spectral Sampling	0.72 - 5.8 nm/pixel	0.63 - 5.06 nm/pixel	0.78 - 6.27 nm/pixel
Spatial Resolution	RMS spot diameter < 9 µm	RMS spot diameter < 18 µm	RMS spot diam. < 9 µm
Aberrations	Insignificant astigmatism, keystone or smile (for all)		
Numerical Aperture	F/2.4	F/2.4	F/2.4
Slit Width, default	30 µm (18, 50, 80, 150 µm)	30 µm (18, 50, 80, 150 µm)	30 µm (18, 50, 80, 150 µm)
Effective Slit Length	11.84 mm	8.98 mm	10.50 mm
Total Efficiency (typical)	> 50%, independent of polarization (for all)		
Stray Light	< 0.5% (halogen lamp, 590 nm low-pass filter) for all		

Electrical Characteristics

Sensor	Interline CCD	Interline CCD	CMOS
Interface	Base CameraLink	Firewire	Base CameraLink
Camera Output	Digital 12-bit	Digital 12-bit	Digital 12-bit
Frame rate (full / binning)	33 Hz / 120 Hz	11 Hz / 62 Hz (1 x 8 binning)	65 Hz / (180 Hz w/binning)
Cooling	N/A	N/A	N/A
Frame Grabber	NI-PCI 1428*	N/A	NI-1429
Pixel Size	7.4 µm x 7.4 µm	6.45 µm x 6.45 µm	
Camera Control	Base CameraLink	Firewire	CameraLink
Exposure Time Range	0.1 - 100 ms	1 µm - 120 s	0.1 - 100 ms
Power Consumption	< 5 W	< 5W	< 5 W
Input Voltage	24 V	24 V	24 V

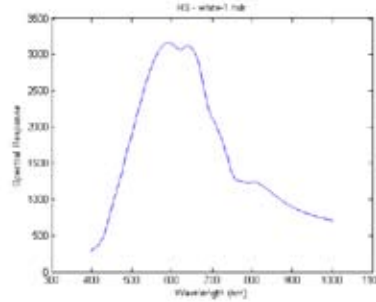
Environmental Characteristics

Storage	-20 to 50 C	-20 to 50 C	-20 to 50 C
Operating	5 to 40 C non-condensing	5 to 40 C non-condensing	5 to 40 C non-condensing
Size (LxWxH)	330 x 85 x 90 mm	330 x 85 x 90 mm	330 x 85 x 90 mm

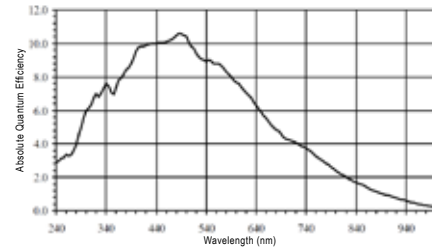
Mechanical Characteristics

Body	Anodized Al w/mounting screw holes (for all)		
Weight	5.0 kg	5.0 kg	2.7 kg
Lens Mount	Standard C-mount	Standard C-mount	Standard C-mount
User Adjustments	None	None	None
Shutter	Yes, w/USB control	Yes	Yes, w/USB control

The PS Series hyperspectral cameras provide high spatial and spectral resolution, low noise, and a rugged structure for VNIR applications in the laboratory and the field. Each camera is an integration of an imaging spectrograph and a monochrome area camera (sensitive high speed interline CCD sensor) and contains a Firewire interface. The user can choose either a low-cost Standard Series spectrograph (ImSpector V10), or an Enhanced Series spectrograph (ImSpector V10E) that provides higher quality images.



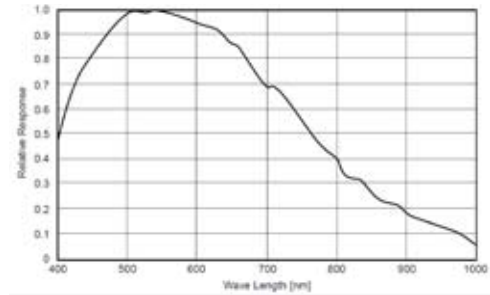
Spectral response of HS camera with spectral flattening filter



Spectral response of HS camera without flattening filter

The PFD Series of hyperspectral cameras is a new family of visible and VNIR cameras which are based on a CMOS sensor and include a CameraLink interface.

The VNIR camera may be combined with a SWIR hyperspectral camera to extend the wavelength range to the entire 400-2500 nm region.



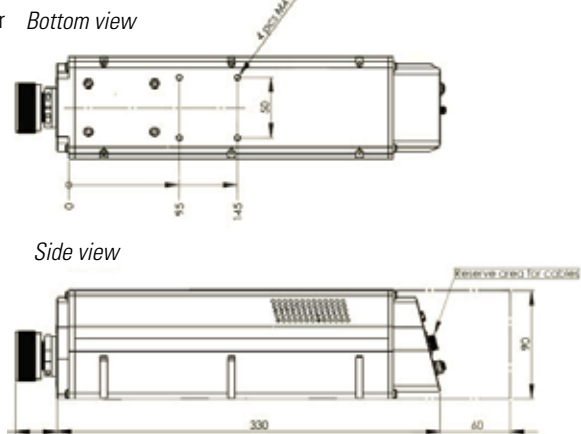
Spectral response of PS camera without flattening filter

The VNIR camera extends the capabilities of a visible hyperspectral camera to 1000 nm, thus allowing additional application options and performance.

