NIRvana® LN

SWIR For Science

- World's Most Sensitive SWIR Camera
- Liquid Nitrogen Cooling to -190°C
- <10 e-/p/s Dark Current and <15e- Read Noise
- Non-Destructive Readout Mode for Real-Time Monitoring
- Cold Shielding to Minimise Scene Noise

What Makes Scientific Quality SWIR Cameras?

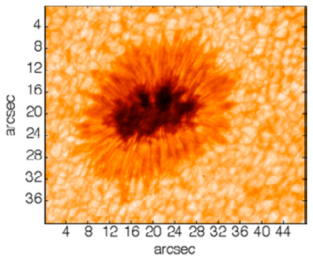
With Scientific Imaging comes unique challenges. Light levels are often low, image quality requirements are high, and reliability is paramount.

The NIRvana® range of Scientific InGaAs cameras from Teledyne Princeton Instruments is specifically designed to meet the demanding requirements of scientific imaging.

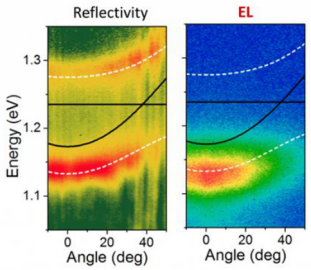
With sensitivity often the primary requirement for scientific imaging, **the NIRvana range uses large pixels, high quantum efficiencies and unbeaten low dark current noise to provide industry-leading signal to noise ratios**. Combined with this is the incredible image quality achieved through advanced pixel correction algorithms, overcoming the inherent challenges of InGaAs sensors.

Camera noise sources are not alone in infrared imaging. Thermal photons from the scene and from the camera housing are ever-present, conveying background noise. The NIRvana series uses integrated cold shielding to keep these photons, and hence this unwanted background noise out of images.

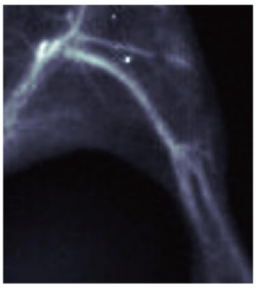
High speeds and short minimum exposure times provide the versatility required for scientific imaging. From whole animal imaging to spectroscopy of nanomaterials, the NIRvana range has a solution for your application.



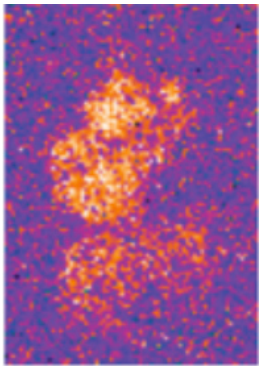
Sunspot Imaging



Imaging & Spectroscopy of Nanomaterials



In vivo *Imaging*



Singlet Oxygen Imaging

Further Benefits of the NIRvana LN:

- Liquid nitrogen cooling with 30+ hours hold time
- Maximum exposure times of over 1 hour capture the dimmest signals
- Non-Destructive Readout allows real-time monitoring of long-exposure acquisitions
- Imaging and spectroscopy possible within one powerful, intuitive software package

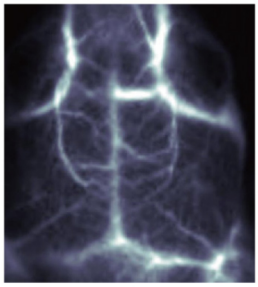
NIRvana Application Highlights

NIRvana® has a peerless scientific pedigree with **10 publications in Nature journals using NIRvana® cameras since 2017**. Whatever your scientific interest, and whether your research takes place in a university lab or in industry, the NIRvana range of cameras is there to deliver the performance you need.

NIRvana cameras cover a massive range of application areas. Below are some comments shared with us by researchers using NIRvana in their experiments.

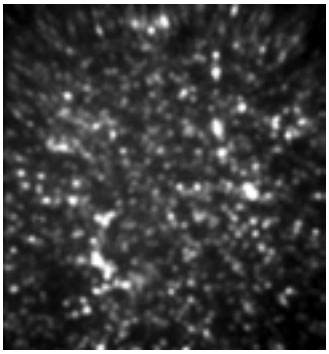
- Nanotube fluorescence
- Small-animal imaging
- Nondestructive testing
- Semiconductor analysis
- NIR probe development
- NIR-II imaging
- NIR spectroscopy
- 1064 nm Raman spectroscopy
- Astronomy (J band, H band)
- Adaptive optics
- Low-light / night vision
- Laser-illumination imaging

Deep Penetration *in vivo* Imaging in NIR-II



"The NIRvana 640 is highly sensitive, with a high signal-to-noise ratio, providing clear structural information about the blood vessels."

Prof. Fan Zhang, & Dr. Zhang Hongxin,
Department of Chemistry, Fudan University, China



Measuring Spectra of Single Quantum Dots

"The unprecedented long integration times and low dark counts [of the NIRvana LN] enabled single-nanocrystal spectral experiments, which cannot be achieved with conventional InGaAs detectors for these dots."

