COSMOS™

LARGE AREA CMOS CAMERAS

The Next Generation of High-Performance, Large-Array Cameras for Astronomy

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Teledyne Imaging In Astronomy

High-performance image sensors and systems

Teledyne Imaging's sensors, cameras, and imaging systems for aerospace and defense are the synthesis of Teledyne's suite of technologies, products, and solutions to address virtually any imaging requirement for airborne, space, defense, or security applications.

Ground Astronomy	Earth Observation	Space Science	Planetary Exploration	Space Astronomy
30+ Telescopes	80 Flown Missions	50 Flown Missions	12 Flown Missions	10 Flown Missions
10 Under Construction	20 Planned Missions	10 Planned Missions	2 Planned Missions	2 Planned Missions
500+ Sensors Delivered	2000+ Years in Orbit	600+ Years in Space	300+ Years Space Exploration	2200+ Years in Space

LACera Large Area CMOS Technology – Only from Teledyne Imaging

LACera™ represents the dawning of a new era in CMOS technology, exclusively developed and owned by Teledyne Imaging. Building on Teledyne's legacy of CCD and CMOS sensor and camera technology and design, LACera is a monumental step forward in CMOS capabilities for advanced imaging, enabling the next generation of discovery.

The challenge of CMOS sensors has been maintaining performance when scaling to larger formats; in particular offering the combination of speed and low noise architecture. LACera delivers deep-cooled, low-noise performance on a multi-megapixel scale with global shutter, 18-bit readout, and glow reduction technology.

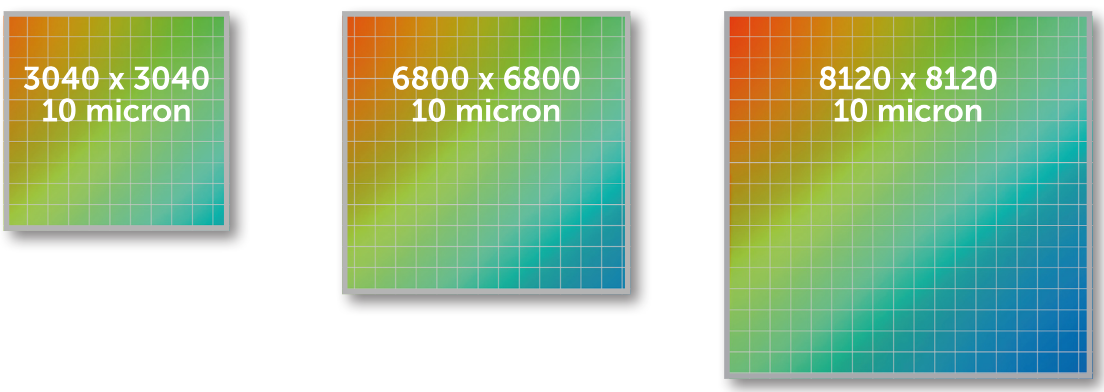
LACera represents a critical element of advanced imaging solutions and is only possible with the nature and scale of Teledyne. From pixel, sensor, and ROIC design, through low noise electronics, to deep cooling, and system interface, Teledyne is the only company capable of delivering this one hundred percent organic solution in large-format CMOS. Look for the LACera logo shown on exclusive LACera features.

Introducing COSMOS

COSMOS is a portfolio of large area CMOS cameras, conceived and designed to deliver unprecedented performance. The COSMOS concept started with our customers, whose research and applications require camera functionality and performance that is not commercially available with either CCD or CMOS technology. Having experience in all aspects of sensor and camera design, Teledyne was well positioned to combine its resources to answer this challenge. Our CCD and CMOS sensor design teams were challenged to merge their expertise to deliver unmatched sensor performance with superior sensitivity, large pixels, large area, low noise and fast framerate. The answer is LACera, proprietary Teledyne sensor technology that is the foundation of all future large format CMOS camera products, starting with COSMOS. Beyond the sensor, our camera designers were tasked with developing low-noise electronics and novel sensor cooling and packaging. The Teledyne team addressed typical CMOS issues such as “glow”, limited dynamic range, and compromised global shutter.

The result is COSMOS, the only large format, high performance CMOS camera designed and manufactured entirely within a single source. Teledyne has combined its “best in class” team to deliver a turnkey product that answers the demands of many customers, specifically COSMOS for ground-based astronomy. Additional markets, such as X-ray and electron microscopy for example, will incorporate LACera technology in additional product portfolios that will be announced throughout 2021.