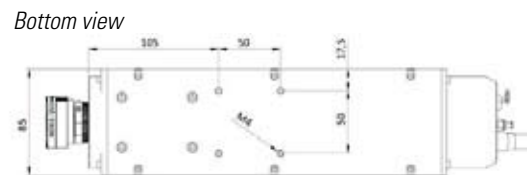
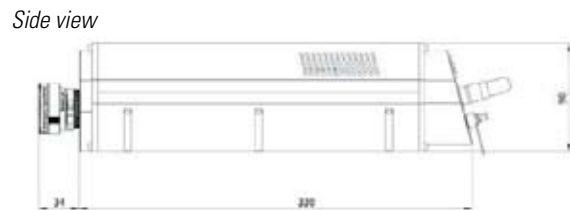
Note: All VNIR cameras with enhanced spectrographs can be used with mirror more details.

Applications

- Forensics
- Scanning of art works
- Counterfeit detection
- Fruit and vegetable ripeness and bruising
- Life science applications including fluorescence monitoring
- Plant and vegetation research
- Environmental monitoring
- Hyperspectral microscopy



HS V10E & PS V10E Cased cameras



PFD V10E Cased cameras

VNIR Cased Cameras Ordering Information		
Part Number	Description	Product Name
MRC-303-002-01	VNIR Spectral Camera with Enhanced Spectrograph. 11 fps, 1392x1040 IT CCD, Firewire, cables included	PS-FW-11-V10E
MRC-303-002-02	VNIR Spectral Camera with Enhanced Spectrograph. 30 fps, 1600x1200 IT CCD, Cameralink frame grabber + cables	HS-CL-30-V10E
MRC-303-002-05	VNIR Spectral Camera with Enhanced Spectrograph. 65 fps, 1312x1024 CMOS, CameraLink frame grabber + cables	PFD-CL-65-V10E

VNIR 400 – 1000 nm, continued

HYPERSPECTRAL CAMERAS

The uncased VNIR camera models are fully functional hyperspectral cameras without the housing. These models are more economical but lack the protection provided by the exterior casing. Uncased models also lack the computer controlled shutter that is included in complete cameras for the purpose of establishing the dark background levels.

The VNIR uncased camera package includes: power supply (CameraLink cameras only), Firewire cable (Firewire cameras only), National Instruments CameraLink frame grabber and data cable (CameraLink cameras only), power cord set, and software CD.

Uncased Camera Specifications

Optical Characteristics	PS-FW-11-V10-OEM	HS-CL-30-V10E-OEM	PS-FW-11-V10E-OEM	PFD-CL-65-V10E-OEM
Range (nm)	400-1000	400-1000	400-1000	400-1000
Resolution (spatial x spectral)	1392 x 1040 (990 active)	1600 x 1200 (840 active)	1392 x 1040 (950 active)	1312 x 1024
Spectrograph	ImSpector V10	ImSpector V10E	ImSpector V10E	ImSpector V10E
Spectral Resolution	6.8 nm (30 µm slit)	2.8 nm (30 µm slit)	2.8 nm (30 µm slit)	2.8 nm (30 µm slit)
Spectral Sampling	0.63 - 5.0 nm/pixel	0.72 - 5.8 nm/pixel	0.63 - 5.06 nm/pixel	0.78 - 6.27 nm/pixel
Spatial Resolution	RMS spot diameter < 80 µm	RMS spot diameter < 9 µm	RMS spot diameter < 18 µm	RMS spot diameter < 9 µm
Aberrations	Smile < 45 µm, keystone < 40 µm	Insignificant astigmatism, keystone or smile	Insignificant astigmatism, keystone or smile	Insignificant astigmatism, keystone or smile
Numerical Aperture	F/2.8	F/2.4	F/2.4	F/2.4
Slit Width, default	50 µm (25, 80, 150 µm)	30 µm (18, 50, 80, 150 µm)	30 µm (18, 50, 80, 150 µm)	30 µm (18, 50, 80, 150 µm)
Effective Slit Length	8.98 mm	11.84 mm	8.98 mm	10.50 mm
Total Efficiency (typical)	> 50%, independent of polarization	> 50%, independent of polarization	> 50%, independent of polarization	> 50%, independent of polarization
Stray Light	< 0.5% (halogen lamp, 590 nm low-pass filter)	< 0.5% (halogen lamp, 590 nm low-pass filter)	< 0.5% (halogen lamp, 590 nm low-pass filter)	< 0.5% (halogen lamp, 590 nm low-pass filter)

