

Long Exposure Imaging

RETIGA

NEW E20 CMOS Camera

Specification and testing
with preliminary data
January 2023

E

SERIES



RETIGA™ E-Series Cameras

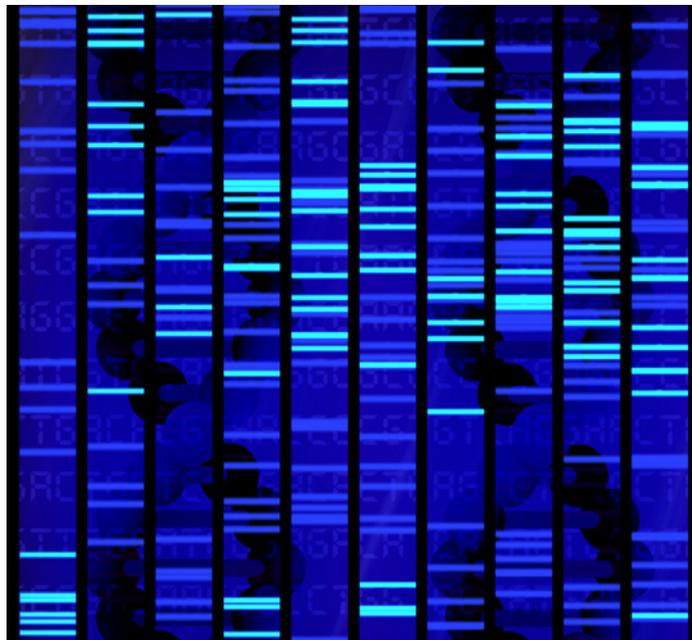
LONG EXPOSURE OPTIMIZED CMOS CAMERA

- » Exposures to 60 minutes with dark current of $< 0.003 \text{ e-}/\text{p/s}$
- » Superior image quality with the speed of CMOS
- » High resolution (7 to 20 MP), low read noise ($< 2.1 \text{ e-}$)
- » Cooled to -25°C
- » Industry-leading chamber sealing technology
- » Compact form factor for easy integration

The Ultimate Long-Exposure CMOS Camera

The Retiga E7 camera is the first in a series of low-cost, low thermal signal, high-resolution complementary metal oxide semiconductor (CMOS) cameras for long exposure imaging. Designed for easy integration into more complex imaging systems, the Retiga E7 is the CMOS camera with the thermal control needed to substitute for CCD cameras. Users needing exposures ranging from tens of milliseconds to tens of minutes can rely on the Retiga E7 camera to meet their needs.

The Retiga E7 is a 7-megapixel camera with $4.5\mu\text{m}$ pixels and greater than 70% quantum efficiency. The sensor is cooled to -25°C , minimizing dark current contributions even when integrating for many minutes.



Capable of both long exposures and fast 50 frames per second imaging, with a mode change, the E7 provides the most flexibility for those integrating a camera into an imaging system. Unlike CCDs, the E7 CMOS doesn't suffer from pixel blooming and smearing when your sample provides very bright and very dim signals.

The Retiga E7 has an extremely low dark current. The long exposure performance is produced through a combination of sensor power control, sensor cooling, and dynamic dark field correction. This is all accomplished using air cooling. This makes the E7 the ideal solution for users developing gel documentation, chemiluminescence imaging, and other long exposure methods.

Extended Dynamic Range Imaging

The goal of **Extended Dynamic Range (EDR) mode**, is to combine Full Well mode's ability to capture bright signals with Sensitivity mode's ability to detect dim signals above the camera readout noise.

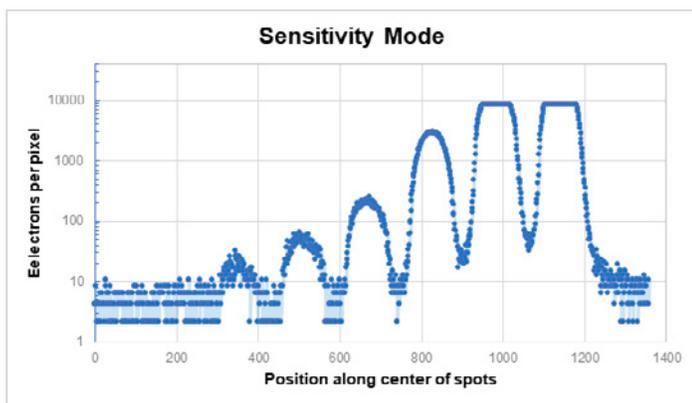
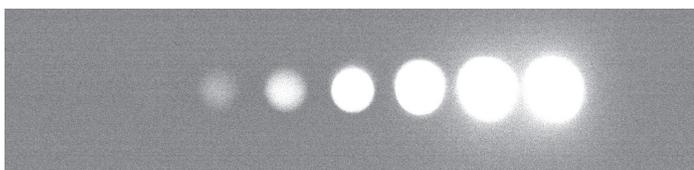
Generation of an Extended Dynamic Range (EDR) image by the Retiga E7 is dependent on the camera capturing two exposures of equal duration, one with Sensitivity gain mode and one with Full-Well gain mode. In the resulting image, the full well capacity remains equivalent to that found in Full-Well gain state, but low intensity signals are better preserved because of the low read noise provided by Sensitivity gain mode.