COSMOS-09 COSMOS-46 COSMOS-66



- 0.7 e- read noise for detection of faint objects
- Up to 50 fps for capturing dynamic events
- 6k x 6k and 8k x 8k sensor sizes for maximum field of view
- >90% peak quantum efficiency for high sensitivity
- Deep cooled for low dark current
- Rolling and global shutter

Specifications

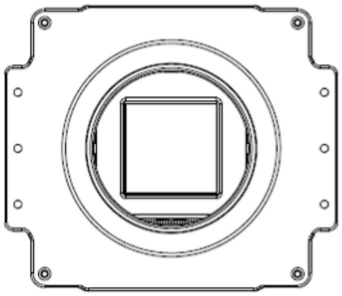
Camera Specifications

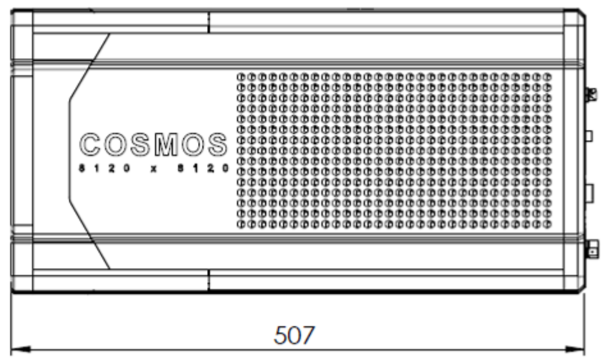
Feature	COSMOS-09	COSMOS-46	COSMOS-66
CMOS image sensor	Back illuminated; grade 1; 100% fill factor		
Dark current @ -25°C (with ambient air @ +20°C)	0.05 e-/p/s (typical)		
Quantum efficiency	> 90% Peak QE, See QE curves on page 4		
Pixel format	10 µm		
Imaging area	31 x 31 mm	68 x 68 mm	81 x 81 mm
Resolution	3040 x 3040	6800 x 6800	8120 x 8120
Sensor Cooling temperature	<-25°C (typical) with liquid chiller; <-20°C (typical) with air		
Cooling method	Thermoelectric air or liquid cooling (liquid chiller required)		
Full well	Single pixel: >80 ke- (typical)		
ADC settings	12, 14, 16, and 18 bit		
System read noise	< 3 e-rms in all readout modes, <1 e- rms in optimal modes		
Frame rate (fps)	50	20	10
Shutter	Electronic, rolling, and global		
Nonlinearity	<1%		
Binning	2 x 2; 4 x 4		
Data interface	CoaXPress®	CoaXPress®	CoaXPress®
I/O signals	Two MCX connectors for programmable frame readout, shutter, trigger in		
Operating environment	-30°C to +30°C non-condensing		
ROI	Multiple regions of interest		
Certification	CE		
Power supply	110/220 V		

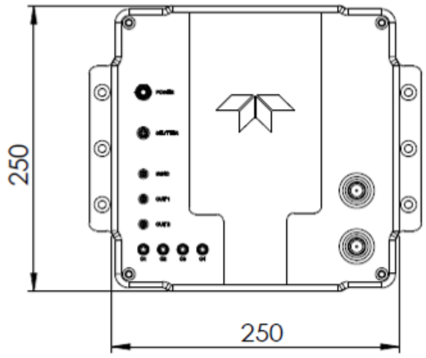
Specifications are preliminary and subject to change.
Certification CE

Mechancial and Electrical Specifications

Physical Size (H x W x L)	25 x 25 x 50 cm
Weight	< 15 kg
Mounting	Multiple Mechanical Options Available
Cooling	Heat Exchanger “Air and Liquid >600W compressor type liquid chiller”
Min sensor temperature	-25 °C
Thermostating precision	+/-1.0 °C
Ports/Cabling	CXP12 4-Lane
Camera I/O	OUT-A, OUT-B, Trigger, Sync External Shutter Control - TTL logic Power
Window	Fused SiO_2 (Grade 0A), NO AR
Cover Set	Black anodized Al
External Lights	(1) tri-color LED indicator
Power supply	110/220 V
Operation environment	Temperature:-30°C ~30°C Relative humidity:≤ 90% Altitude:0~3900 meter
Storing environment	Temperature:-30°C ~ 50°C Relative humidity:≤ 90% Altitude:0~3900 meter







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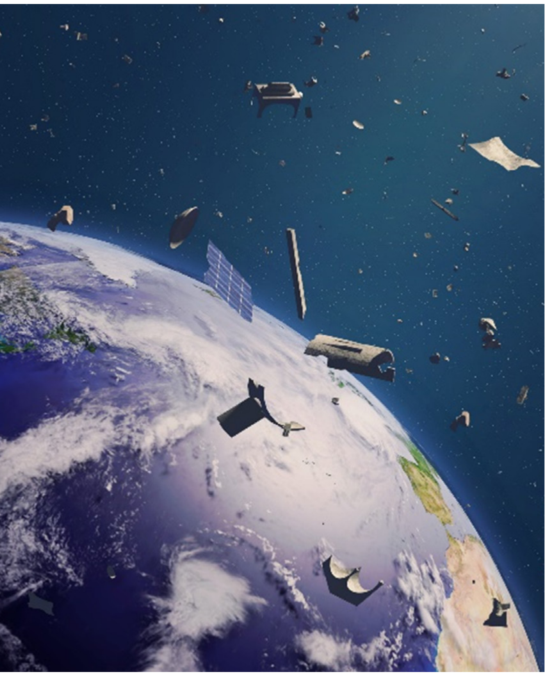
Applications