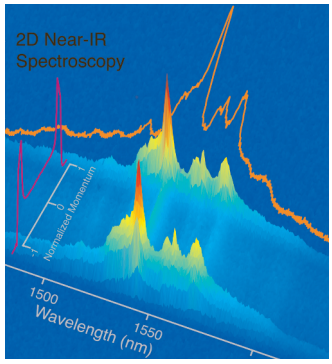
Dr. Han Htoon,
Center for Integrated Nanotechnologies, Los Alamos National Laboratory

Energy-Momentum Resolved Spectroscopy

"Unlike other InGaAs 2D detectors we tested, the TE cooling and background subtraction features have allowed us to easily acquire long exposures to resolve photoluminescence from very dilute emitter samples."

Prof. Rashid Zia,

School of Engineering, Brown University, USA



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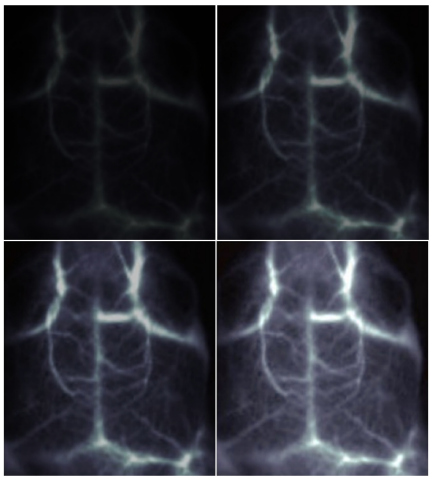
What Sets NIRvana Apart

Liquid Nitrogen Cooling

The NIRvana LN is cooled by liquid nitrogen down to an unbelievable -190°C (80K). With this deep cooling comes incredible performance: less than 10e-/p/s of dark current. This is a value some 3 orders of magnitude lower than typical thermo-electrically cooled cameras.

With such low dark current, exposure times of over an hour are within reach, enabling researchers to see the unseen.



Non-Destructive Readout

During exposure times of up to an hour, how can you make sure that you're only capturing the light you want to capture? The NIRvana LN has a unique capability: Non-Destructive Read Out allows you to periodically check what the camera has captured during the elapse of one single long exposure, without resetting the collected signal. Never come back to overexposed images again.

Unparalleled Thermal Management

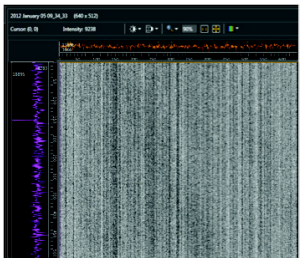
The exemplary thermal management and lifetime vacuum guarantee of NIRvana cameras demonstrate Teledyne Princeton Instruments' 40 years of experience in cooling technology.

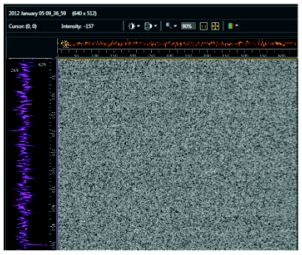
The low temperatures achieved, and as importantly the stability with which they are maintained, provide the lowest noise for long exposures and vital baseline stability for quantitative measurements[1].

Our all-metal hermetic vacuum seals are completely maintenance-free. The NIRvana series are the only SWIR cameras guaranteed against moisture or loss of vacuum for the entire lifetime of the camera.

[1] - For further information, please see our NIRvana Thermal Management Technical Note: www.princetoninstruments.com/nirvana/thermal

Optimum Image Quality

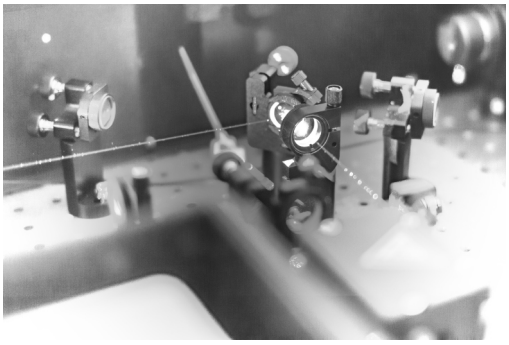




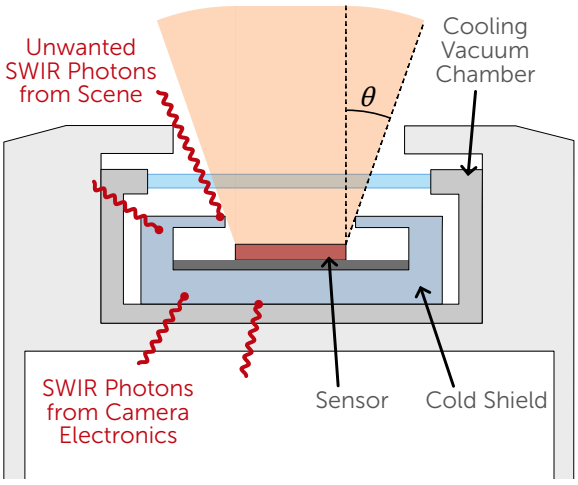
InGaAs sensors are subject to a number of factors that affect image quality. Individual pixel defects, star defects, column-to-column variations and multiple pixel clusters are all universal features of InGaAs sensors. Without careful correction, these defects can throw off analysis routines and reduce image quality.

