ASTRONOMY

UV-VIS-SWIR
Cameras and Spectrographs

Princeton Instruments
Envision the Universe with Princeton Instruments

Who We Are
Princeton Instruments not only helps astronomers see more of the universe, we help you understand more of what you see.

Our state-of-the-art cameras, spectrometers, optics, and coatings are utilized at leading observatories around the world, providing the most innovative technologies to meet the very latest challenges.

Whether your work calls for slow-scan imaging that necessitates hours of integration or for time-resolved photometry that demands blazing fast frame rates, Princeton Instruments has the right solution!

What We Do
Over the course of six decades, we’ve developed and perfected many vision-expanding technologies for astronomy.

Deeper detector cooling, quicker device readout, higher spectral sensitivity over the UV-VIS-NIR-SWIR range, back-thinned CMOS and CCD sensors, InGaAs focal plane arrays, and aberration-free spectrographs are just a few of our key contributions.

We provide both off-the-shelf and customized detectors and coatings for even the most sophisticated astronomical observations.

Our innovations do not stop with hardware! Princeton Instruments offers the most comprehensive set of software tools available to the astronomy community. We make integration easy, regardless of installation size or application complexity.
We Serve You

Hundreds of Princeton Instruments cameras are being used by astronomers all over the world to enable varied and novel investigations. Recent astronomical discoveries have been astounding, and the pace of discovery is increasing.

We understand the formidable technical requirements of today’s astronomers, including the need to collect, store, and analyze enormous amounts of data.

Princeton Instruments provides a complete lineup of scientific-grade cameras, spectrometers, and software for observations from VUV to SWIR!
Princeton Instruments
Advanced Solutions for Astronomical Imaging and Spectroscopy

From high-speed imaging to long exposures, ultraviolet to infrared, Princeton Instruments has you covered. Our cameras utilize the most advanced detector cooling technologies, which enable you to stare at the universe for hours, while our fast readout and high frame rates are perfect for time-resolved photometry and speckle imaging.

Whatever your application, Princeton Instruments has the right solution!
One way in which Princeton Instruments helps keep astronomers at the forefront of discovery is by continually introducing and improving detector and optical technologies. Our core capabilities encompass the design and manufacture of scientific-grade camera systems, spectrographs, software, optics, and coatings. Expertise gained through decades of experience allows us to offer technological innovations that are reliable as well as remarkable.
Camera Sensors

CCD
Princeton Instruments offers astronomers a number of distinct sensors from which to choose. Primary CCD types include thinned back-illuminated CCDs and back-illuminated deep-depletion CCDs. Our latest BLAZE cameras feature “super-depleted” back-illuminated sensors for 75% quantum efficiency at 1000 nm.

EMCCD
Electron-multiplying CCDs with back-illuminated architectures are engineered to address the challenges of ultra-low-light imaging applications at high speed without the use of external image intensifiers. They are capable of single-photon detection.

BI-sCMOS
Aided by the latest fabrication technology, scientific CMOS cameras with back-illuminated sensors deliver 95% peak quantum efficiency and very low read noise, providing a legitimate alternative to CCD cameras for time-resolved photometry applications.

InGaAs SWIR FPA
Cameras with an InGaAs focal plane array (FPA) are also available. InGaAs is a III-V compound semiconductor that provides excellent photosensitivity in the near-infrared, or NIR, and the shortwave-infrared, or SWIR, regions of the spectrum.

Princeton Instruments has the broadest range of detector technologies for VUV-to-SWIR imaging and spectroscopy.

Advanced New SeNsR™ Technology
Thanks to its unique bi-directional clocking ability, BLAZE offers a new SeNsR operating mode for low-light applications. With SeNsR, it is now possible to rapidly shift the charge (i.e., signal) on the CCD without reading out the data.

1. Using a fiber or mask, the center rows of pixels are exposed, leaving the rest of the CCD dark. Spectral data is collected for Sample (S1), which is then shifted up on the CCD and held in position without reading out the data.

2. A second exposure is then taken as Reference (R1) and then the Sample and Reference “signals” are shifted down on the CCD.