Exoplanets

Exoplanet study is at the forefront of astronomy, with various techniques, such as transit photometry and radial velocity, used for identification and characterization.

These techniques often require a camera with high precision, low noise, large dynamic range and high duty cycle to detect any small variations in the luminosity of the exoplanet's associated star. The deep cooling and low read noise of 0.7 e-, 3x lower than our world-leading CCD sensors, empowers COSMOS to measure these slight variations.

Greater than 90% peak quantum efficiency is achieved with COSMOS' back-illuminated sensor, and alongside high dynamic range, allows for high precision measurements. The advanced CMOS technology utilized within COSMOS provides 100% duty cycle, essential for dense, high cadence measurements.



Orbital Object Tracking

Orbital object tracking involves monitoring objects within Earth's orbit, such as asteroids, space debris, or satellites.

Lower orbit objects move rapidly across the sky, requiring a large field of view to most accurately capture the object's position. The large field of view of the COSMOS allows low orbital objects to be captured over a longer period of time, resulting in minimal movement of the telescope tracking system. The high frame rate ensures accurate tracking throughout the entire movement of the object across the sky.

Higher orbital objects are typically fainter and thus require higher sensitivity cameras. The >90% quantum efficiency achieved by COSMOS allows for detection of these fainter objects, with the low read noise allowing for fast image capture, without sacrificing sensitivity.

Solar Physics

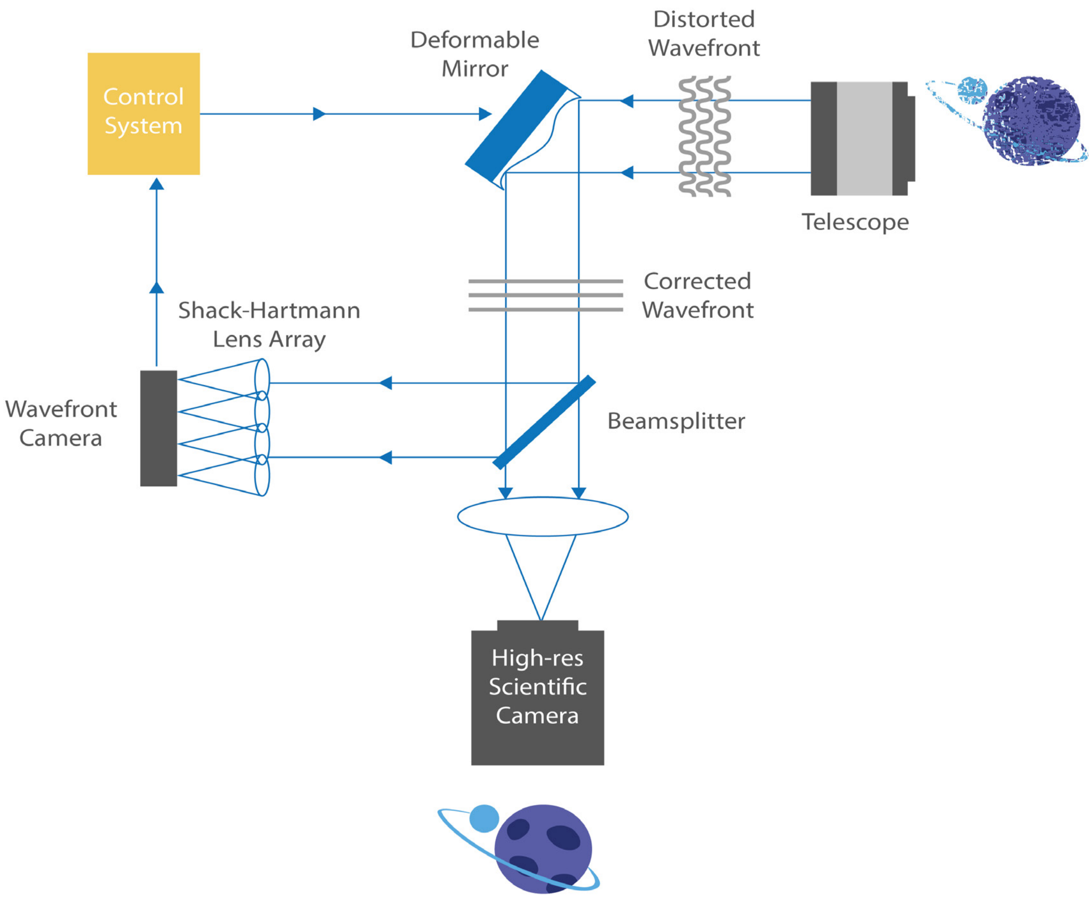
The Sun is continually changing. Studying these dynamic events can provide valuable insight into the processes within a star. With high spatial and temporal resolution, the COSMOS allows for accurate investigation into the dynamic events of the solar atmosphere. The large pixel size and large pixel array of the COSMOS provides the most comprehensive field of view, allowing capture of the entire area of an event, such as a sunspot, to be imaged within one sensor.