The NIRvana range of cameras have unique capabilities for dealing with these defects powerfully and transparently[2], providing a scientific image quality and imaging workflow that provides data you can trust.

Minimized Scene Noise



A unique challenge in infrared imaging is that SWIR photons are, in fact, everywhere. We aren't of course able to see them to allow us to easily trace and eliminate background photon sources. But all background light contributes background noise, which can in many cases outstrip camera-based noise sources depending on the severity. Indeed, due to blackbody radiation, all room temperature objects are constantly emitting SWIR photons, as are the electronic circuits and housings of SWIR cameras.



The NIRvana range of cameras features Cold Shielding. This is a physical barrier that blocks unwanted photons outside a specified cone angle, θ, as shown in the diagram opposite. This shield is cooled to the same ultra-low temperature as the sensor leading to negligible thermal photon emission[3].

Additionally, world-leading thermal management engineering isolates thermal photons from camera electronics and maintains a lower camera housing temperature, reducing further the possibility of unwanted photon detection.

[2] - For further information, please see our NIRvana Image Corrections Technical Note: www.princetoninstruments.com/nirvana/corrections

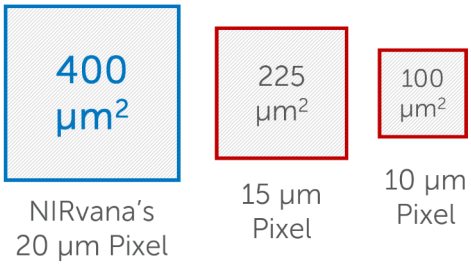
[3] - For further information, please see our NIRvana Cold Shielding Technical Note: www.princetoninstruments.com/nirvana/shielding

Unbeaten Sensitivity

The NIRvana range of cameras represent the height of SWIR sensitivity.

Large Pixels Collect More Light

As sensitivity scales with pixel area, the 20 µm pixels used by the NIRvana range of cameras provide 1.8x the light collection ability of a 15 µm pixel, and 4x that of a 10 µm pixel.

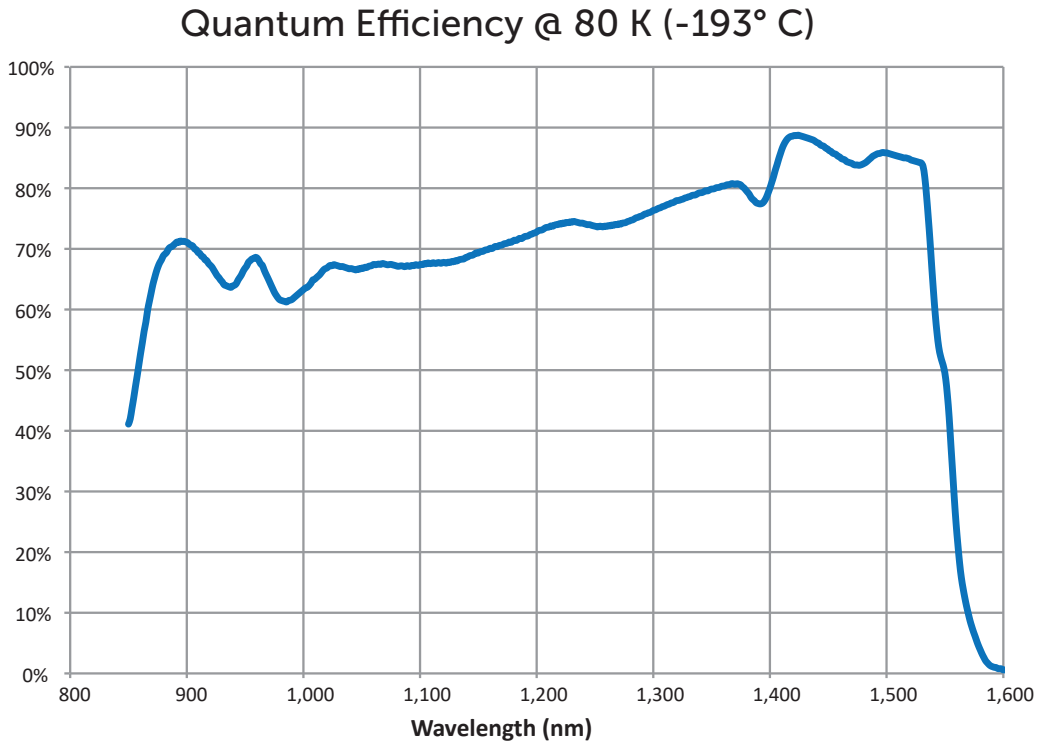


Low Noise Operation

Dark Current Noise is typically the largest noise source in InGaAs imaging. Due to the low cooling temperatures achieved, the NIRvana LN suffers the lowest dark current in InGaAs imaging, orders of magnitude below thermo-electrically cooled cameras. Combined with incredibly low read noise, the NIRvana LN provides the best signal to noise performance of any InGaAs camera.