3. Sample (S1) is re-exposed and shifted up.

4. Reference (R1) is re-exposed and the process is repeated, alternating sample-reference exposures – S1, R1, S2, R2, S3, R3, Sn, Rn, etc. – until the desired accumulations are achieved.

5. Sample spectral data is accumulated as S1+S2+S3+…+Sn while reference data is accumulated as R1+R2+R3+…+Rn. Accumulated sample and reference data is then read out for processing.
Patented eXcelon® Technology

Patented eXcelon technology for CCDs and EMCCDs, developed by Princeton Instruments and based on either standard thinned back-illuminated or standard back-illuminated deep-depletion architectures, provides two significant advantages:

► Higher sensitivity across broader wavelength range than standard thinned back-illuminated CCDs and standard back-illuminated deep-depletion CCDs

► Lower etaloning for eXcelon thinned back-illuminated CCDs (and etaloning almost eliminated for eXcelon back-illuminated deep-depletion CCDs)
Proprietary ArcTec™ Cooling Technology

The most advanced thermoelectric cooling technology available for scientific-grade cameras, Princeton Instruments ArcTec uses custom-designed Peltier devices, advanced multi-stage thermoelectric cooling, and permanent all-metal UHV seals to achieve unprecedented, condensation-free TRUE -100°C sensor cooling without liquid nitrogen.

ArcTec design advantages:

► Ultra efficient heat exchanger

► Options are available that cool with air only, liquid only (for vibration-sensitive and thermally sensitive environments), or both.

► An all-metal, hermetically sealed vacuum design that is guaranteed for life!

NIRvana InGaAs cameras as well as SOPHIA and BLAZE large-format CCD cameras feature our advanced ArcTec cooling.
LightField® Software

Used in concert with our many award-winning imaging and spectroscopy instruments, Princeton Instruments LightField is the new benchmark for scientific software:

- Complete control of Princeton Instruments cameras and spectrometers
- Powerful 64-bit software package includes Microsoft® Windows® 10 support
- Built-in math engine for real-time data analysis
- Integrated LabVIEW® (National Instruments), MATLAB® (MathWorks), and Python® (PDF) automation support
- Synchronized view allows quick comparison to the same region or peak in two or more datasets
- Supports Princeton Instruments IntelliCal® wavelength and intensity spectral calibration
- Dependable data integrity via automatic saving to disk and retention of both raw and corrected data
- Works seamlessly in multi-user facilities by remembering each user's hardware and software configurations
- Exports to your favorite file formats, including FITS

princetoninstruments.com
Your Astronomy Ecosystem: Complete Integration

Built on decades of experience serving the astronomy community, Princeton Instruments has developed one of the most comprehensive software and hardware ecosystems.

Rest assured, whether it's a project involving a single camera or a complex system involving multiple telescopes/cameras/spectrographs, Princeton Instruments provides tools ready to speed up the work.

- **SDK**
  - **PICam**: The PICam 64-bit SDK is included for free with all Princeton Instruments hardware.
  - **Linux**: PICam is also compatible with open-source Linux distributions.
  - **ASCOM**: Astronomy Common Object Model (ASCOM) compliant drivers are available for easy integration.

- **LabVIEW/MATLAB/Python**: If you use LabVIEW, MATLAB, or Python, LightField makes integration easy, allowing you to command the software directly from whichever program you prefer.

- **Maxim DL**: Maxim DL (Diffraction Limited) support is provided through the ASCOM driver interface.

- **PICam**: The PICam 64-bit SDK is included for free with all Princeton Instruments hardware.

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Our partnership with the astronomy community has enabled some amazing discoveries...
Camera Customization

Decades of technical expertise and application experience allow us to tailor the performance of our standard optical detection systems to meet your specific needs.

Figure 1 shows a 4” multispectral imager designed and built by Princeton Instruments. High sensitivity and correspondingly high low-light-level spatial resolution — less than a kilometer at 100 km altitude — are achieved by utilizing a scientific-grade, back-illuminated CCD (27.6 mm x 27.6 mm; 2048 x 2048 pixels). The multispectral imager’s CCD is thermoelectrically cooled to -70°C. A lifetime vacuum guarantee is provided.