EDR images have approximately two and a half fold more dynamic range than either of the single capture gain states. This allows better measurement of bright and dim samples present in your sample. The trade-off for this is the doubling of the total exposure time.

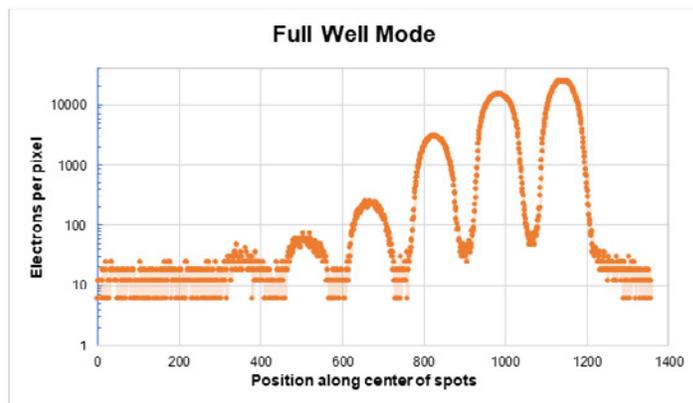
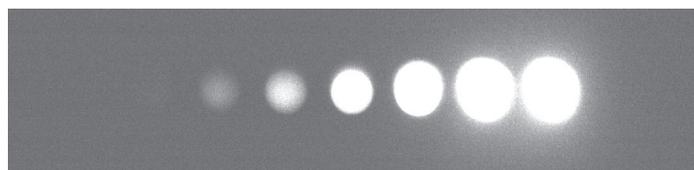
In the images below of a Harta plate captured at 120 seconds one can see the power of EDR. Each image was captured with the Retiga E7 in the mode described using the same exposure times. Accompanying each image is a

pixel intensity plot in electrons along the center line of the Hart plate spots. Contrast has been pushed identically in these plots, with white representing signals of 50 electrons or greater, to allow one to discern the dimmest spots.

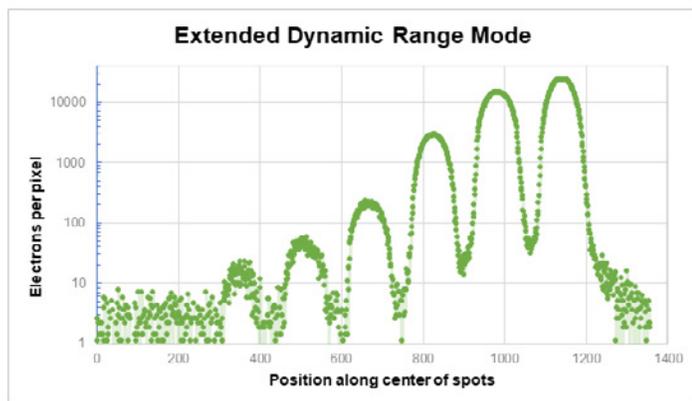
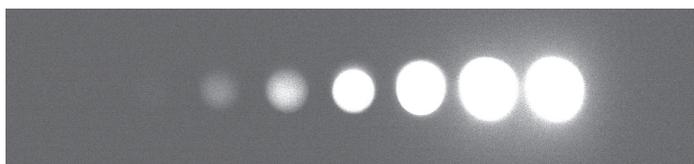
Sensitivity mode



Full Well image



Extended Dynamic Range mode



In **Sensitivity mode**, we detect six spots from the Harta plate, but the two brightest spots saturate, consistent with the lower full well capacity of this mode. In **Full Well mode**, we also detect six spots, with slight saturation at the center of the brightest spot, and the dimmest, while visually detectable is lost to the noise in the line profile.

Extended Dynamic Range mode combines the full well capacity of Full Well, and the low noise of Sensitivity modes to provide more dynamic range image of the sample. The signal of the brightest spot is the same as that in Full Well mode, and yet the intensity of the sixth spot, the dimmest captured here, is clearly distinguishable from the noise.