High Quantum Efficiency

The NIRvana LN achieves high quantum efficiency across a broad range, from 880 to 1540nm, enabling low light imaging across the NIR-II / SWIR region.



Combining These Factors: Signal to Noise Ratio

What is the relative importance of pixel size, quantum efficiency, dark current, read noise, and all the other factors above? The answer depends upon your typical exposure time, background light level, and expected photon budget. But all the complexity can be set aside: **the Signal to Noise Ratio represents the entire balance of factors with one single number**[4]. Equation 1 shows how this is calculated:

$$SNR = \frac{Signal}{Total\ Noise} = \frac{I_s \times t_{exp} \times d_{pixel}^2 \times QE}{\sqrt{\left((I_s + I_b) \times t_{exp} \times d_{pixel}^2 \times QE\right) + \left(\sigma_d \times t_{exp}\right) + \sigma_r^2}}$$

Equation 1: Signal to Noise Ratio for InGaAs Cameras. The first term in Total Noise represents total photon shot noise.

I_s = Irradiance, i.e. incoming signal in (photons / second / μm²)
t_{exp} = Exposure time (seconds)
d_{pixel} = Pixel size (μm)
QE = Quantum Efficiency at the detection wavelength of interest
I_b = Background irradiance, i.e. all background signal (photons / second / μm²)
σ_d = Dark current (e- / pixel / second)
σ_r = Read noise (e-)

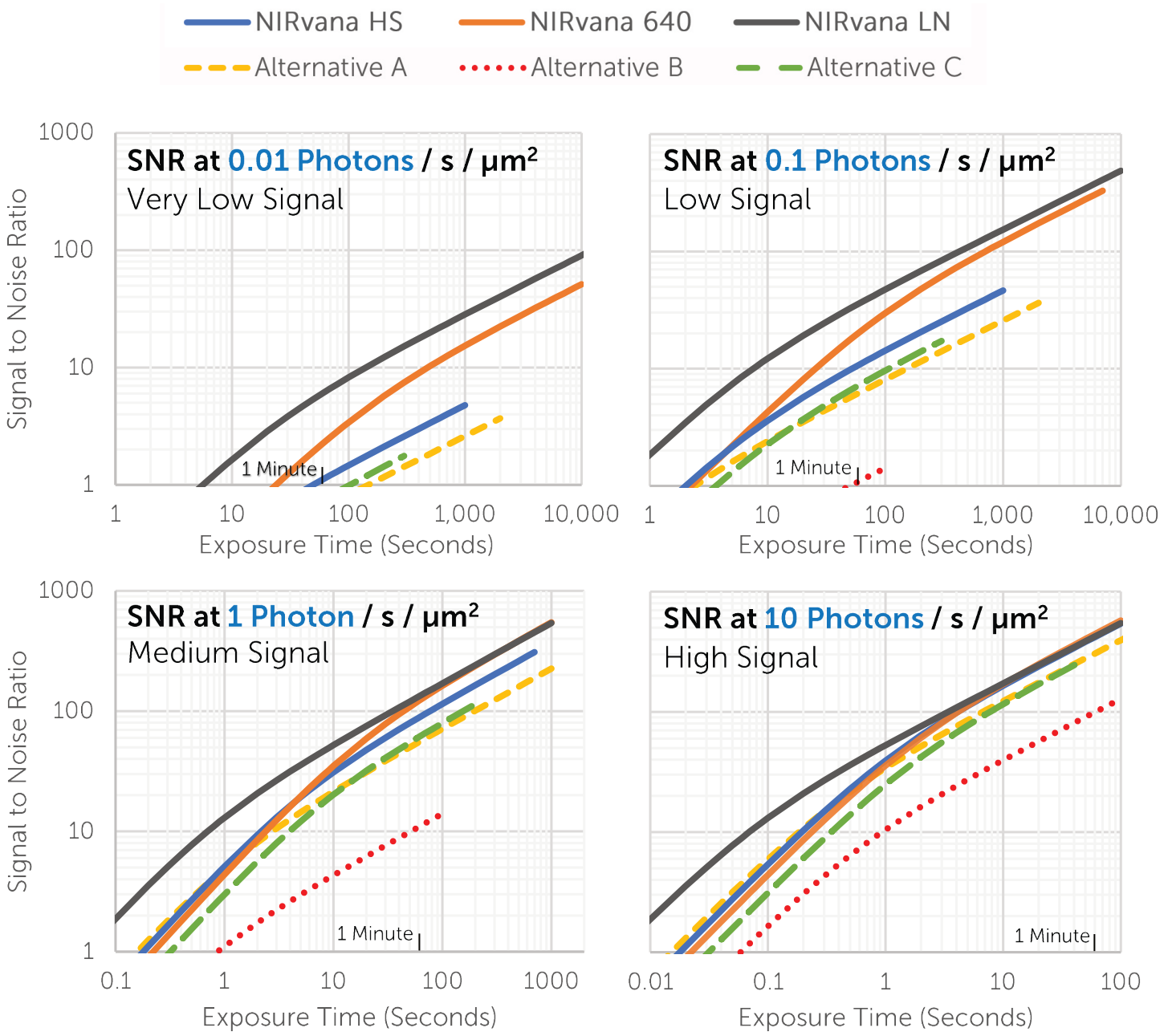
The graphs on the following page show the calculated signal to noise ratios of the three NIRvana cameras compared to three representative alternative cameras. For the calculation the contribution of scene noise from the experimental setup, I_b, is ignored.