We also offer customized coatings, mirrors, optical filters, and optical assemblies.

Figure 1. Sentry 4” multispectral imager.

Figure 2 depicts a field flattener plano concave lens manufactured by Princeton Instruments.

Figure 2. Field flattener plano concave lens.
Princeton Instruments has supplied hundreds of cameras to leading astronomical facilities around the world. Here’s just a snapshot of some of the applications for which they are used!
Pluto and Charon
Acquired using a PIXIS camera with a back-illuminated 2k x 2k CCD. Courtesy of Prof. Elliott Horch, Southern Connecticut State University, New Haven.

Pleiades
Image courtesy of Rozhen National Astronomical Observatory, Bulgaria.

Gravity Waves and Milky Way
Image courtesy of Dr. Young-In Won, Korea Polar Research Institute.

Solar Corona
Image courtesy of Prof. Shadia Habbal, University of Hawaii.
SOPHIA®
The Most Advanced Line of Ultra-Low-Noise Scientific CCD Cameras for Astronomy

► 2k x 2k, 4k x 4k, and larger format back-illuminated CCDs
► eXcelon: patented technology for low fringing and enhanced sensitivity over broad wavelength range
► Proprietary ArcTec: deep thermoelectric cooling technology specially designed to cool large sensors down to -100°C
► Ultra-low-noise electronics design and flexible readout architecture allow detection of faint signals with or without pixel binning
► Fast 3 fps readout @ 2k x 2k for high-speed photometry
► 95% peak quantum efficiency, extended QE from UV to NIR
► All-metal hermetic vacuum seals to last a lifetime
Applications

- Precision photometry
- High-temporal-resolution imaging
- Deep sky survey
- Astrometry
- Exoplanet detection
- Near-earth objects

Typical QE of eXcelon back-illuminated CCDs and standard thinned back-illuminated CCDs. Purple dotted line on the left represents enhanced QE in UV region with optional UV-enhancement coating.

The improvement in QE provided by eXcelon back-illuminated CCDs relative to standard thinned back-illuminated CCDs.

Images courtesy of Rozhen National Astronomical Observatory, Bulgaria.

SOPHIA cameras deliver an unprecedented combination of sensitivity, speed, and flexibility!
BLAZE™
Next-Generation CCD Cameras for Spectroscopy and Imaging

► 1340x100 and 1340x400 formats available for highest NIR sensitivity with new proprietary sensors

► Up to 75% QE @ 1000 nm for best sensitivity in near-infrared range. BLAZE HR: super-depleted, high-resistivity sensors.

► ≤2 e-/pixel/sec for low dark current below sky background. BLAZE BR-LD: inverted-mode, deep-depletion sensors.

► **TRUE -100°C** (using 20°C liquid assist) and -95°C using air (no chillers or cryocoolers) with no fear of condensation. Exclusive ArcTeC technology thermoelectrically cools the CCD.

► ADC rates up to 16 MHz x 2 with discrete dual amplifiers for low-noise and high-speed operation

BLAZE camera and IsoPlane 320 spectrometer used to observe 8-21-17 solar eclipse from Willamette University (Salem, Oregon). Photo courtesy of Ronald Dantowitz, Clay Center Observatory Director, Dexter Southfield School (Brookline, Massachusetts).
Applications

- Near-infrared photometry (r, i, z, and Y bands)
- Solar observations
- Near-infrared spectroscopy

BLAZE cameras deliver the highest NIR quantum efficiency, -100°C thermoelectric cooling, and low/no etaloning for spectroscopic observations that are out of this world!
PIXIS
High-Quantum-Efficiency, Low-Noise Scientific CCD Cameras for Astronomy

- 120 nm to 1100 nm enhanced sensitivity with patented eXcelon technology for low fringing
- >95% peak QE back-illuminated CCDs with up to 2k x 2k pixel array
- -70°C air/water cooling with proprietary XP technology
- USB 2.0 high-speed data interface
- Dual-amplifier design: high-sensitivity readout with reduced read noise for weak signals
- All-metal hermetic vacuum seals with lifetime vacuum guarantee

CCD observation in a filter of the Vilnius seven-color photometric system obtained with the Maksutov-type 35/51 cm telescope at the Molėtai Observatory in Lithuania. The planetary nebula NGC 6543 (Cat’s Eye Nebula) is indicated. Image reprinted from Astronomy & Astrophysics, volume 544, article A49 (2012).