Techniques

Adaptive Optics

Adaptive optics is a technique that provides higher resolution images by counteracting the effects of atmospheric turbulence. In order to correct for these atmospheric changes, the adaptive optics system utilizes a camera with both fast frame rates and low read noise to feed back into the telescope system to make atmospheric adjustments.

With a read noise of 0.7 e-, the COSMOS is able to capture faint stars that are closer to the scientific object of interest. The COSMOS also provides fast frame rates without sacrificing sensitivity, with remarkably low read noise even at higher frame rates. These frame rates combined with short frame times of the COSMOS allow for rapid system adjustments in the most turbulent of atmospheres.

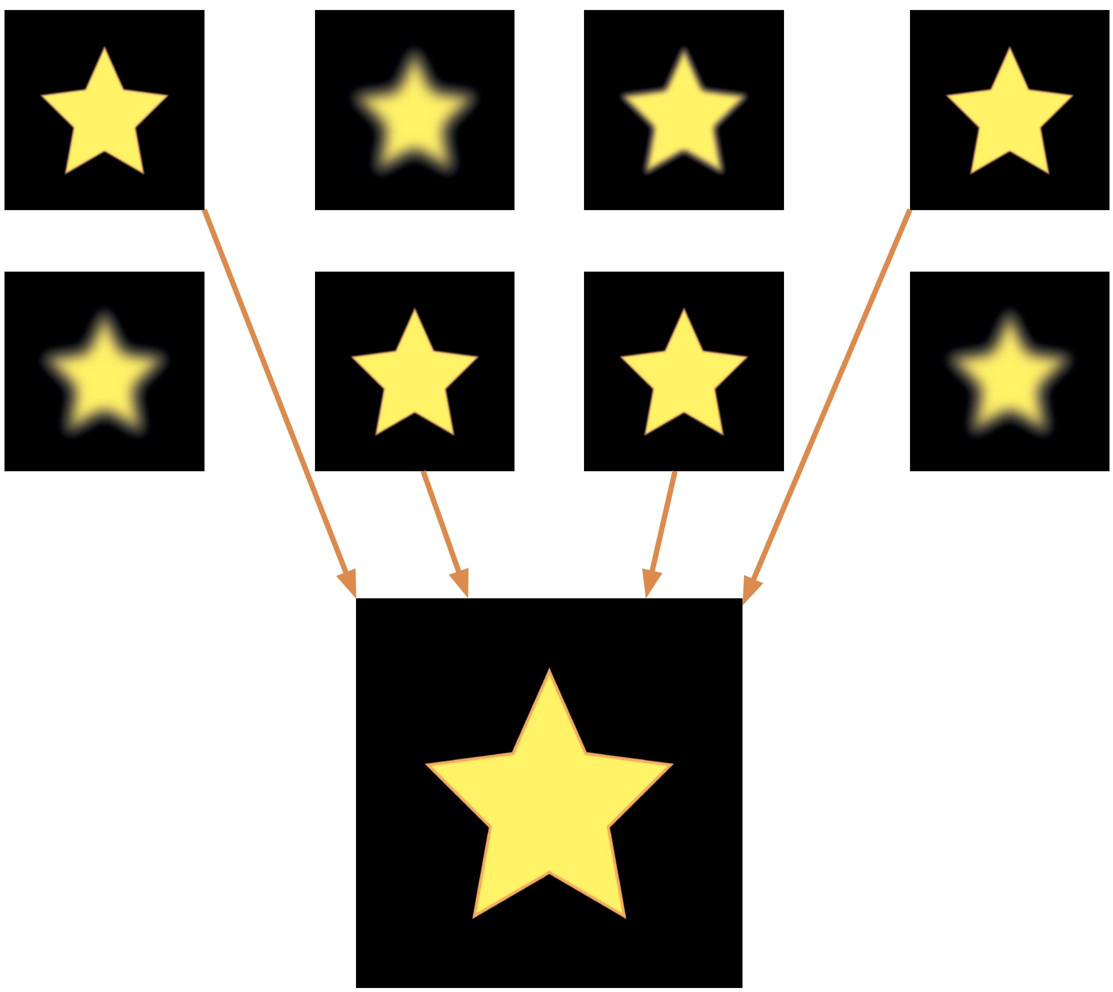


Speckle and Lucky Imaging

Speckle and lucky imaging are two alternative methods for counteracting atmospheric turbulence, which both utilize rapid image acquisition to “freeze” turbulence motion, overall improving image resolution. These techniques both require a camera with fast readout and low noise, not only to counteract the effects of turbulence, but to also detect the object of interest with much shorter exposure times.

The COSMOS is able to combine short exposure time with fast frame rates of up to 50 fps, allowing for rapid image capture to deliver diffraction-limited imaging. The COSMOS is also able to maintain low read noise at higher speeds without sacrificing sensitivity, allowing for fainter objects to be imaged using these techniques.

Multiple frames taken rapidly to “freeze” turbulence motion