Electrical Characteristics

Sensor	Interline CCD	Interline CCD	Interline CCD	CMOS
Interface	Firewire	Base CameraLink	Firewire	Base CameraLink
Camera Output	Digital 12-bit	Digital 12-bit	Digital 12-bit	Digital 12-bit
Frame rate (full / binning)	11 Hz / 62 Hz (1 x 8 binning)	33 Hz / 120 Hz	11 Hz / 62 Hz (1 x 8 binning)	65 Hz / (180 Hz w/binning)
Cooling	N/A	N/A	N/A	N/A
Frame Grabber	N/A	NI-PCI 1428*	N/A	NI-1429
Pixel Size	6.45 µm x 6.45 µm	7.4 µm x 7.4 µm	6.45 µm x 6.45 µm	
Camera Control	Firewire	Base CameraLink	Firewire	CameraLink
Exposure Time Range	1 µm - 120 s	0.1 - 100 ms	1 µm - 120 s	0.1 - 100 ms
Power Consumption	< 5W	< 5 W	< 5W	< 5W
Input Voltage	12 V	12 V	12 V	12 V

Environmental Characteristics

Storage	-20 to 50 C	-20 to 50 C	-20 to 50 C	-20 to 50 C
Operating	5 to 40 C non-condensing	5 to 40 C non-condensing	5 to 40 C non-condensing	5 to 40 C non-condensing
Size (LxWxH)	220 x 60 x 70	260 x 70 x 79 mm	241 x 73 x 79 mm	231 x 80.5 x 78 mm

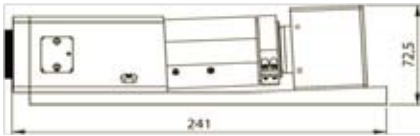
Mechanical Characteristics

Weight	1.8 kg	1.8 kg	1.8 kg	1.8 kg
Body	Anodized Al w/mounting screw holes	Anodized Al w/mounting screw holes	Anodized Al w/mounting screw holes	Anodized Al w/mounting screw holes
Lens Mount	Standard C-mount	Standard C-mount	Standard C-mount	Standard C-mount
User Adjustments	None	None	None	None
Shutter	No	Optional	Optional	Optional

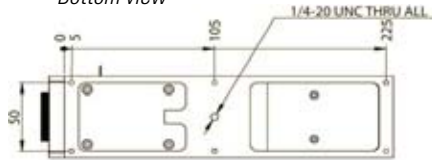
PS V10E OEM



Side view



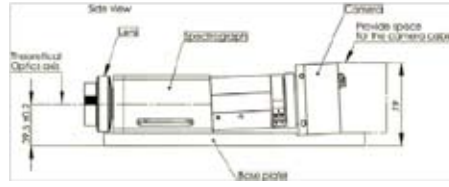
Bottom view



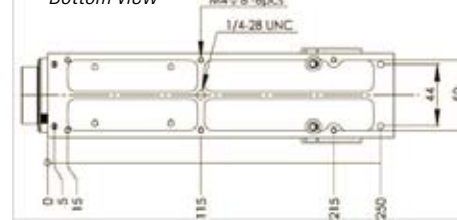
HS V10E OEM



Side view



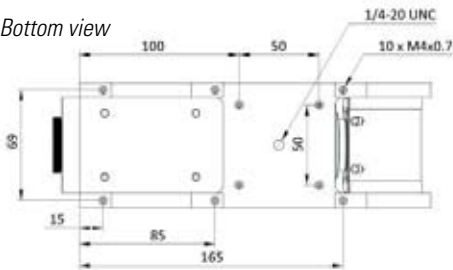
Bottom view



PFD V10E OEM



Bottom view



Side view



PS V10 OEM



VNIR Uncased Cameras Ordering Information

Part Number	Description	Product Name
MRC-301-002-01	OEM VNIR Spectral Camera, with Standard Spectrograph. 11 fps, 1392x1040 IT CCD, Firewire, cables included	PS-FW-11-V10-OEM
MRC-302-002-03	OEM VNIR Spectral Camera, with Enhanced Spectrograph. 30 fps, 1600x1200 IT CCD, CameraLink frame grabber + cables	HS-CL-30-V10E-OEM
MRC-302-002-01	OEM VNIR Spectral Camera, with Enhanced Spectrograph. 11 fps, 1392x1040 IT CCD, Firewire, cables included	PS-FW-11-V10E-OEM
MRC-302-002-06	OEM VNIR Spectral Camera, with Enhanced Spectrograph. 65 fps, 1312x1024 CMOS, CameraLink frame grabber + cables	PFD-CL-65-V10E-OEM

NIR 900 – 1700 nm HYPERSPECTRAL CAMERAS

Middleton Research offers several different hyperspectral cameras within the 900-1700 nm near-infrared range from Specim Ltd. For the extended wavelength range of 970-2500 nm, please refer to the SWIR hyperspectral camera section. NIR cameras provide high spatial resolution (320 or 640 pixels) and high-speed frame rate of 100-400 Hz, suitable for various on-line chemical imaging applications. Each camera is an integration of an imaging spectrograph (ImSpector N17E) and a monochrome area camera (temperature-stabilized InGaAs sensor) and includes either a USB or CameraLink interface. The spectrographs in the NIR cameras are designed for high light throughput and a distortion-free image on the detector. The NIR hyperspectral cameras are equipped with a software-controlled shutter for dark reference measurements and are available as either cased or uncased.