Images of the Andromeda galaxy taken with a PIXIS camera. Courtesy of Dr. Brian Oetiker, Sam Houston State University (Huntsville, Texas).
PIXIS cameras offer eXcelon technology for back-illuminated deep-depletion CCDs, further improving both NIR sensitivity and etaloning performance when compared to standard back-illuminated deep-depletion CCDs!

Applications

- Precision photometry
- Deep sky survey
- Astrometry
- Exoplanets
- Near-earth objects

Gravity waves and Milky Way observed using a PIXIS camera with an all-sky field-of-view module. Image courtesy of Dr. Young-In Won, Korea Polar Research Institute.

Image of solar corona taken with a PIXIS camera. Courtesy of Prof. Shadia Habbal, University of Hawaii.

Typical QE of eXcelon back-illuminated deep-depletion CCDs and standard back-illuminated deep-depletion CCDs. Purple dotted line on the left represents QE in UV region with optional UV-enhancement coating, for non-eXcelon only.

The improvement in QE provided by eXcelon back-illuminated deep-depletion CCDs relative to standard back-illuminated deep-depletion CCDs.
PyLoN™
The Only Cryogenically Cooled Scientific CCD Cameras for Astronomy

► Up to 2048 x 2048 pixel array (with 13.5μm² pitch)
► -120°C (cryogenically cooled) ultra-low dark current back-illuminated CCDs
► >24 hours of liquid nitrogen hold time
► >1,000 frames/sec at 4 MHz readout speed for highest spectral rate
► Dual-amplifier readout design for reduced read noise and increased effective dynamic range
► eXcelon: patented technology for low fringing and enhanced sensitivity over broad wavelength range
► GigE industry-standard, fast-transfer data interface
Cryogenically Cooled eXcelon Sensors

This unique Princeton Instruments technology features:

► Dark current on the order of 1 e-/p/hr for exposure times of minutes to hours
► A single input window for maximum sensitivity
► Refill requirement of only once per day
► Setup flexibility with optional end-on and all-directional dewars

PyLoN cameras utilize digital correlated double sampling and bias stabilization to provide the best read noise performance below 1 MHz readout speed, improved linearity, and a constant baseline for multiple-exposure, long-integration-time applications!

Applications

► Precision photometry
► Steady-state imaging
► Deep sky survey
► Astrometry
► Exoplanets
► Near-earth objects

Image courtesy of Rozhen National Astronomical Observatory, Bulgaria.
ProEM®-HS
The Fastest EMCCD Cameras for High-Speed Applications

- 30 fps at full resolution, supports ROI/binning for ultra-fast frame rates
- eXcelon3: patented technology for low fringing and enhanced sensitivity over broad wavelength range
- OptiCAL electron-multiplying gain calibration: repeatable precision for lifetime of camera
- Base Active Stability Engine (BASE) for stable baseline reference
- All-metal hermetic vacuum seals (lifetime vacuum guarantee)
- GigE industry-standard, fast-transfer data interface

After OptiCAL, a high-precision EM gain calibration method that allows EM gain to be controlled in linear, absolute steps.
Princeton Instruments recommends EMCCD cameras that utilize patented eXcelon3 technology.

Applications

► Adaptive optics
► Lucky imaging
► Speckle imaging
► Exoplanets
► Gamma ray bursts
► Wave front sensors
► Precision photometry

Images of a solar eclipse taken with a ProEM camera at the Aryabhatta Research Institute of Observational Sciences (Nainital, India).