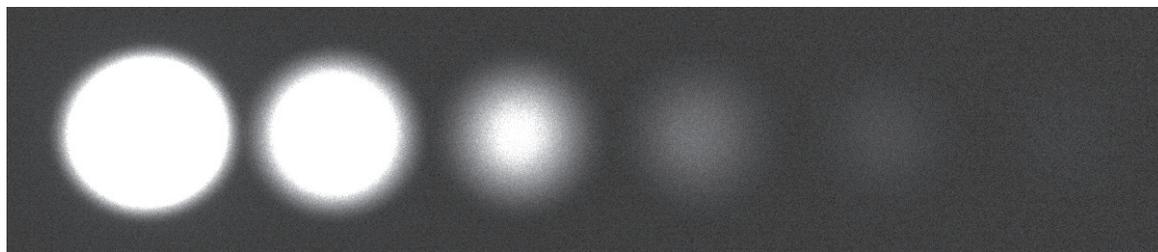
Image Sensitivity and Quality

The Retiga E7 camera has exceptional long exposure imaging quality, as highlighted in the images below. A Harta plate was imaged at low intensities, such that the brightest spots did not saturate the cameras. Twenty-minute exposures with the Retiga E7 CMOS camera and with Teledyne's QImaging Retiga R6 CCD camera are illustrated below. Visually, there's little difference between the sensitivity and dynamic range of the E7 CMOS and the CCD, consistent with them having similar dark current values, pixel size and quantum efficiency.

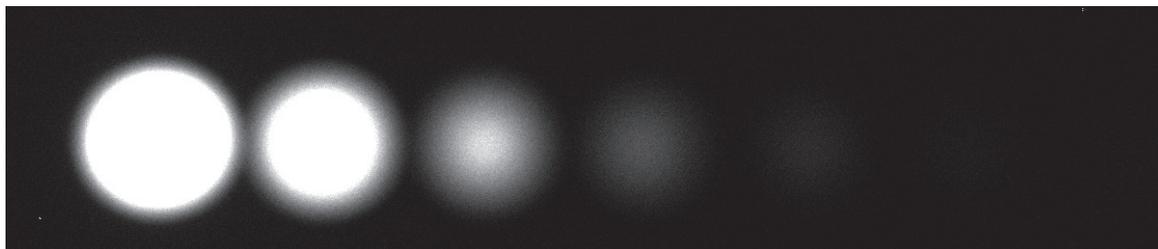
The Retiga Platform is Both Powerful and Flexible

Fast data transfer over USB 3.2 provides 50 full frames per second imaging capability as needed. Precise sensor control, along with cooling to -25°C , allows minutes-long exposures. Two different gain modes select for high sensitivity or high signal level detection. The Retiga E7 provides all the long integration power of CCDs with all the benefits of modern CMOS cameras to enhance your system performance.

20-minute exposure with Retiga E7 gives CCD-like image quality



Retiga E7 (CMOS sensor)



Retiga R6 (CCD sensor)

◀ **Figure 2:** A 20-minute exposure of the Harta plate with at low signal intensity is illustrated here. Top image is the Retiga R6, while the bottom image was captured with the Retiga E6. For display, images were intensity scaled such that the camera floor is set to black, and 5% of the full well capacity was set to white. There were no saturated pixels in either image.

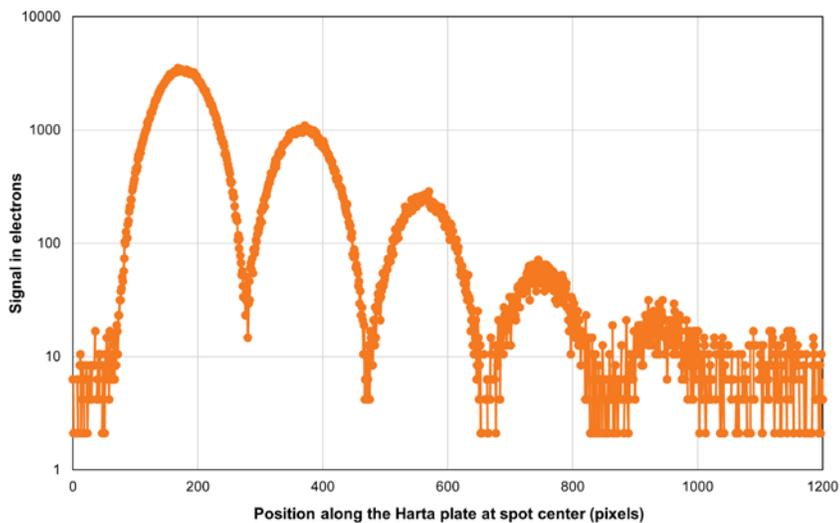
Retiga E7 Long Exposure Image Quality

Heat generates signals in imaging sensors that are indistinguishable from those generated by light. To minimize the heat generated haze and glow generated in long exposure images, several approaches can be used. Optimizing the power usage in the sensor can reduce the generation of heat during the exposure. Similarly, cooling

the sensor reduces the haze and glow generated by heat. Math can be used to correct for the average heat signal based on the properties of the sensor. The Retiga E7 uses all three approaches to reduce dark currents that are equal to or better than many CCDs on the market.