Applications

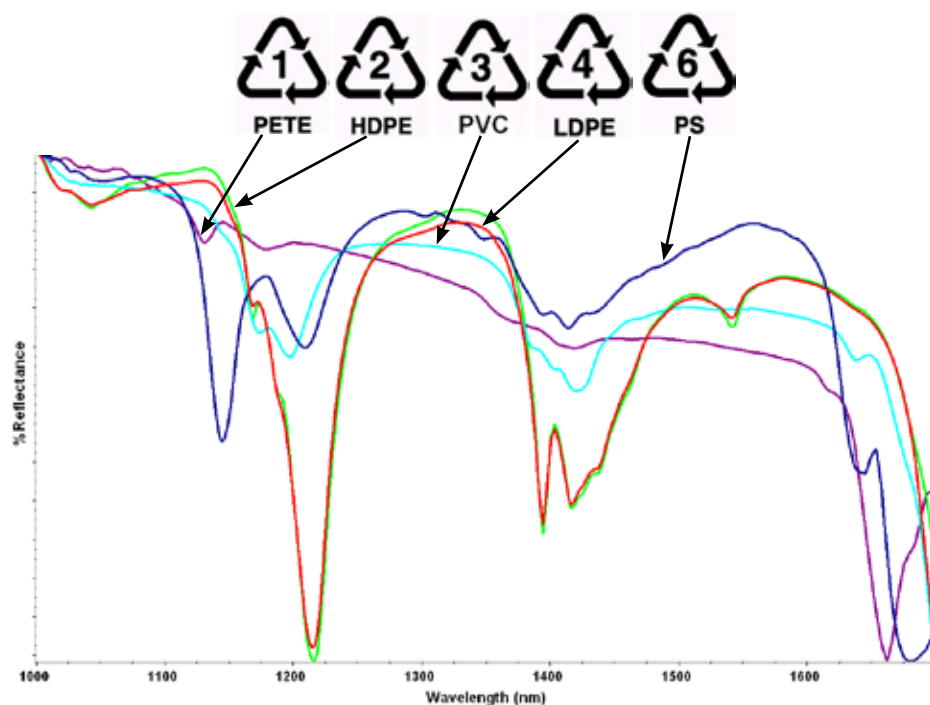
- Moisture profiling
- Food analysis
- Chemical sorting
- Recycling/plastics sorting
- Pharmaceutical quality control
- Medical imaging
- Cosmetics analysis

Cased Camera Package

- Control unit and shutter
- Power supply
- USB cable (1 for the CameraLink cameras, 2 for the USB cameras)
- National Instruments CameraLink frame grabber and data cable (CameraLink cameras only)
- Control cable
- Power cord set
- Software CD

Uncased Camera Package

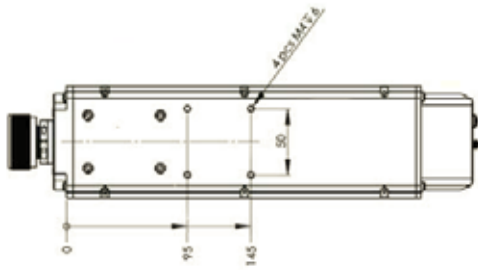
- Power supply
- USB cable (1)
- National Instruments CameraLink frame grabber and data cable (CameraLink cameras only)
- Power cord set
- Software CD