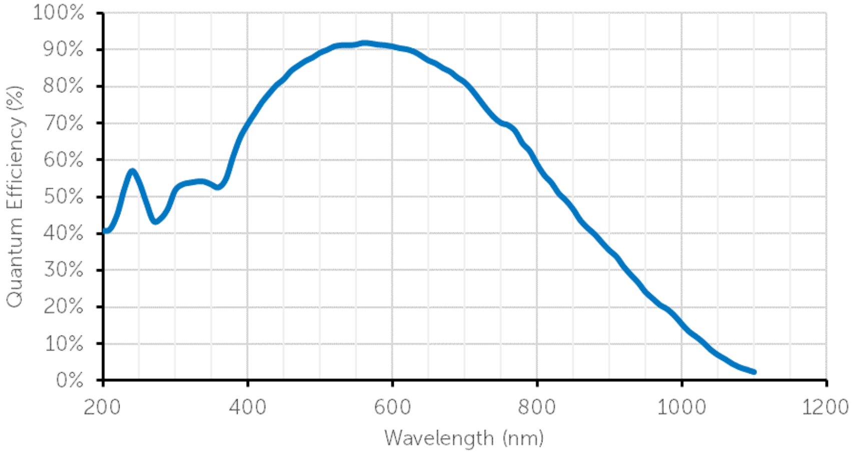
Diffraction limited image

Key Features Explored

Unbeatable Sensitivity

COSMOS achieves near-perfect light collection thanks to **back-illumination**, with quantum efficiency peaking at over 90%.

What's more, with minimal **0.7e- read noise and 0.05e-/p/s dark current**, the COSMOS surpasses both CCD and EMCCD technology in its ability to detect weak signals.



Over **90% Peak QE!** And with **UV and NIR sensitivity!**

Resolution

Resolution from ground-based astronomy is often limited by atmospheric turbulence. Techniques such as lucky and speckle imaging "freeze" any turbulence through the fast acquisition of images, improving the resolution over a larger field of view than with adaptive optics. The COSMOS, with up to 50 fps (at full array) and up to 8k x 8k sensor size, is able to provide large area images with improved resolution at a fast rate.

Applications such as exoplanet transit imaging and solar physics require a high time resolution to ensure dynamic events that occur on short time scales are detected. These applications require a camera that has rapid readout times in comparison to traditional CCDs. COSMOS is an ideal solution, providing up to 50 millisecond readout speed, with full frame, for high temporal resolution imaging.

Orion Nebula. Image courtesy of Southwest Research Institute (Boulder, Colorado)

Fast Frame Rates

LACera Large Area CMOS

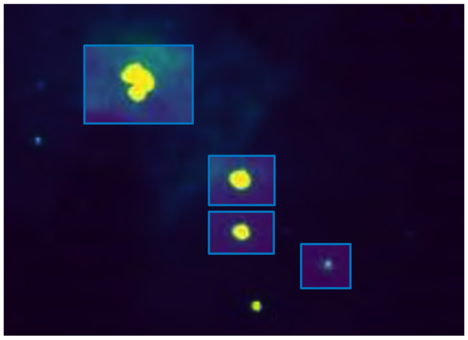
With fast frame rates and high sensitivity, COSMOS is well suited to dynamic imaging applications. Further, the short readout times can enable quick decision making and analysis.