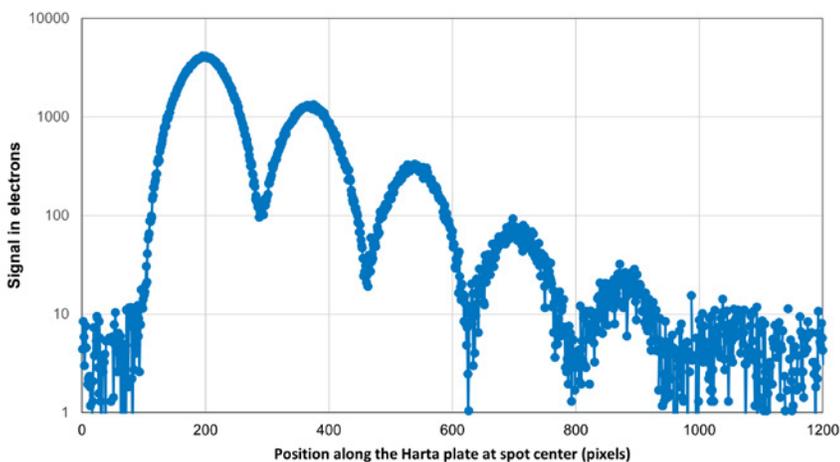
Quantifying the signal intensities from the Retiga E7 and the Retiga R6 CCD cameras

Retiga E7 – Harta plate signal at 20 minutes



◀ **Figure 3:** Image intensities in gray scales were converted to electrons by subtracting the camera bias (0 light at 0 exposure time) and multiplying the remainder against the camera gain, expressed as electrons/gray level, from the camera Certificate of Performance. The intensities along the center line of the Harta plate from *Figure 1* are plotted with the electrons per pixel plotted on a Log scale on the Y axis, and pixel position from left image to right image on the X axis.

Retiga R6 CCD camera – Harta plate signal at 20 minutes



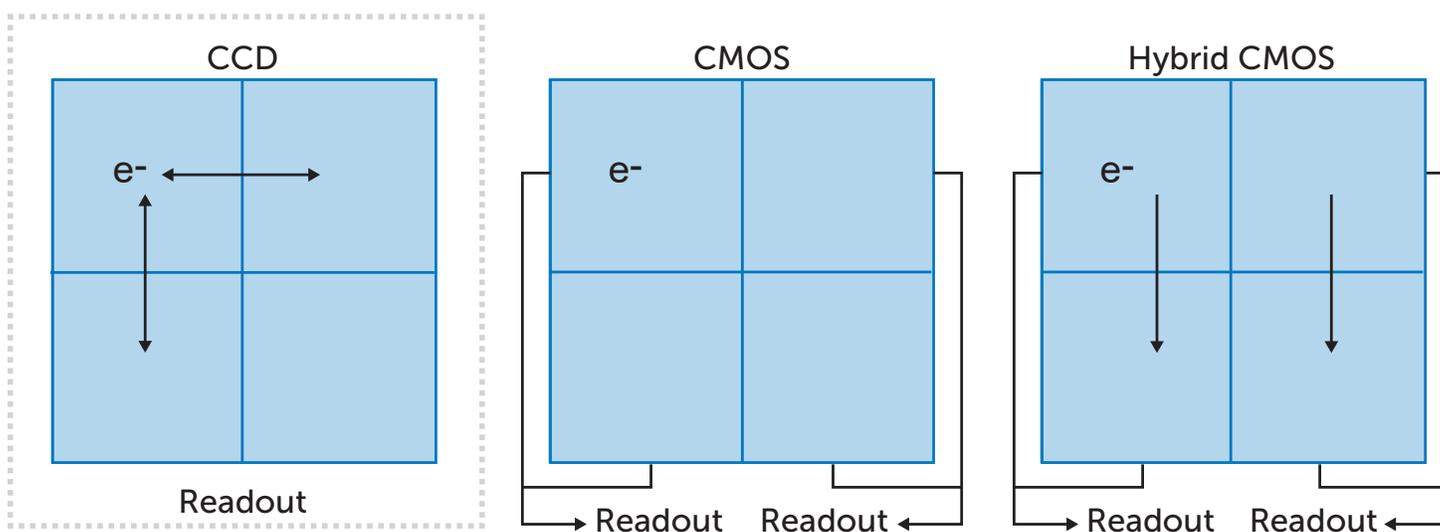
Retiga E7: Hybrid Binning

Charge coupled devices (CCDs) have electrical connections between each pixel. Moving accumulated signal from one pixel into the next is almost completely noise free. One approach in CCDs to increase the signal over the large readout noise is to bin.

Binning in a CCD camera increases the total signal without increasing camera noise, at the expense of worse spatial sampling by the bigger "super-pixel." For 2x2 binning in a CCD, one expects the signal-to-noise ratio (SNR) to increase by 4. The movement of electrons, the signal, in CCD sensors is illustrated to the left in the figure below.