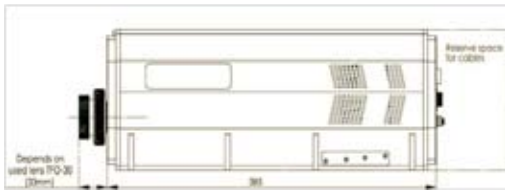
Spectra of recyclable plastics



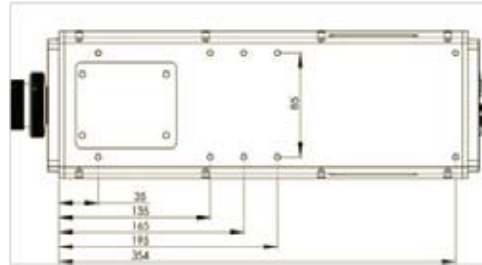
XL/XF/VL Cased



Side view



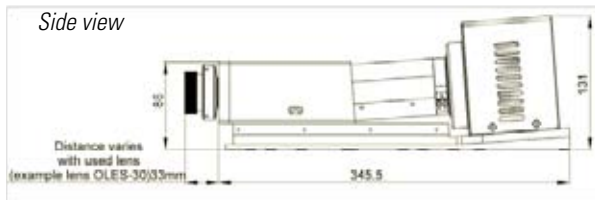
Bottom view



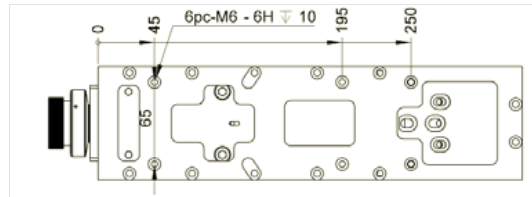
XL/XF OEM



Side view



Bottom view



NIR 900 – 1700 nm, continued

HYPERSPPECTRAL CAMERAS

Cased and Uncased Camera Specifications

Optical Characteristics	XL	XF	VL
Range (nm)	900-1700	900-1700	900-1700
Resolution (spatial x spectral)	320 x 256 (240 active)	320 x 256 (240 active) or 640 x 512	320 x 256 (240 active)
Spectrograph	ImSpector N17E	ImSpector N17E	ImSpector N17E
Spectral Resolution	5 nm (30 µm slit)	5 nm (30 µm slit)	5 nm (30 µm slit)
Spectral Sampling	4 nm/pixel	4 nm/pixel	4 nm/pixel
Spatial Resolution	RMS spot diameter < 30 µm	RMS spot diameter < 30 µm	RMS spot diameter < 30 µm
Aberrations	Insignificant astigmatism, smile or keystone	Insignificant astigmatism, smile or keystone	Insignificant astigmatism, smile or keystone
Numerical Aperture	F/2.0	F/2.0	F/2.0
Slit Width, default	30 µm (18, 50, 80 µm)	30 µm (18, 50, 80 µm)	30 µm (18, 50, 80 µm)
Effective Slit Length	9.6 mm	9.6 mm	9.6 mm
Total Efficiency (typical)	> 50%, independent of polarization	> 50%, independent of polarization	> 50%, independent of polarization
Stray Light	< 0.5 % (halogen lamp, 1400 nm notch filter)	< 0.5 % (halogen lamp, 1400 nm notch filter)	< 0.5 % (halogen lamp, 1400 nm notch filter)

Electrical Characteristics

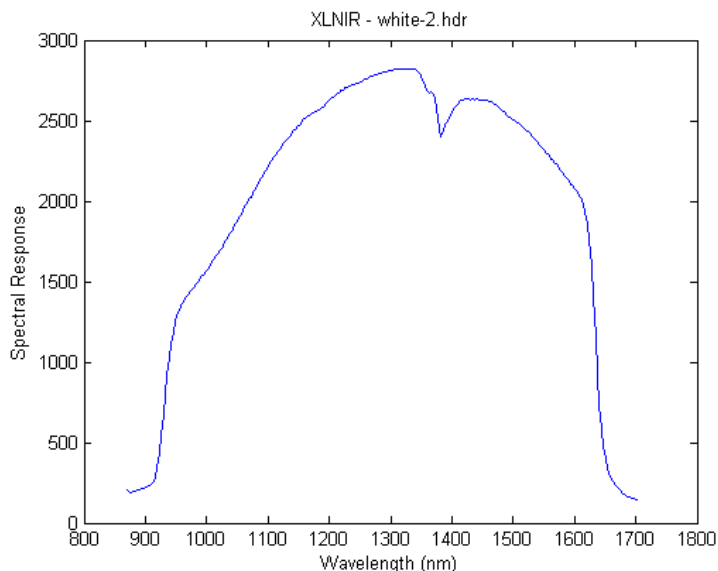
Sensor	TE-cooled InGaAs photodiode array	TE-cooled InGaAs photodiode array	TE-cooled InGaAs photodiode array
Interface	USB or Base CameraLink	Base CameraLink	Base CameraLink
Camera Output	12-bit, USB2, CameraLink	12-bit, USB2, CameraLink	12-bit, CameraLink
Frame rate (full)	100 Hz	120, 350, or 400 Hz	100 Hz
Cooling	Forced convection cooling	Forced convection cooling	Forced convection cooling
Frame Grabber	NI-PCI 1428 (CameraLink Cameras only)	NI-PCI 1428	NI-PCI 1428
Pixel Size	30 x 30 µm	30 x 30 µm	30 x 30 µm
Camera Control	USB or CameraLink	CameraLink	CameraLink
Exposure Time Range	1 µs - 500 ms	1 µs - 500 ms	1 µs - 500 ms
Power Consumption	< 4 W, Cooler - 30 W	< 4 W, Cooler - 30 W	< 30 W
Input Voltage	12 V	12 V	12 V

Environmental Characteristics

Storage	-20 to 85 C	-20 to 85 C	-20 to 85 C
Operating	5 to 40 C, non-condensing	5 to 40 C, non-condensing	5 to 40 C, non-condensing

Mechanical Characteristics

	XL and XF		VL	
	Uncased	Cased	Uncased	Cased
Size (LxWxH)	350 x 100 x 130 mm	385 x 120 x 135 mm	350 x 100 x 115 mm	385 x 120 x 135 mm
Weight	4.5 kg	5.38 kg	4.4 kg	
Body	Anodized Al w/ mounting screw holes	Anodized Al w/mounting screw holes	Anodized Al w/mounting screw holes	Anodized Al w/mounting screw holes
Lens Mount	Standard C-mount	Standard C-mount	Standard C-mount	Standard C-mount
User Adjustments	None	None	None	None
Shutter	Optional	Yes, w/USB control	Optional	Yes, w/USB control