Typical QE of eXcelon3 back-illuminated EMCCDs and standard thinned back-illuminated EMCCDs. Solid/dashed purple lines on the left represent enhanced QE in UV region with optional UV-enhancement coatings.

The improvement in QE provided by eXcelon3 back-illuminated EMCCDs relative to standard thinned back-illuminated EMCCDs.
KURO™
The First Back-Illuminated sCMOS Cameras for Ultra-Fast Astronomy Applications

► >95% peak QE back-illuminated sCMOS sensors
► Up to 4 MP resolution, 11 μm² pixel pitch
► 100% light-sensitive pixel area (fill factor), no microlenses
► 82 fps @ 2k x 2k, more than 3,000 fps at reduced resolution
► 12-bit and 16-bit readout
► Extended UV and NIR sensitivity
► USB 3.0 data interface (high bandwidth)
► 1.3 e- rms (low readout noise) to detect weak signals
► Thermoelectric cooling (air/water)

Photos of KURO camera courtesy of Eliot Young, Southwest Research Institute (Boulder, Colorado).
These new, back-illuminated sCMOS sensors provide CCD-like quantum efficiency (>95%) and dynamic range while preserving the impressive frame rates of previous-generation, front-illuminated sCMOS cameras!

**Applications**

- Adaptive optics
- Lucky imaging
- Speckle imaging
- Exoplanets
- Near-earth objects
- Solar astronomy

*Images captured with a KURO back-illuminated sCMOS camera. Star cluster (left), Orion Nebula. Courtesy of Southwest Research Institute (Boulder, Colorado).*

Back-illuminated sCMOS technology provides higher QE than front-illuminated sCMOS sensors across a broad spectral range, including the UV. Unlike front-illuminated sCMOS sensors, which claim ~80% peak QE by relying on microlenses that reduce fill factor (and significantly degrade quantum efficiency when light is incident at any angle other than normal to the sensor surface), back-illuminated sCMOS sensors deliver >95% peak QE without microlenses or their associated compromises.
NIRvana®
The Only Scientific-Grade InGaAs Cameras on the Market for Quantitative Near-Infrared (NIR) / Shortwave-Infrared (SWIR) Imaging and Spectroscopy Applications

-85°C (thermoelectrically cooled) for long integration time and low dark noise

► 640 x 512 high-speed InGaAs FPA (with 20 μm² pixel pitch)

► Fast 110 fps @ 10 MHz (full-frame readout)

► 0.9 μm to 1.7 μm response (>80% typical QE from 1.0 μm to 1.6 μm)

► All-metal hermetic vacuum seals (lifetime vacuum guarantee)

► GigE industry-standard, fast-transfer data interface

► 16-bit digitization and low read noise for outstanding dynamic range

Thermoelectrically cooled NIRvana cameras use a single optical window with double-sided antireflective coating to provide the highest photon throughput, >98% transmission, in the NIR / SWIR band.
Princeton Instruments utilizes unique vacuum technology and advanced thermoelectric cooling to chill the high-speed, high-QE InGaAs sensor of the NIRvana down to -85°C and achieve the lowest possible dark noise.

Applications

- High-frame-rate imaging in NIR / SWIR
- Time-resolved coronal observations in NIR / SWIR
- J and H band applications
- Exoplanet transit surveys
- Photometric measurements of M-types and brown dwarfs
- Low-elevation observatories

The first evidence of fast reconnection in a solar filament eruption was found via the New Vacuum Solar Telescope and a NIRvana camera (Yunnan Astronomical Observatory, China).

The quantum efficiency of a standard InGaAs FPA thermoelectrically cooled to -85°C.
NIRvana® LN
Scientific Camera Cryogenically Cooled to 83 K (-190°C) for NIR / SWIR Imaging

- 0.9 μm to 1.6 μm response
  (70% typical QE from 1.3 μm to 1.6 μm)
- >30 hours of liquid nitrogen hold time
- >60 minute integration time with ultra-low dark noise
- Integrated cold shield limits the effects of ambient thermal background
- 640 x 512 low-read-noise InGaAs FPA (with 20 μm² pixel pitch)
- ~3 fps at full resolution
- GigE industry-standard, fast-transfer data interface
- Supports nondestructive readout (NDRO) mode

InGaAs delivers superb photosensitivity in the NIR and SWIR regions of the spectrum.
The InGaAs sensor of the NIRvana LN is cooled via liquid nitrogen down to 83 K (-190°C) in order to improve signal-to-noise ratio for the most demanding NIR / SWIR applications. The camera’s 16-bit digitization and low-read-noise sensor provide outstanding dynamic range.