CMOS sensors traditionally have no electrical connections between individual pixels. Binning occurs on CMOS cameras after readout. CMOS binning adds up signal, but also adds up the sensor read noise from each pixel. However, since 4 measurements of the pixel intensity were made, the variability is decreased by the square root of the number of measurements. In binning 2x2 on a CMOS sensor, the SNR would increase by 2.

Hybrid CMOS sensors, including that in the E7, have electrical connections between neighboring pixels, usually along the same column. This provides CCD-like charge accumulation without extra noise for that pixel pair. Hybrid binning 2x2 pixels then is a combination of CCD-like binning along the column, with the mathematical binning of rows after readout. This provides a lower total noise than classic CMOS and a 2.8 fold increase in SNR.



Retiga E7

Specifications	Camera Performance
Sensor	CMOS sensor
Active Array Size	3200 x 2200 (7.1 Megapixel)
Pixel Area	4.5 μ m x 4.5 μ m (20.25 μ m ²)
Sensor Area	14.4 mm x 10 mm, 17.6 mm diagonal
Peak QE%	> 73%
Readout Mode	Global shutter
Binning	2x1 charge domain (on chip) binning up to 4x4 digital binning
Linearity	> 99%
Cooling Options	Air cooled to -25°C

Camera Modes

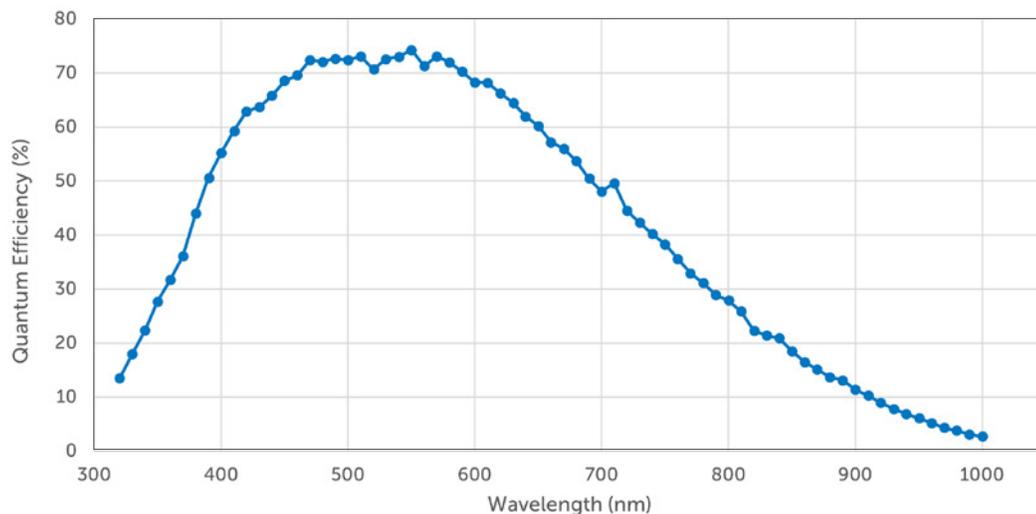
Specifications	Speed	Long Exposure	16-Bit Extended Dynamic Range (EDR)
Bit-Depth	12-bit	12-bit	16-bit
Maximum Frame Rate	51 FPS	3.2 FPS	1.6 FPS*
Line Time	8.62 μ Sec	137.92 μ Sec	137.92 μ Sec
Maximum Exposure Time	120 seconds	60 minutes	60 minutes
Dark Current	0.1 e ⁻ /p/sec	0.001 e ⁻ /p/sec	0.001 e ⁻ /p/sec
Full Well Capacity			
Full Well (gain 1)	23 Ke ⁻	23 Ke ⁻	—
Sensitivity (gain 2)	8 Ke ⁻	8 Ke ⁻	—
EDR			23 Ke ⁻
Read Noise			
Full Well (gain 1)	5.1 e ⁻ /	5.1 e ⁻ /	—
Sensitivity (gain 2)	2.1 e ⁻ /	2.1 e ⁻ /	—
EDR	—	—	2.1 e ⁻
Gain			
Full Well (gain 1)	6.0 e ⁻ /gray	6.0 e ⁻ /gray	—
Sensitivity (gain 2)	2.1 e ⁻ /gray	2.1 e ⁻ /gray	—
EDR	—	—	0.35 e ⁻ /gray

* EDR combines two exposures of equal time, but different gain modes. Setting the exposure to 60 minutes will take 120 minutes of acquisition.