Spectral response of NIR camera with spectral flattening filter

NIR Cased and Uncased Cameras Ordering Information		
Part Number	Description	Product Name
MRC-303-003-01	NIR Spectral Camera with Enhanced Spectrograph. 100Hz, 320x256 InGaAs, USB, cables included	XLNIR-USB-100-N17E
MRC-302-003-01	OEM NIR Spectral Camera, with Enhanced Spectrograph. 100Hz, 320x256 InGaAs, USB, cables included	XLNIR-USB-100-N17E-OEM
MRC-303-003-02	NIR Spectral Camera with Enhanced Spectrograph; 100Hz, 320x256 InGaAs, CameraLink frame grabber+cable	XLNIR-CL-100-N17E
MRC-302-003-02	OEM NIR Spectral Camera with Enhanced Spectrograph; 100Hz, 320x256 InGaAs, CameraLink frame grabber+cable	XLNIR-CL-100-N17E-OEM
MRC-303-003-06	NIR Spectral Camera with Enhanced Spectrograph.350 Hz, 320x256 InGaAs, CameraLink frame grabber + cable	XFNIR-CL-350-N17E
MRC-302-003-06	OEM NIR Spectral Camera, with Enhanced Spectrograph. 350 Hz, 320x256 InGaAs, CameraLink frame grabber + cable	XFNIR-CL-350-N17E-OEM
MRC-302-003-07	OEM NIR Spectral Camera, with Enhanced Spectrograph. 120 Hz, 640x512 InGaAs, CameraLink frame grabber + cable	XFNIR-CL-120-N17E-OEM
MRC-302-003-08	OEM NIR Spectral Camera, with Enhanced Spectrograph. 400 Hz, 640x512 InGaAs, CameraLink frame grabber + cable	XFNIR-CL-400-N17E-OEM
MRC-303-003-03	NIR Spectral Camera with Enhanced Spectrograph.100Hz, 320x256 InGaAs, Cameralink frame grabber + cable	VLNIR-CL-100-N17E
MRC-302-003-03	OEM NIR Spectral Camera, with Enhanced Spectrograph. 100Hz, 320x256 InGaAs, Cameralink frame grabber + cable	VLNIR-CL-100-N17E-OEM

SWIR 1000 – 2500 nm HYPERSPPECTRAL CAMERA

Middleton Research offers a high-speed short-wave infrared hyperspectral camera from Specim Ltd covering the wavelength range of 1000-2500 nm. For the NIR range (900-1700 nm), please refer to the NIR hyperspectral camera section. The SWIR camera is one of the most versatile hyperspectral cameras offering an extended wavelength range. The SWIR camera is an excellent solution for chemical imaging applications including pharmaceutical quality monitoring, plastics sorting, and food analysis. The hyperspectral camera is an integration of an imaging spectrograph (ImSpector N25E) and a four-stage cooled mercury-cadmium-telluride (MCT) focal plane array camera. The optical elements and transmission diffraction grating are designed for a high quality image on the detector. The MCT detector is thermoelectrically cooled to minimize the dark current and provides high sensitivity and stability. The temperature stability and rugged housing enable the camera to be used in outdoor and process applications.

Features

- Non-uniformity correction at different camera integration times to account for the possible pixel-to-pixel differences of the actual FPA camera component
- Wavelength calibration to achieve best wavelength accuracy across the entire wavelength range
- Compatibility with optional SpectralDAQ camera driver and data collection software

SWIR Camera Package

- Controller Module to drive the thermoelectric cooling, control the built-in shutter and to communicate with the camera
- Power supply for both the camera and controller
- Cables
 - LVDS data cable to connect the camera and the frame grabber
 - USB to connect the computer and the Controller
 - Serial cable for camera control
 - Controller Cable to connect the Controller and the SWIR camera
- National Instruments (NI) LVDS frame grabber with NI Image Acquisition software
- Power cord set
- Calibration files and calibration report
- Software CD



SWIR camera controller module

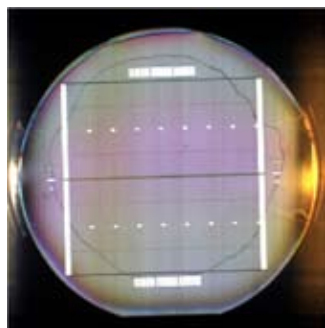


Applications

- Chemical imaging for research and development
- Process Analytical Technology applications
- Pharmaceutical manufacturing monitoring
- Plastics sorting
- Mineral mapping
- Food and agricultural product analysis
- Moisture content distribution
- Semiconductor quality monitoring