Applications

► Steady-state imaging
► Long-integration coronal observations

Images of sunspots (1565.3 nm channel) taken using a NIRvana camera at the Yunnan Astronomical Observatory in China.

The quantum efficiency of a standard InGaAs FPA cryogenically cooled to -190°C.
## Camera Specifications

<table>
<thead>
<tr>
<th>SOPHIA CCD</th>
<th>PIXIS CCD</th>
<th>PyLoN CCD</th>
<th>BLAZE CCD</th>
</tr>
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<tbody>
<tr>
<td>2048BX</td>
<td>1024BX/BRX</td>
<td>2048BX</td>
<td>100HR</td>
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<td>4096BX</td>
<td>1024BX</td>
<td>2048BX</td>
<td>100LD</td>
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<td>1300BX</td>
<td>1340X</td>
<td>1300BX</td>
<td>400HR</td>
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<tr>
<td>2048BX</td>
<td>1340X</td>
<td>2048BX</td>
<td>400LD</td>
</tr>
</tbody>
</table>

### Sensor Type
- **Back-Illuminated CCD with eXcelon**
- **Exclusive Back-Illuminated High-Resistivity Silicon**

### Resolution (pixels)
- **SOPHIA CCD**
  - 2048 x 2048
  - 4096 x 4096
- **PIXIS CCD**
  - 1024 x 1024
  - 1340 x 1300
  - 2048 x 2048
- **PyLoN CCD**
  - 1340 x 1300
  - 2048 x 2048
- **BLAZE CCD**
  - 1340 x 100
  - 1340 x 400

### Pixel pitch (µm)
- **SOPHIA CCD**
  - 15 x 15
  - 13 x 13
  - 20 x 20
  - 13.5 x 13.5
- **PIXIS CCD**
  - 20 x 20
  - 13.5 x 13.5
- **PyLoN CCD**
  - 13.5 x 13.5
  - 20 x 20
- **BLAZE CCD**
  - 20 x 20
  - 13.5 x 13.5

### Sensor Cooling
- **SOPHIA CCD**
  - -90°C
  - -70°C
  - -60°C
  - -110°C
- **PIXIS CCD**
  - -95°C / -100°C
- **PyLoN CCD**
  - -90°C
  - -70°C
  - -60°C
  - -110°C
- **BLAZE CCD**
  - -90°C
  - -70°C
  - -60°C
  - -110°C

### Typical dark charge (e-/p/s)
- **SOPHIA CCD**
  - 0.00025 e-/p/s (BX)
  - 0.0004 e-/p/s (BX), 0.02 e-/p/s (BRX)
  - 0.001 e-/p/s
  - 0.005 e-/p/s
  - 0.000083 e-/p/s
  - 0.00001 e-/p/s
  - 0.0015 e-/p/s
  - 0.0005 e-/p/s
  - 0.0015 e-/p/s
  - 0.0005 e-/p/s
- **PIXIS CCD**
  - 0.0004 e-/p/s (BX)
  - 0.00083 e-/p/s
  - 0.0001 e-/p/s
  - 0.001 e-/p/s
  - 0.0005 e-/p/s
  - 0.0015 e-/p/s
- **PyLoN CCD**
  - 0.0004 e-/p/s (BX)
  - 0.000083 e-/p/s
  - 0.00001 e-/p/s
  - 0.0015 e-/p/s
  - 0.0005 e-/p/s
  - 0.0015 e-/p/s
- **BLAZE CCD**
  - 0.0004 e-/p/s (BX)
  - 0.000083 e-/p/s
  - 0.00001 e-/p/s
  - 0.0015 e-/p/s
  - 0.0005 e-/p/s
  - 0.0015 e-/p/s