Specification

Digital Interface	USB 3.2 (10 Gbps)
Lens Interface	C-Mount
Mounting Points	2 x 1/4"-20 TPI mounting points per side
Camera Weight	0.8 Kg, 1.76 lbs
Camera I/O	Read Out Trigger Ready Exposure Out Trigger In

Retiga E7



Accessories Included

- USB 3.2 Cable and Card
- Trigger Cables
- Power Supply
- Quickstart Guide

Maximum Frame Rates

Mode	Unbinned Frame Rate	2x2 Binning Frame Rate
Long Exposure	3.1 FPS	6.2 FPS
Fast Capture	51 FPS	102 FPS
EDR	1.5 FPS	3 FPS

KEY FEATURES

Easiest System Integration

- » True plug-n-play convenience
- » Teledyne’s ultimate software development kit, (SKD), provides complete control of camera operations
- » Easy, seamless integration to your system
- » Python, C++, LabVIEW, MATLAB compatibility
- » Full optical, mechanical, and software support
- » PVCam™ API drivers automate descriptions of functions, parameters, and valued used to create a user-designed interface for Retiga E7 cameras and accessories

Retiga E20

Specifications	Camera Performance
Sensor	CMOS sensor
Active Array Size	5472 x 3648 (20 Megapixel)
Pixel Area	2.4 μ m x 2.4 μ m (5.76 μ m ²)
Sensor Area	13.1 mm x 8.7 mm, 15.7 mm diagonal
Peak QE%	85% at 500nm
Readout Mode	Rolling shutter
Binning	Up to 4x4 digital binning
Linearity	> 99%
Cooling Options	Air cooled to -25°C*

*Anticipated

Camera Modes

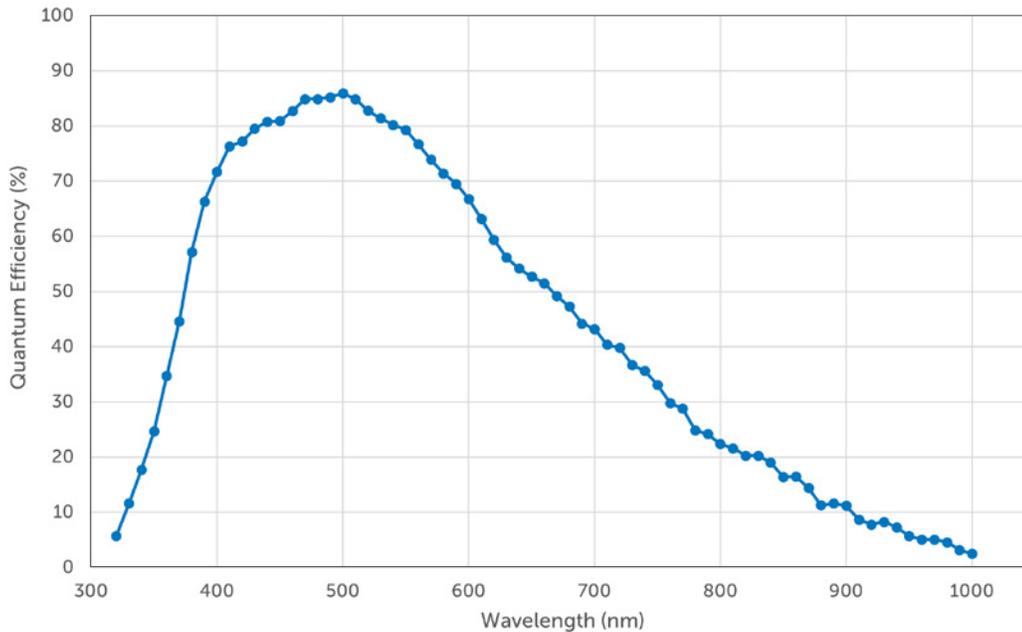
Specifications	Speed	Long Exposure	16-Bit Extended Dynamic Range (EDR)
Bit-Depth	12-bit	12-bit	16-bit
Maximum Frame Rate	22 FPS	1.5 FPS	0.7 FPS*
Maximum Exposure Time	120 seconds	60 minutes	60 minutes
Dark Current	0.1 e ⁻ /p/sec	0.003 e ⁻ /p/sec	0.003 e ⁻ /p/sec
Full Well Capacity			
Full Well (gain 1)	10 Ke ⁻	10 Ke ⁻	—
Sensitivity (gain 2)	1.2 Ke ⁻	1.2 Ke ⁻	—
EDR			10 Ke ⁻
Read Noise			
Full Well (gain 1)	3 e ⁻ /	3 e ⁻ /	—
Sensitivity (gain 2)	< 2 e ⁻ /	< 2 e ⁻ /	—
EDR	—	—	< 2 e ⁻ /
Gain			
Full Well (gain 1)	2.4 e ⁻ /gray	2.4 e ⁻ /gray	—
Sensitivity (gain 2)	0.29 e ⁻ /gray	0.29 e ⁻ /gray	—
EDR	—	—	0.15 e ⁻ /gray

* EDR combines two exposures of equal time, but different gain modes. Setting the exposure to 60 minutes will take 120 minutes of acquisition.