Frame rate at full resolution, High Speed Mode, Rolling Shutter		
	Resolution	Framerate
COSMOS-66	8120 x 8120	25
COSMOS-42	6500 x 6500	31
COSMOS-09	3260 x 3260	61

Frame rate at reduced resolution, Rolling Shutter		
Aperture / Region Size	High Speed (14 bit)	High Dynamic Range (16 bit)
8120 x 8120	25	15
6800 x 6800	31	19
3040 x 3040	61	38
2048 X 2048	98	61
1600 x 1600	125	78
1024 x 1024	195	122
512 x 512	390	244
256 x 256	781	488

Multiple Regions of Interest

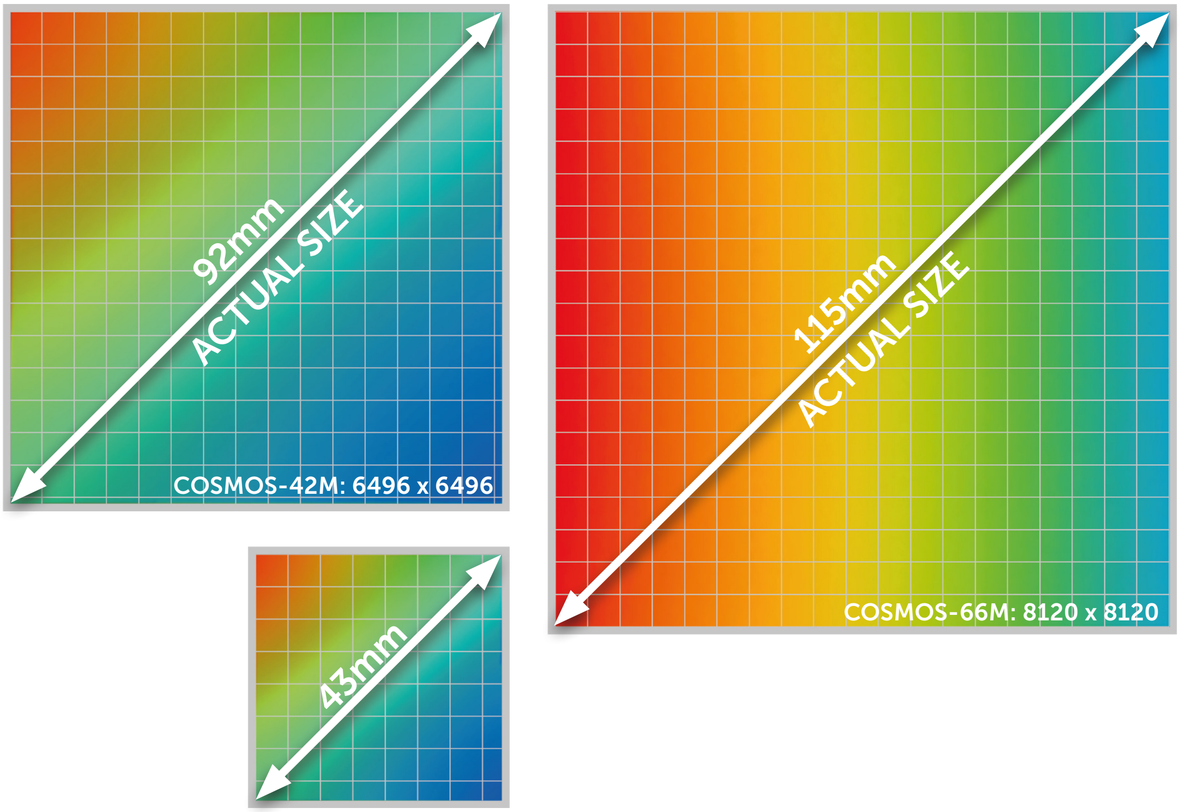
Improve readout speed while reducing unnecessary data through selecting multiple regions of interest (imaging apertures). For example, capture a reference star in one region, and a star or object of interest in another.



Star Cluster. Image courtesy of Southwest Research Institute (Boulder, Colorado)

Large Sensor Size

COSMOS multiple sensor size options allow researchers to tailor a camera to a specific optical system, achieving the maximum image size possible to capture larger areas than ever before. Choices include the 92 mm diagonal, 6.5k x 6.5k pixel COSMOS-42M and the ground-breaking 115mm diagonal, 8k x 8k pixel COSMOS-66M.



Unmatched Dynamic Range and Linear Response

High dynamic range allows for fine measurements of both very bright objects and very dim objects within the same image. Due to its low noise performance combined with 18-bit readout, COSMOS offers an incredibly wide dynamic range, providing a true dynamic range of 54,000, or 94dB. Scientific imaging requires quantitative measurements. A key factor for accurate measurements is linearity, ensuring that output intensity increases exactly proportionally with detected light. Thanks to our proprietary Analog to Digital Converter (ADC) design present in LACera technology, COSMOS provides unsurpassed linearity across its entire dynamic range, solving a common issue for previous generation CMOS cameras.