### Max full frame rate (fps)
- **SOPHIA CCD**
  - 3 fps
  - <1 fps
  - 1.7 fps
  - 1.07 fps
  - 0.44 fps
  - 2.04 fps
  - 0.92 fps
  - 218 fps
  - 140 fps
  - 54 fps
  - 35 fps
- **PIXIS CCD**
  - 16 MHz (4 MHz/port)
  - 2 MHz
  - 4 MHz
  - 16 MHz
  - 10 MHz
  - 16 MHz
  - 10 MHz
- **PyLoN CCD**
  - 16 MHz (4 MHz/port)
  - 2 MHz
  - 4 MHz
  - 16 MHz
  - 10 MHz
  - 16 MHz
  - 10 MHz
- **BLAZE CCD**
  - 16 MHz (4 MHz/port)
  - 2 MHz
  - 4 MHz
  - 16 MHz
  - 10 MHz
  - 16 MHz
  - 10 MHz

### Max read-out speed (MHz/Port)
- **SOPHIA CCD**
  - 0.00025 e-/p/s (BX)
  - 0.0004 e-/p/s (BX), 0.02 e-/p/s (BRX)
  - 0.001 e-/p/s
  - 0.005 e-/p/s
  - 0.000083 e-/p/s
  - 0.00001 e-/p/s
  - 0.0015 e-/p/s
  - 0.0005 e-/p/s
  - 0.0015 e-/p/s
  - 0.0005 e-/p/s
- **PIXIS CCD**
  - 0.0004 e-/p/s (BX)
  - 0.00083 e-/p/s
  - 0.0001 e-/p/s
  - 0.001 e-/p/s
  - 0.0005 e-/p/s
  - 0.0015 e-/p/s
- **PyLoN CCD**
  - 0.0004 e-/p/s (BX)
  - 0.000083 e-/p/s
  - 0.00001 e-/p/s
  - 0.0015 e-/p/s
  - 0.0005 e-/p/s
  - 0.0015 e-/p/s
- **BLAZE CCD**
  - 0.0004 e-/p/s (BX)
  - 0.000083 e-/p/s
  - 0.00001 e-/p/s
  - 0.0015 e-/p/s
  - 0.0005 e-/p/s
  - 0.0015 e-/p/s

## Camera selection guide

<table>
<thead>
<tr>
<th>Dynamic range</th>
<th>Yes</th>
<th>Yes</th>
<th>Yes</th>
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<tr>
<td>Sensitivity</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<td>Speed</td>
<td>Very Good</td>
<td>Good</td>
<td>Good</td>
<td>Very Good</td>
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<td>UV-VIS-NIR-SWIR</td>
<td>UV-VIS-NIR</td>
<td>UV-VIS-NIR</td>
<td>UV-VIS-NIR</td>
<td>UV-VIS-NIR</td>
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<td>Computer interface</td>
<td>USB 3.0</td>
<td>USB 2.0</td>
<td>GigE</td>
<td>USB 3.0</td>
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<td></td>
<td>ProEM-HS EMCCD</td>
<td>KURO BI-sCMOS</td>
<td>NIRvana InGaAs</td>
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<tr>
<td>----------------------</td>
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<td></td>
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<tr>
<td>Sensor type</td>
<td>Back-Illuminated EMCCD with eXcelon3</td>
<td>Back-Illuminated sCMOS</td>
<td>InGaAs</td>
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<td>Resolution (pixels)</td>
<td>512 x 512</td>
<td>1200B</td>
<td>640</td>
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<td>1024 x 1024</td>
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<tr>
<td></td>
<td>1024 x 1024</td>
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<td>640LN</td>
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<tr>
<td>Pixel pitch (µm)</td>
<td>16 x 16</td>
<td>10 x 10</td>
<td>13 x 13</td>
<td></td>
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<td></td>
<td>11 x 11</td>
<td>20 x 20</td>
<td>20 x 20</td>
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<td>Sensor cooling</td>
<td>-90°C</td>
<td>-70°C</td>
<td>-65°C</td>
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<td></td>
<td>-25°C</td>
<td>-85°C</td>
<td>-65°C</td>
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<td></td>
<td>-190°C</td>
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<tr>
<td>Typical dark charge</td>
<td>0.001 e-/p/s</td>
<td>0.002 e-/p/s</td>
<td>0.7 e-/p/s</td>
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<tr>
<td></td>
<td>0.002 e-/p/s</td>
<td>300 e-/p/s</td>
<td>1500 e-/p/s</td>
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</tr>
<tr>
<td></td>
<td>10 e-/p/s</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Max full frame rate</td>
<td>61 fps</td>
<td>30 fps</td>
<td>25 fps</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>82 fps (12 bits)</td>
<td>41 fps (12 bits)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>110 fps</td>
<td>2.77 fps</td>
<td></td>
</tr>
<tr>
<td>Max read-out speed</td>
<td>20 MHz</td>
<td>36.67 MHz</td>
<td>30 MHz</td>
<td></td>
</tr>
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<td></td>
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<td>10 MHz</td>
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<tr>
<td></td>
<td></td>
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<td>250 kHz</td>
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**Camera selection guide**