Specification

Digital Interface	USB 3.2 (10 Gbps)
Lens Interface	C-Mount
Mounting Points	2 x ¼"-20 TPI mounting points per side
Camera Weight	0.8 Kg, 1.76 lbs
Camera I/O	Read Out Trigger Ready Exposure Out Trigger In

Retiga E20



Accessories Included

- USB 3.2 Cable and Card
- Trigger Cables
- Power Supply
- Quickstart Guide

Maximum Frame Rates

Mode	Frame Rate*
Speed	22 FPS
Long Exposure	~ 1.5 FPS
16-Bit Standard	~ 1.5 FPS
16-Bit EDR	~ 0.7 FPS

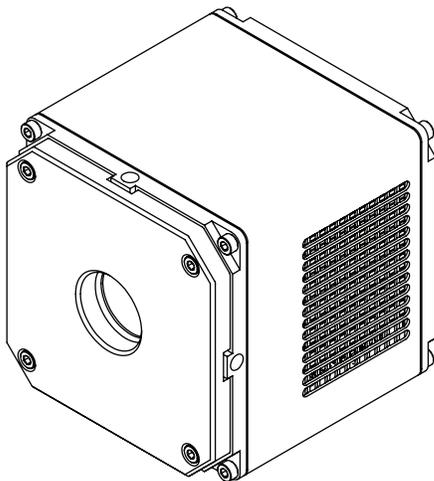
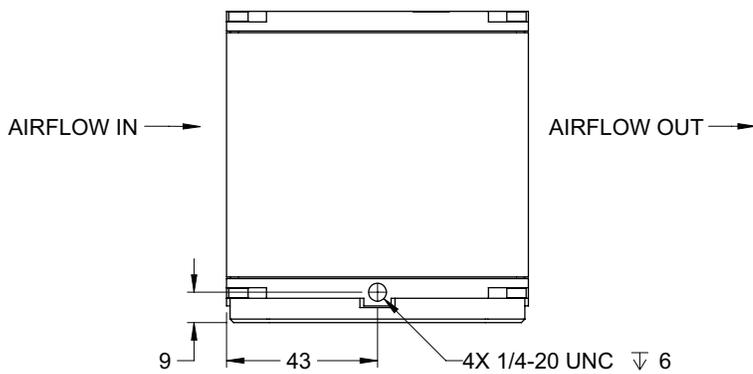
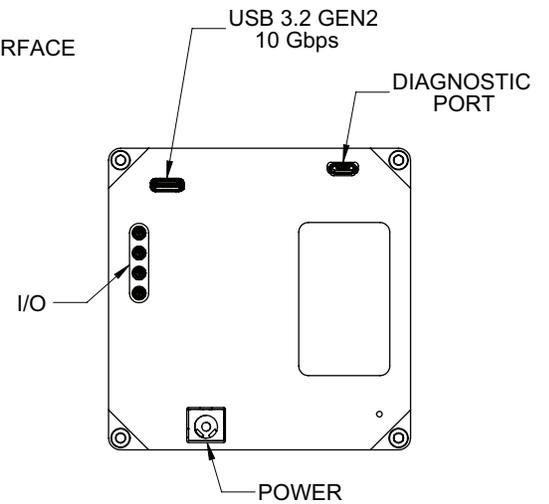
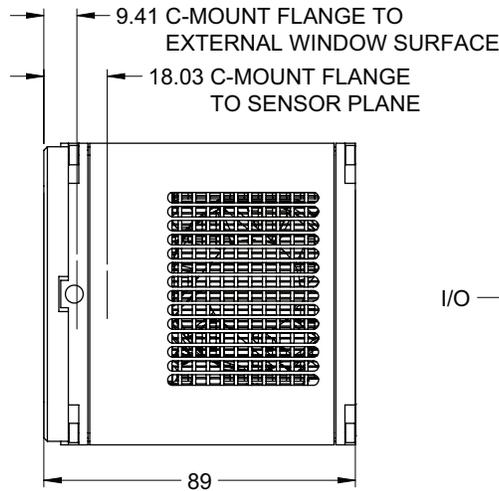
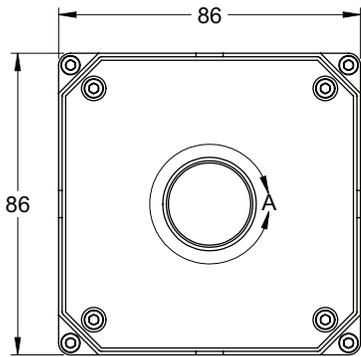
*Anticipated

KEY FEATURES

Easiest System Integration

- » True plug-n-play convenience
- » Teledyne’s ultimate software development kit, (SKD), provides complete control of camera operations
- » Easy, seamless integration to your system
- » Python, C++, LabVIEW, MATLAB compatibility
- » Full optical, mechanical, and software support
- » PVCam™ API drivers automate descriptions of functions, parameters, and valued used to create a user-designed interface for Retiga E7 cameras and accessories

Technical Drawings



SOFTWARE & ENGINEERING SUPPORT

Data Exchange

Full integration into your system design platform and development environment:

- » True plug-n-play convenience
- » Teledyne's ultimate software development kit, (SKD), provides complete control of camera operations
- » Easy, seamless integration to your system
- » Python, C++, LabVIEW, MATLAB compatibility
- » Full optical, mechanical, and software support
- » PVCam™ API drivers automate descriptions of functions, parameters, and values used to create a user-designed interface for Retiga E-Series cameras and accessories

Engineering

All support documents are available:

- » 3D STEP files
- » Software SKD
- » Operating Manual
- » Software Manual

Request documents and software/drivers:
photometrics.info@teledyne.com

Retiga E-Series Cameras

THE ULTIMATE LONG-EXPOSURE CMOS CAMERA

The Retiga E-Series cameras are a major breakthrough in CMOS thermal noise control for applications that require exposure times stretching from seconds to minutes. Cost efficient cameras that can capture weak signals using long exposures are the foundation of many areas of scientific research, including PCR and protein analysis.

The Retiga E-Series addresses an urgent issue faced by systems manufacturers in various industries who rely on the low dark current characteristics of CCD devices, many of which will soon be phased out.

- The Retiga E7 is a 7 Megapixel CMOS camera with low read noise (2.2 electrons) and ultra-low dark current (0.001 electrons/pixel/second or less)
- The Retiga E20 is a 20 Megapixel CMOS camera with low read noise (2.2 electrons) and ultra-low dark current (0.003 electrons/pixel/second or less*)

Both cameras are comfortably able to detect weak signals while integrating over several minutes. It is the next generation of long exposure camera, following the highly successful CCD-based Retiga R-series.

Teledyne Photometrics, a part of Teledyne's Vision Solutions Group, manufactures industry leading scientific CMOS and CCD cameras used in Life Science research. With more than 40 years of experience, Teledyne Photometrics has established itself as a trusted provider of high-quality imaging devices, serving multiple industries.

Teledyne Photometrics continues its market leadership with the Retiga E-Series, designed to be integrated with other devices, with sizing and interfaces derived from the OEM focused BSI-Express. This camera follows on from the boundary pushing Kinetix, the first scientific CMOS with 500 fps speed, 0.7 electron read noise and large field of view. Similarly, the award winning Prime 95b lead the industry into using back illuminated sensors for high detection efficiency.

*Anticipated

CONTACTS

Contact your local Teledyne Photometrics representative for additional information.

Teledyne Photometrics – USA

Tel: +1 520-889-9933

Toll Free: +1 800-874-9789

photometrics.info@teledyne.com

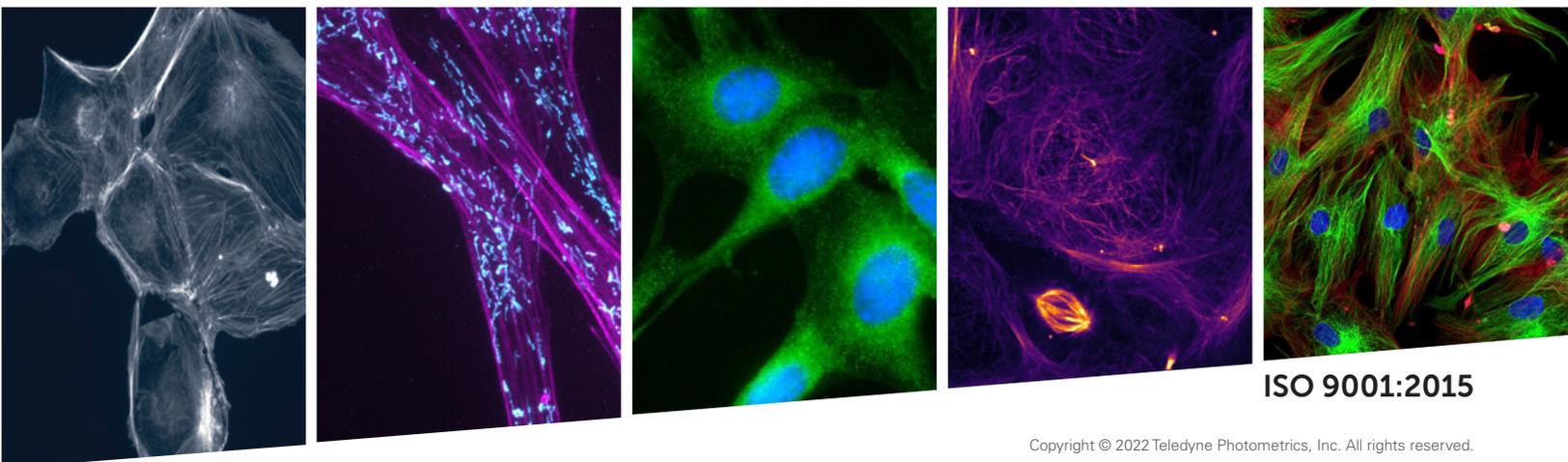
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