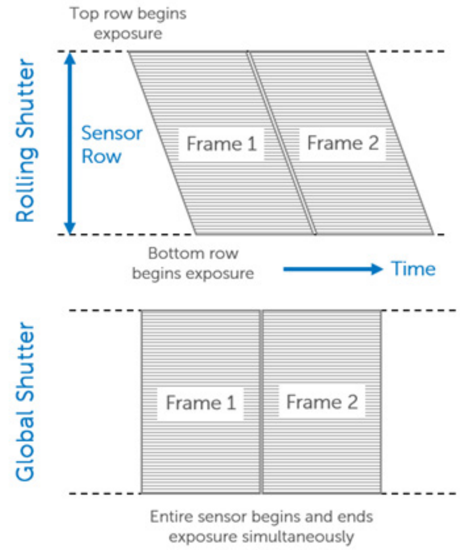
Capture bright and dim objects in the same image with huge 18-bit dynamic range
Image: Pleiades, courtesy of Rozhen National Astronomical Observatory, Bulgaria

Global Shutter CMOS

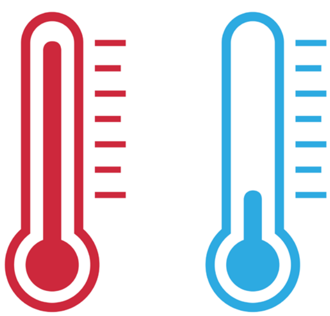
CMOS cameras do not require physical shutters, using electronic shutters in their place. Global shutter devices can start and end the exposure of the entire frame simultaneously, and are often necessary for the capture of fast moving objects.

This is achieved on CMOS through the addition of a 'storage area' to each pixel where the collected signal is stored at the end of an exposure, before then being read out. However, on back-illuminated devices, a global shutter previously wasn't possible as this storage area would be exposed to light by the back-illumination process, meaning 'parasitic' light could be detected while pixels were awaiting readout.

With LACera technology, not only have we achieved back-illumination with a global shutter, we have redesigned the pixel structure to minimize this parasitic light sensitivity, providing both the best sensitivity and artifact-free imaging.



Deep Cooling & Lifetime Vacuum



For many astronomical observations, long exposure times are needed, thus deep camera cooling is necessary to reduce the thermal dark current noise. However, large CMOS sensors with high speed readout in fact generate a large amount of heat, even compared to CCD sensors. The COSMOS builds on Teledyne Imaging's industry-leading cooling performance to overcome this challenge, achieving -30°C cooling with low dark current.

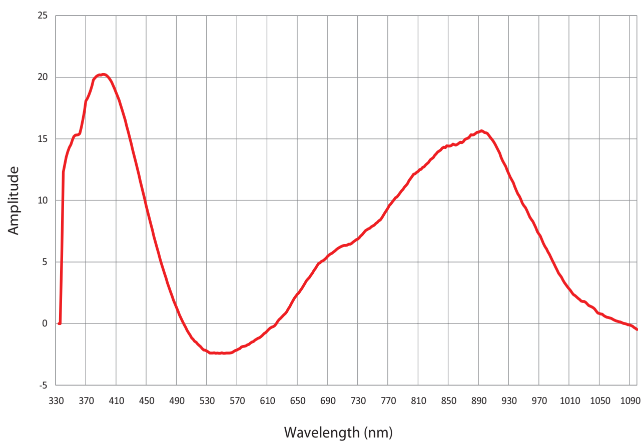
What's more, unlike other CMOS sensors, LACera technology sensors are specifically designed to be cooled from the moment of manufacture. This gives COSMOS far superior image quality, free of glows found in other back-illuminated sensors.

This is further improved by our all-metal, hermetically sealed vacuum enclosure (protected by a lifetime warranty), preventing the outgassing or degradation problems of other cameras.

eXcelon®

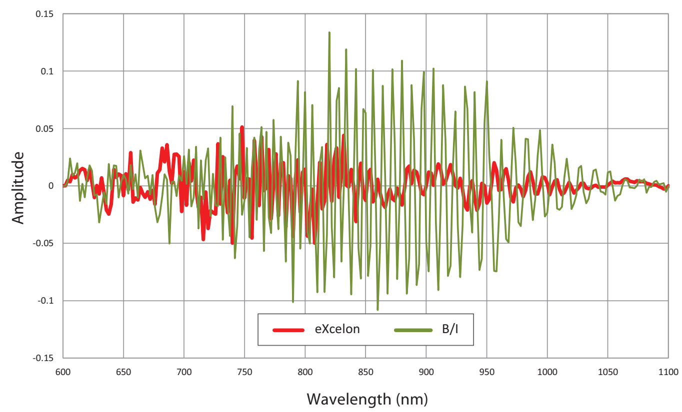
eXcelon delivers the highest sensitivity in the NIR along with extremely low etaloning

Teledyne's patented, breakthrough eXcelon technologies radically improve the sensitivity of back-illuminated detectors across a wide wavelength range. Another advantage is significantly reduced etaloning when imaging in the NIR region (750 to 1100 nm).