SWIR camera mounted for industrial monitoring



Semi-conductors / Solar cells



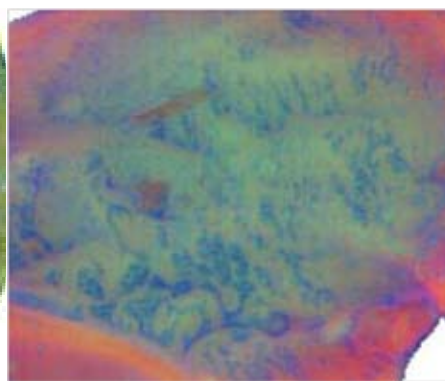
Art



Bio-tech



Pharmaceuticals



Dairy

SWIR 1000 – 2500 nm HYPERSPPECTRAL CAMERA

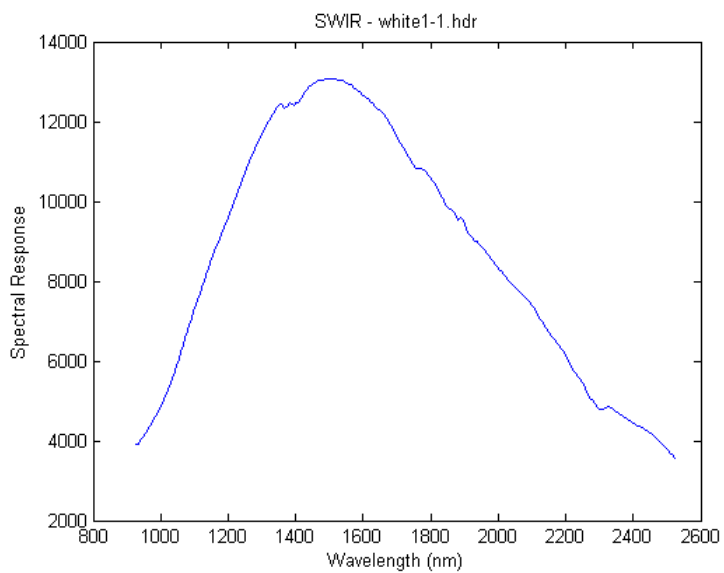
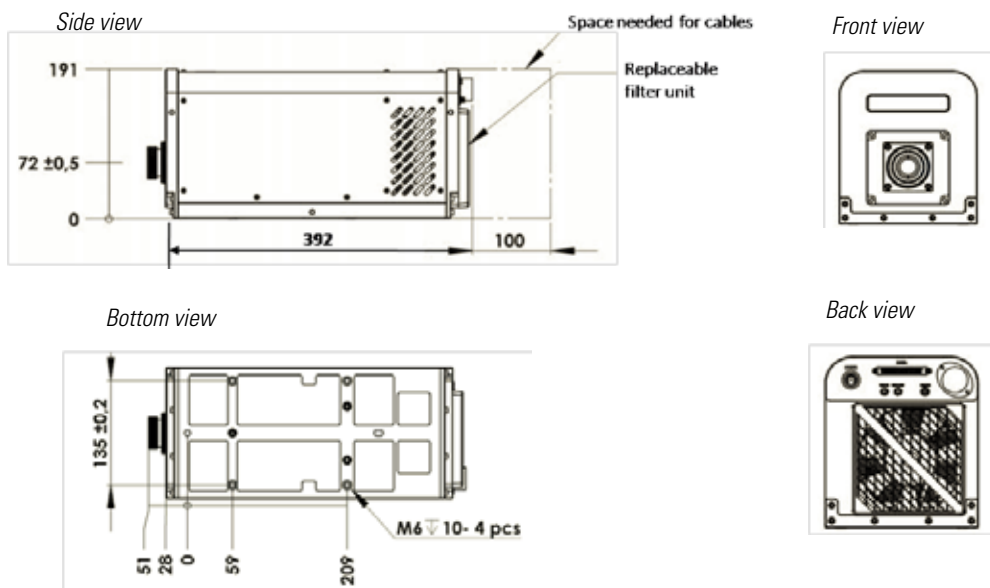
SWIR Camera Specifications

Optical Characteristics	SWIR-LVDS-100-N25E
Range (nm)	1000-2500
Resolution (spatial x spectral)	320 x 256 (240 active)
Spectrograph	ImSpector N25E
Spectral Resolution	10 nm (30 µm slit)
Spectral Sampling	6.3 nm/pixel
Spatial Resolution	RMS spot diameter < 30 µm
Aberrations	Insignificant astigmatism, smile or keystone < 5 µm
Numerical Aperture	F/2.0
Slit Width, default	30 µm (50 or 80 µm available on request)
Effective Slit Length	9.6 mm
Total Efficiency (typical)	> 50 %, independent of polarization
Stray Light	< 0.5 % (halogen lamp, 1400 nm notch filter)

Electrical Characteristics	
Sensor	MCT camera
Interface	LVDS
Camera Output	14-bit LVDS
Frame rate (full / binning)	100 Hz
Cooling	4-stage Peltier for detector array, additional Peltier for active cooling of the detector package
Frame Grabber	NI-PCI 1422
Pixel Size	30 x 30 µm (pixel size)
Camera Control	Serial Port
Exposure Time Range	0.1 - 20 ms
Power Consumption	< 200 W
Input Voltage	24 V
Signal-to-noise ratio	800:1 (at max. signal level)
Data cable	length: 5 m

Environmental Characteristics	
Storage	-20 to 50 C
Operating	5 to 40 C, non-condensing

Mechanical Characteristics	
Size (LxWxH)	Sensor: 329 x 170 x 151 mm Power supply: 120 x 240 x 70 mm Control module: 260 x 260 x 95 mm
Weight	Sensor: 8.5 kg, Power supply: 1.9 kg, Control box: 3.4 kg
Body	Anodized Al and painted steel w/mounting screw holes
Lens Mount	Standard C-mount
User Adjustments	No
Shutter	Yes



Spectral response of SWIR camera with spectral flattening filter

SWIR Cased Camera Ordering Information		
Part Number	Description	Product Name
MRC-303-005-01	SWIR Spectral Camera with Enhanced Spectrograph. 100Hz MCT LVDS frame grabber and cable included	SWIR-LVDS-100-N25E

LWIR 8 – 12 μm HYPERSPSCTRAL CAMERAS

Middleton Research offers three long-wave infrared hyperspectral cameras covering the range 8-12 μm from Specim Ltd. These cameras are used in various applications including security, camouflage detection, and geological mapping. The three models optimize different parameters, such as sensitivity and resolution.