Incoming signal is explored over 3 orders of magnitude from 'high' signals of 10 photons / s / μm², which would equate to 4000 photons per pixel per second for the NIRvana cameras, to 'very low' signals of 0.01 photons / s / μm², for which very long exposure times would be necessary to achieve adequate signal to noise. The graphs are shown up to the point where pixel saturation would occur through the combination of collected signal and dark current.

The dominance of low dark current and large pixel sizes is evident; **the NIRvana camera range offers superior sensitivity in practically every case.** For the alternative cameras, due to their higher dark current, saturation of the pixel is frequently seen before an adequate signal to noise ratio can be achieved.

In real-life imaging situations, scene noise that we discounted here will be present in almost all cases. The presence of **cold shielding** in the NIRvana range of cameras will then be very likely to **significantly increase the NIRvana cameras' lead in signal to noise ratio**, compared to alternatives without cold shielding which would suffer from greater background noise I_b.

[4] - For further information, please see our NIRvana Signal and Noise Technical Note: www.princetoninstruments.com/nirvana/signalandnoise



Camera	Read Noise	Dark Current	QE	Pixel Size	Full Well Cap.
Alternative A	30 e-	600 e-/p/s	90%	15 µm	1400 ke-
Alternative B	50 e-	4000 e-/p/s	90%	10 µm	450 ke-
Alternative C	55 e-	300 e-/p/s	80%	15 µm	110 ke-

Signal to Noise Ratio graphs for different incident signal levels, defined in photon flux, in photons per second per square micrometer incident on the pixel. Each SNR line ends at pixel saturation. The NIRvana range of cameras are shown in comparison to three alternative cameras representative of cameras on the market, with specifications given in the table above. Theoretical calculation based on specification sheet values.

NIRvana LN Specifications

Feature	NIRvana LN
Sensor	2D InGaAs FPA
Imaging format	640 x 512
Active area	12.8 mm x 10.24 mm
Pixel size	20 µm x 20 µm
Optical Mount	F-Mount, Spectrometer Mount
Spectral response	0.9 µm to 1.6 µm
Quantum efficiency	>70% from 1.3µm to 1.6µm; peak QE is 88%
Pixel well capacity (e-)	400,000 (typical)
Nominal gain (e-/count)	7
Typical system read noise (e-)	15 (typical)
Cooling temp. @ 20°C ambient	83K (-190°C) (typical)
Dark current (e-/p/s) @ 83K (190°C)[5]	10 (typical)
Thermostating precision	±1.0°C across entire temperature range
Cooling method; Hold time	Liquid nitrogen; >30 hours
Blemish specification[6]	Grade A: <2% defects
Cold shield[7]	f#/2.0; Light cone angle θ = 14.4°
Output interface	GigE
Digitization	16 bits
Scan rate	250KHz, 125KHz
Frame rate[8]	2.77 fps @ 250KHz 1.4 fps @ 125KHz
Readout modes	Standard readout mode, Non-destructive readout mode (NDRO)
Binning and ROI	Software only
Shutter	Global shutter
Exposure time	100 µs to >60 minutes
Window material	Fused silica (AR coated)
Operating temperature	0°C to +30°C
Weight	15.43 lbs (7.0 kg) empty, 19.40lbs (8.8kg) full
Dimensions (L x W x H)	11.65" x 8.20" x 11.7" (295.30 mm x 206.50 mm x 297.20 mm)
Certification	CE

[5] - Measured with a cold target at -174°C (99K)

[6] - For detailed blemish specifications, please contact Princeton Instruments

[7] - See page 5 for explanation of Cold Shield specifications

[8] - Frame rate measured with 1ms exposure time

All specifications are typical performance and are subject to change. NOTE: Export of this camera outside of the United States is prohibited by law unless accompanied by a valid Export License as issued by the United States Department of Commerce.