<table>
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<tr>
<th>Dynamic range</th>
<th>Yes</th>
<th>No</th>
<th>No</th>
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<tr>
<td>Sensitivity</td>
<td>Yes</td>
<td></td>
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<td>Yes</td>
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<tr>
<td>Speed</td>
<td>Excellent</td>
<td>Excellent</td>
<td>Excellent</td>
<td>Good</td>
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<tr>
<td>UV-VIS-NIR-SWIR</td>
<td>UV-VIS-NIR</td>
<td>UV-Vis</td>
<td>NIR-SWIR</td>
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<td></td>
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<tr>
<td>Computer interface</td>
<td>GigE</td>
<td>USB 3.0</td>
<td>GigE</td>
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IsoPlane® Spectrometers

Best-in-Class, Astigmatism-Free Imaging Spectrometers Set New Standards of Performance and Versatility

- Patented, astigmatism-free design
- High resolution across the entire focal plane
- ±0.01 nm* high wavelength accuracy with IntelliCal
- ±0.0015 nm* high wavelength repeatability with IntelliCal
- Extremely high stray-light rejection
- Fixed-position camera mount with micrometer focus adjustment

* IsoPlane 320 with 1200 groove/mm grating @ 435 nm

PIXIS camera and IsoPlane 320 spectrometer used for spectroscopic detection of space debris test at SHAO 60 cm telescope. Photo courtesy of Prof. Zhenghong Tang, Shanghai Astronomical Observatory, Chinese Academy of Sciences.

BLAZE camera and IsoPlane 320 spectrometer used to observe 8-21-17 solar eclipse from Willamette University (Salem, Oregon). Photo courtesy of Ronald Dantowitz, Clay Center Observatory Director, Dexter Southfield School (Brookline, Massachusetts).
Additional Photo Credits

Page 4 (left to right)
Giant Magellan Telescope. Courtesy of GMTO.
Okayama Astrophysical Observatory. Courtesy of NAOJ.
Royal Observatory Greenwich. Courtesy of Royal Museums Greenwich.
Fuxian Solar Observatory. Courtesy of Yunnan Observatories, CAS.
Cerro Tololo Inter-American Observatory. Courtesy of NOAO.

Page 5 (left to right)
Haleakala Observatory 1.6 Meter Telescope. Courtesy of AMOS.
Xinglong Observatory 2.16 Meter Telescope. Courtesy of NAOC.
Okayama Astrophysical Observatory 188 cm Telescope. Courtesy of NAOJ.
Okayama Astrophysical Observatory 188 cm Telescope. Courtesy of NAOJ.
Rozhen National Astronomical Observatory 2 Meter RCC Telescope. Courtesy of Rozhen NAO.

Page 20
Background image: ESO / F. Comeron

Pages 18, 22, 24, 26, 28, 30, 34
Background images: ESO
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