High Sensitivity HS Model

The LWIR hyperspectral camera has an uncooled bolometer FPA camera with a wavelength range of 8-12 μm , a moderate spectral resolution of 200 nm, and 30 spectral bands. It is a compact model that is appropriate for many industry applications.

LWIR-HS / LWIR-HR



LWIR Camera Specifications

Optical Characteristics	LWIR HS	LWIR HR	LWIR C
Range	8-12 μm	8-12 μm	8-12 μm
Resolution (spatial x spectral)	384 x 42	384 x 119	384 x 84
Spectral Resolution	400 nm	100 nm diffraction limited	100 nm diffraction limited
Spectral Sampling	145 nm / band	50 nm / band	48 nm / band
Spatial Sampling	0.0564 degrees	0.0564 degrees	0.063 degrees
Aberrations	Insignificant astigmatism, smile or keystone < 0.1 pixels	Insignificant astigmatism, smile or keystone < 0.1 pixels	Insignificant astigmatism, smile or keystone < 0.1 pixels
Optics temperature	Uncooled	Uncooled	Stabilized
Numerical Aperture	F/1.0	F/1.0	F/2.0
Field of View	With fore lens L62: 21 degrees	With fore lens L62: 21 degrees	With fore lens L43: 24 degrees

Electrical Characteristics

Sensor	LWIR uncooled microbolometer	LWIR uncooled microbolometer	MCT
Camera Output	14-bit LVDS	14-bit LVDS	14-bit LVDS
Frame rate (full / binning)	60 Hz	60 Hz	100 Hz
Cooling	Uncooled	Uncooled	Stirling-cycle cooler
Frame Grabber	NI-PCI 1422 or 1424s National Instruments	NI-PCI 1422 or 1424 National Instruments	NI-PCI 1422 or 1424 National Instruments
Pixel Size	25 x 25 μm (pizel size)	25 x 25 μm (pizel size)	24 x 24 μm (pizel size)
Power Consumption	3.5 W	3.5 W	< 200 W
Signal-to-noise ratio	Target 400 K, 8 μm : 240, 10 μm : 210, 12 μm : 180 *	Target 800 K, 8 μm : 530, 10 μm : 402, 12 μm : 150 *	Target 300 K, 8 μm : 450, 10 μm : 580, 12 μm : 230 *
NESR (mW / m2sr μm)	8 μm : 171, 10 μm : 161, 12 μm : 139 *	8 μm : 2130, 10 μm : 1540, 12 μm : 2470 *	8 μm : 21, 10 μm : 18, 12 μm : 40 *
NETD / spectral pixel			0.2 K *

Environmental Characteristics

Storage	-20 to 50 C	-20 to 50 C	-20 to 50 C
Operating	5 to 40 C, non-condensing	5 to 40 C, non-condensing	5 to 40 C, non-condensing

Mechanical Characteristics

Size (LxWxH)	100 x 143 x 185 mm	100 x 143 x 185 mm	175 x 285 x 200 mm
Weight	3.5 kg	3.5 kg	13.1 kg
Body	Anodized Al and painted steel	Anodized Al and painted steel	Anodized Al and painted steel
Shutter	Yes (shutter / internal calibration)	Yes (shutter / internal calibration)	Yes (shutter / internal calibration)

* x2 software binning

Please note: Specifications are subject to change without notice.



High Resolution HR Model

The LWIR HR model has a wavelength range of 8-12 μm and a high spectral resolution of 70 nm and 85 bands, ideal for applications where the targets are at temperatures higher than ambient or where an IR source is used to illuminate the sample. The HR model is based on an uncooled bolometer FPA camera. Similar to the HS model, the HR model is compact and useful in many applications including gas emissions analysis and IR chemical imaging.

Cooled C Model

The LWIR C model has a wavelength range of 8-12 μm and is an integration of a state-of-the-art temperature-stabilized imaging spectrograph and a cooled, highly sensitive MCT FPA detector. With a spectral resolution of 48 nm, 84 spectral bands, and an image rate of up to 100 Hz, the LWIR hyperspectral camera C model is ideal for the most challenging ground-based applications including remote sensing and security.

Applications

- Geological mapping
- Mineral classification
- Volcanology
- Water temperature
- Camouflage detection
- Gas detection
- Flame analysis
- Land cover type recognition



LWIR-C

LWIR Camera Package

- Fore objective
- Control unit including power supply
- Control cable
- LVDS frame grabber
- LVDS data cable
- Power cord set
- Software CD
- Transport case

LWIR Camera Comparative Performance

SNR Table

Spectral Camera	300K	400K	800K	NESR
LWIRHS	63	210	1250	160 mW/(m ² srμm)
LWIRC	630	1600	-	16 mW/(m ² srμm)
LWIRHR	17	67	402	1600 mW/(m ² srμm)

LWIR Cased Camera Ordering Information		
Part Number	Description	Product Name
MRC-303-007-01	LWIR hyperspectral camera - high sensitivity model	LWIRHS-LVDS-60-L120P
MRC-303-007-02	LWIR hyperspectral camera - high resolution model	LWIRHR-LVDS-60-L140M
MRC-303-007-03	LWIR hyperspectral camera - cooled model	LWIRC-LVDS-100-L120M