% QE Increase (eXcelon : BI)

B_eXcelon provides superior QE over the standard back-illuminated ("B/I") version in the UV-NIR range.



Etaloning Performance Comparison - eXcelon : B/I

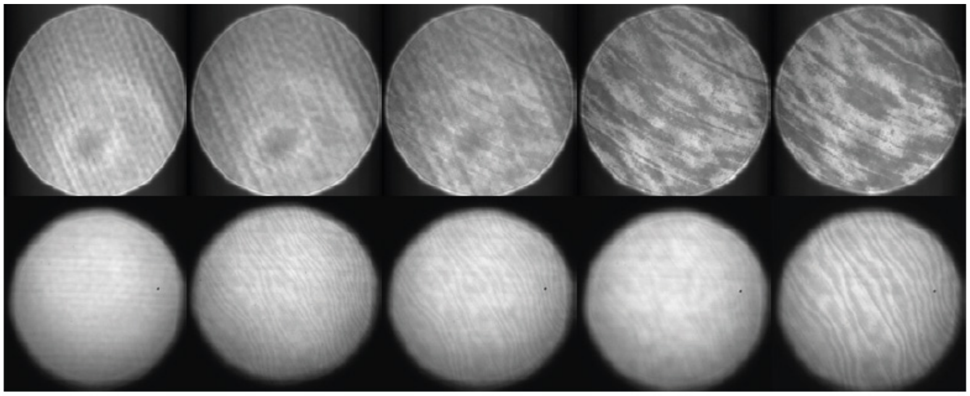
B_eXcelon provides superior QE over the standard back-illuminated ("B/I") version in the UV-NIR range.

eXcelon is available as an option for most Teledyne CCD and CMOS sensors

600 nm | 700 nm | 800 nm | 900 nm | 1000 nm

Standard Back-Illuminated CCD

eXcelon Back-Illuminated CCD



Data taken with white light source through a monochromator comparing etaloning performance of eXcelon vs. back-illuminated CCDs.

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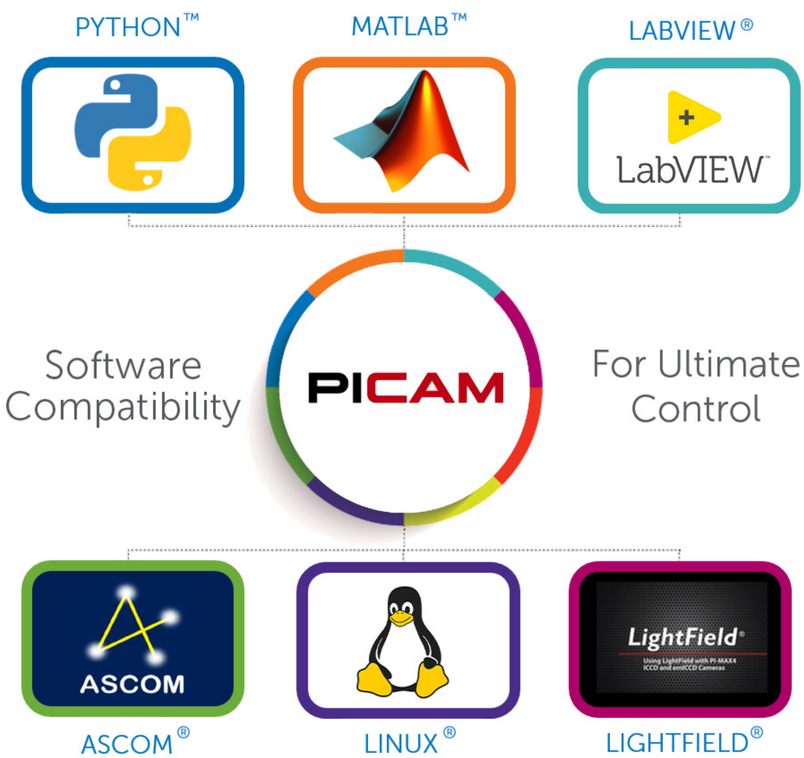
Software

PICAM API and SDK, from Teledyne Princeton Instruments, offers complete control over all cameras. Available for all 64-bit Windows and Linux systems, PICAM allows for the ultimate flexibility, providing developers, scientists and integrators the ability to build their own control and user interface directly on top of the driver. PICAM configures the identified hardware by adjusting parameters within its interface.

For those who require a "plug-and-go" system, LightField® Software allows for complete control of COSMOS on an ease of 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.



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