Software Support & Integration

LightField® Software allows for complete control of all Teledyne Princeton Instruments cameras and spectrometers on an easy to use platform. LightField software also includes simple image post-processing software and a built-in, smart math engine to obtain the most from acquired data.

Teledyne Princeton Instruments LightField® provides **imaging and spectroscopy** within one powerful and versatile software package.

LightField® also makes integration easy with LabVIEW® (National Instruments), MATLAB® (MathWorks) or Python®, allowing you to command the software directly from whichever program you prefer.

For those requiring a custom solution, the PICAM API and SDK, from Teledyne Princeton Instruments offer complete control over all cameras, available for all 64-bit Windows and Linux systems.

Teledyne Princeton Instruments: Part of Teledyne Imaging

Teledyne Imaging is a group of leading-edge companies aligned under the Teledyne umbrella. Teledyne Imaging forms an unrivaled collective of expertise across the spectrum and decades of experience. Individually, each company offers best-in-class solutions. Together, they combine and leverage each other's strengths to provide the deepest, widest imaging and related technology portfolio in the world.

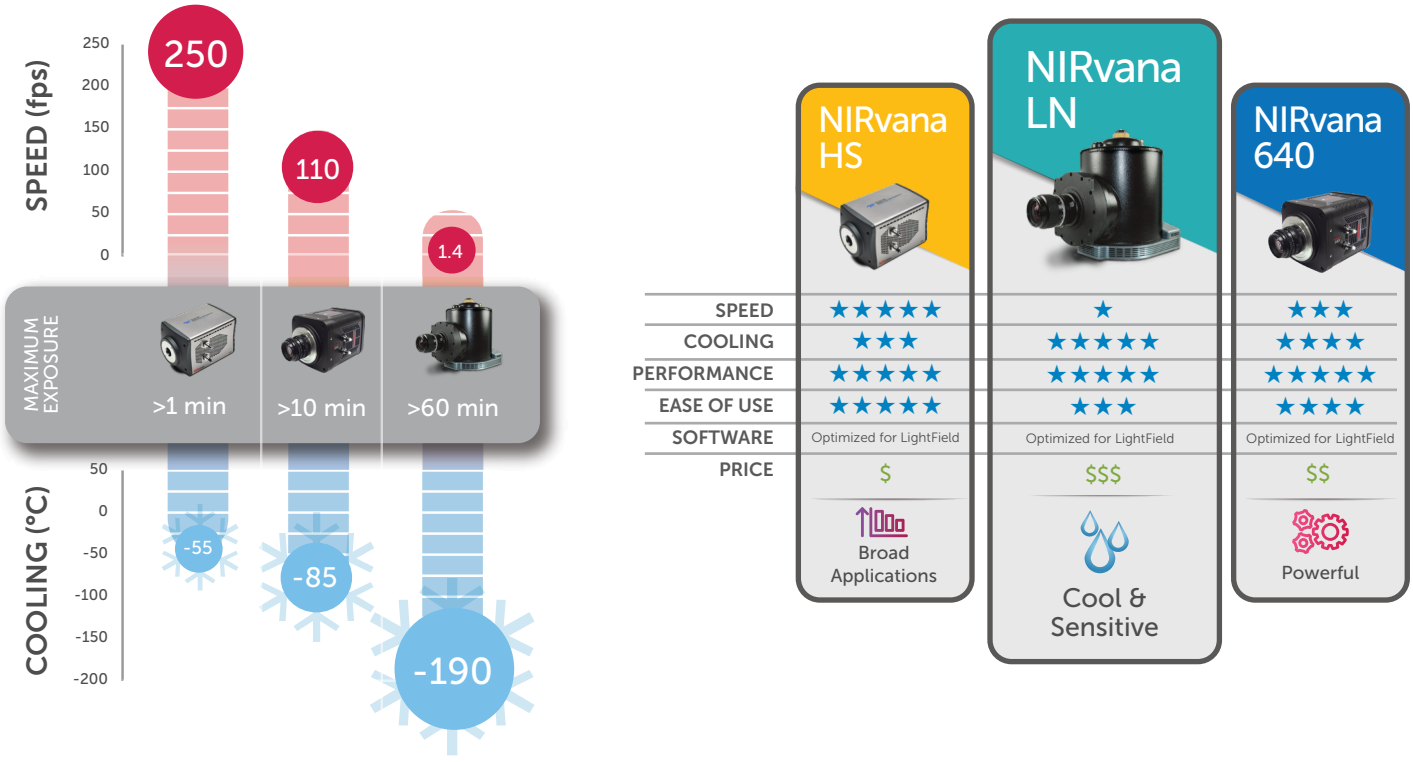
Teledyne Princeton Instruments (TPI), a business unit of Teledyne Digital Imaging US, Inc, designs and manufactures high-performance CCD, CMOS, ICCD, EMCCD, emICCD, and InGaAs cameras; spectrographs; and optics-based solutions for the scientific research, industrial imaging, and OEM communities. We take pride in partnering with our customers to solve their most challenging problems in unique, innovative ways.

Teledyne Princeton Instruments has a vast history of facilitating key research in many fields. Our family of NIRvana® cameras has enabled numerous scientific and commercial advances by delivering the world's best SWIR imaging performance.

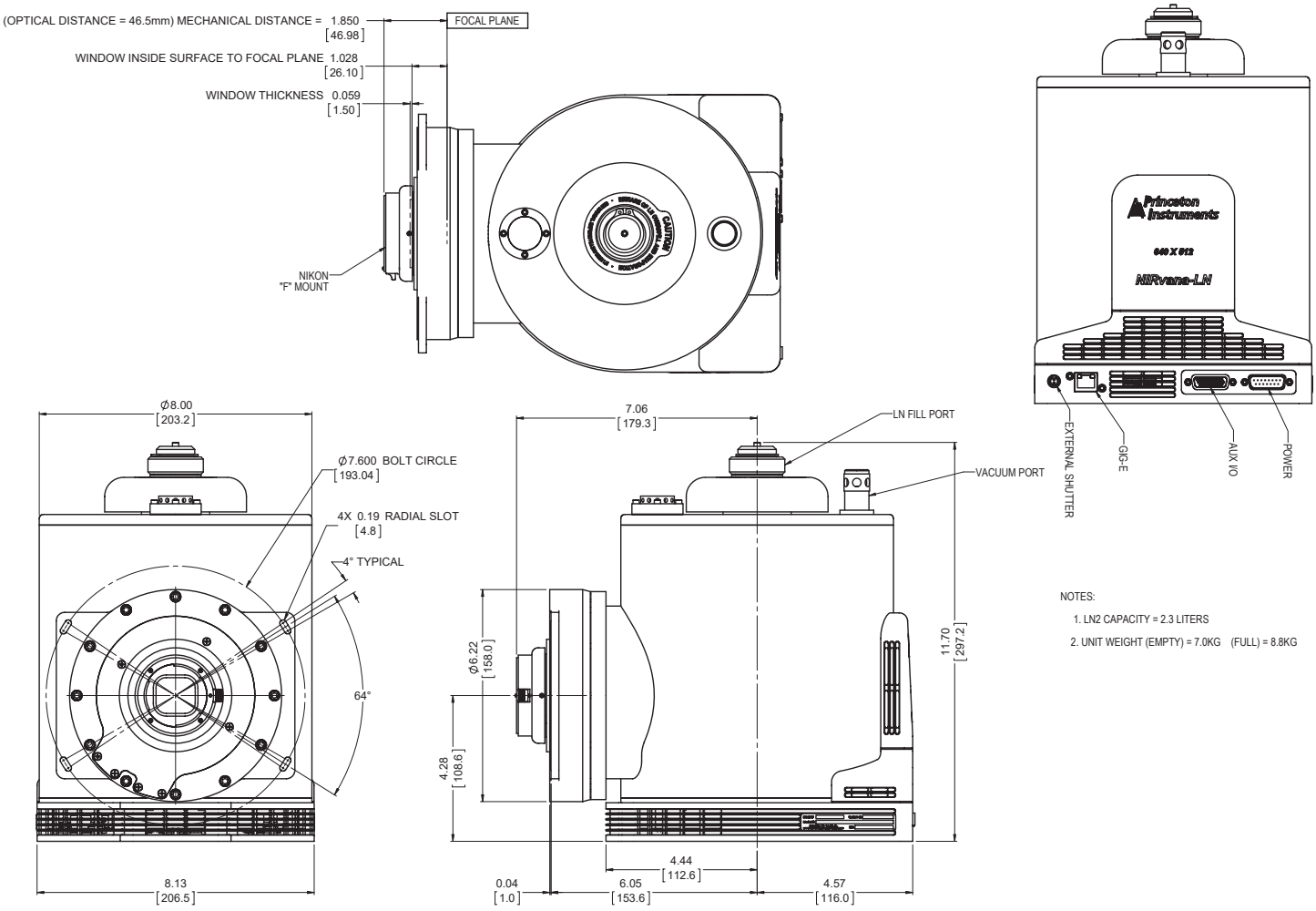
The NIRvana Camera Range

*Need more speed? Consider the **NIRvana HS**!*

*Need sensitivity without liquid nitrogen? Consider the **NIRvana 640**!*



Outline Drawings with F-Mount

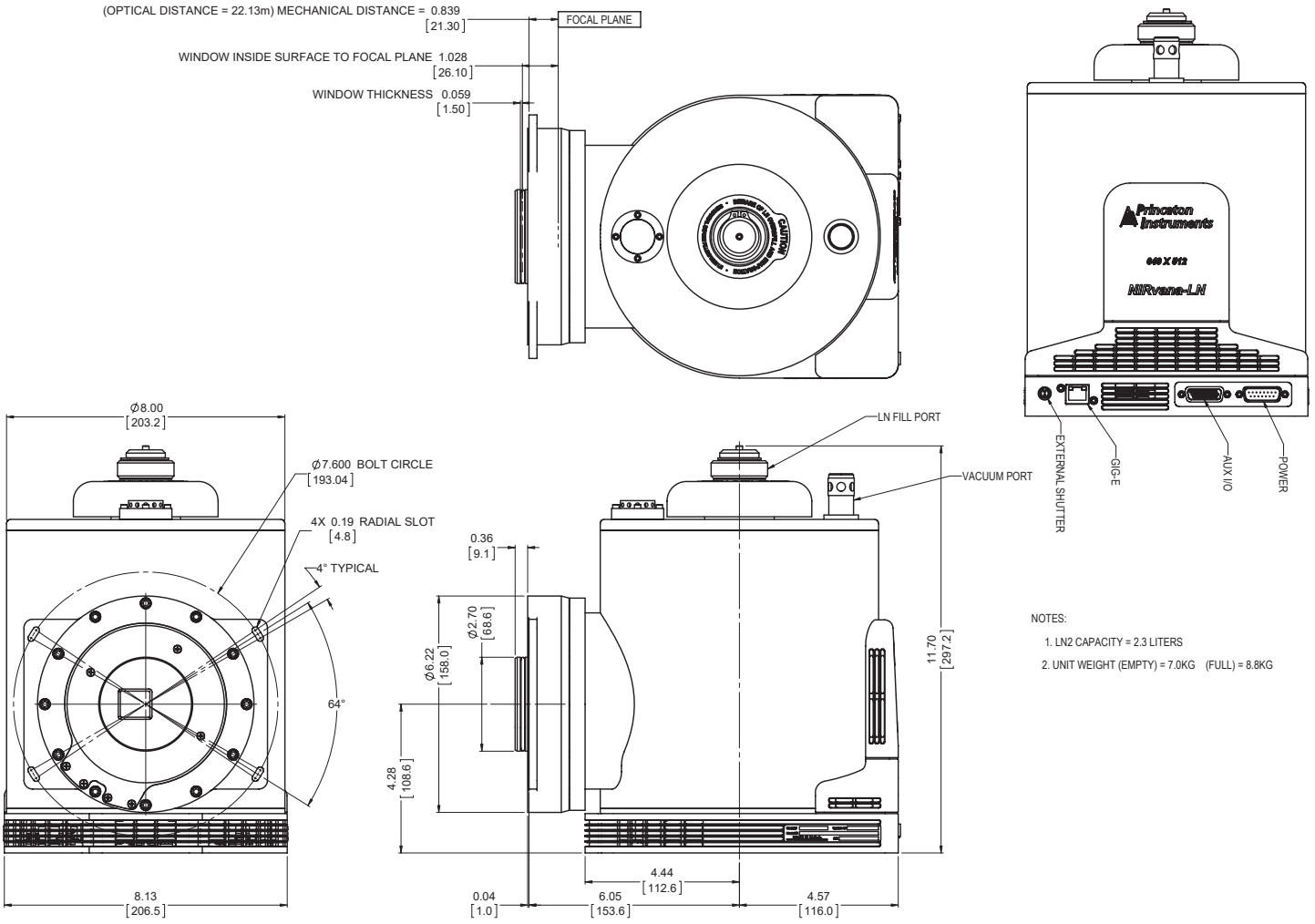


NOTES:

1. LN2 CAPACITY = 2.3 LITERS
2. UNIT WEIGHT (EMPTY) = 7.0KG (FULL) = 8.8KG

Spectrometer adapter is available upon request.

Outline Drawings with Isoplane 320 Spectrometer Mount



F-mount adapter is available upon request.

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NIRvana® LN

SWIR FOR SCIENCE

Contact your local Teledyne Princeton Instruments representative for additional information.

Teledyne Princeton Instruments – USA
Tel: +1 609.587.9797
pi.info@teledyne.com

China
Tel: +86 157 2153 5343
pi.info.china@teledyne.com

France
Tel: +33.1.70.38.19.00
EVR@teledyne.com

Germany
Tel: + 49 (0) 89-660 779 3
pi.germany@teledyne.com

Japan
Tel: +81.3.6709.0631
PI.Nippon@teledyne.com

United Kingdom
Tel: +44 (0) 7810 835 719
pi.info@teledyne.com