



Retiga E Family – User Manual



## Teledyne Photometrics

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We declare under our sole responsibility the compliance of the product with FCC Part 15, Subpart B, EN 61326-1, EN 55011, EN 61000-3-2, EN 61000-3-3, EN 61000-4-2, EN 61000-4-3, EN 61000-4-4, EN 61000-4-5, EN 61000-4-6, EN 61000-4-11

Any modification of the product, not authorized by us, will invalidate this declaration.

Product Name: Retiga E7

Identification: 01-RET-E7-M-C

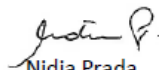
Directive: Electromagnetic Compatibility (2014/30/EU)

Test acc. To: FCC Part 15, Subpart B  
EN 61326-1:2021  
EN 55011:2016/A11:2020, EN 61000-3-2  
EN 61000-3-3, EN 61000-4-2  
EN 61000-4-3, EN 61000-4-4  
EN 61000-4-5, EN 61000-4-6  
EN 61000-4-11

The product is marked with:



Date: **June 9<sup>th</sup>, 2025**

  
Nidia Prada  
Quality Manager  
Teledyne Photometrics



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Any modification of the product, not authorized by us, will invalidate this declaration.

Product Name: Retiga E9

Identification: 01-RET-E9-M-C

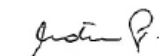
Directive: Electromagnetic Compatibility (2014/30/EU)

Test acc. To: FCC Part 15, Subpart B  
EN 61326-1:2021  
EN 55011:2016/A11:2020, EN 61000-3-2  
EN 61000-3-3, EN 61000-4-2  
EN 61000-4-3, EN 61000-4-4  
EN 61000-4-5, EN 61000-4-6  
EN 61000-4-11

The product is marked with:



Date: **June 9<sup>th</sup>, 2025**

  
Nidia Prada  
Quality Manager  
Teledyne Photometrics



# H.B. Compliance Solutions

## EMC Test Report

For the

**Teledyne Photometrics**

**Retiga E7**

Tested under

EN 61326-1: 2021 - Measurement, Control and Laboratory Use

Class A

Radio Disturbance & Immunity Characteristics

July 27, 2023

### Prepared for:

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### Prepared By:

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Tempe, Arizona 85282

### Reviewed By:



Hoosamuddin Bandukwala



Cert # ATL-0062-E

**Engineering Statement:** The measurements shown in this report were made in accordance with the procedure indicated, and the emissions from this equipment were found to be within the limits applicable. I assume full responsibility for the accuracy and completeness of these measurements, and for the qualifications of all persons taking them. It is further stated that upon the basis of the measurement made, the equipment tested is capable of operation in accordance with the EN 61326 standards under normal use and maintenance. All results contained herein relate only to the sample tested.

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# H.B. Compliance Solutions

## EMC Test Report

For the

**Teledyne Photometrics**

**Retiga E9**

Tested under

EN 61326-1: 2021 - Measurement, Control and Laboratory Use

Class A

Radio Disturbance & Immunity Characteristics

November 19, 2024

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# H.B. Compliance Solutions

## Un-Intentional Radiator Test Report

For the

**Teledyne Photometrics**

**Retiga E7**

Tested under

The FCC Rules contained in Title 47 of the CFR, Part 15 Subpart B

For Class A Digital Device

July 29, 2022

**Prepared for:**

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**Reviewed By:**



Hoosamuddin Bandukwala



Cert # ATL-0062-E

**Engineering Statement:** The measurements shown in this report were made in accordance with the procedure indicated, and the emissions from this equipment were found to be within the limits applicable. I assume full responsibility for the accuracy and completeness of these measurements, and for the qualifications of all persons taking them. It is further stated that upon the basis of the measurement made, the equipment tested is capable of operation in accordance with the requirements of Part 15 of the FCC Rules under normal use and maintenance. All results contained herein relate only to the sample tested.

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# H.B. Compliance Solutions

## Un-Intentional Radiator Test Report

For the

**Teledyne Photometrics**

**Retiga E9**

Tested under

The FCC Rules contained in Title 47 of the CFR, Part 15 Subpart B

For Class A Digital Device

November 19, 2024

**Prepared for:**

Teledyne Photometrics

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Cert # ATL-0062-E

**Engineering Statement:** The measurements shown in this report were made in accordance with the procedure indicated, and the emissions from this equipment were found to be within the limits applicable. I assume full responsibility for the accuracy and completeness of these measurements, and for the qualifications of all persons taking them. It is further stated that upon the basis of the measurement made, the equipment tested is capable of operation in accordance with the requirements of Part 15 of the FCC Rules under normal use and maintenance. All results contained herein relate only to the sample tested.

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## Table of Contents

Chapter 1 – Overview .....	14
About This Manual .....	14
Precautions .....	14
Environmental Requirements .....	15
Storage Requirements .....	15
Microscopes, Lenses and Tripods .....	15
Repairs .....	15
Cleaning .....	15
Chapter 2 – System Installation .....	16
Introduction .....	16
Software Compatibility .....	16
Host Computer Requirements .....	16
System Installation .....	17
Installing the USB Interface Card .....	17
Connecting the USB cable .....	18
Chapter 3 – Theory of Operation .....	19
Introduction .....	19
CMOS Image Sensor Structure .....	19
Rolling and Global Shutter Readout .....	20
Digital Binning .....	21
Hybrid Binning (Retiga E7 only) .....	21
Sensor Clearing .....	22
Bias Offset Settings .....	22
Pixel Noise Filters .....	22
Chapter 4 – Operating Features .....	25
Readout Modes and Gain States .....	25
Regions of Interest (ROIs) .....	26
Device Synchronization (Triggering) .....	26
Trigger Modes .....	27
Expose Out Modes .....	28
Fan Speed Control .....	29
Time Stamps .....	30
Chapter 5 – Troubleshooting .....	31
Chapter 6 – Basic Specifications .....	33
Retiga E Camera Dimensions .....	33
Camera Weight .....	33
Power Supply Specifications .....	33
Sensor Specifications .....	34
Retiga E Quantum Efficiency Comparison .....	35



## Chapter 1 – Overview

### About This Manual

The Retiga E Family Scientific CMOS user manual is divided into six chapters. Teledyne Photometrics recommends you read the entire manual before operating the camera to ensure proper use. The chapter contents are briefly described below.

**Note: The information provided applies only to the Retiga E Family CMOS cameras and is not applicable to any other Teledyne Photometrics camera.**

1. **System Installation** – Instructions on how to connect the camera to the computer via the USB 3.2 Gen2 interface
2. **Theory of operation** – A basic overview of CMOS technology as used in the Retiga E CMOS cameras
3. **Basic specifications** – specifications for the Retiga E CMOS cameras

### Precautions

The CMOS sensor and other system electronics are extremely sensitive to electrostatic discharge (ESD). To avoid permanently damaging the system, please observe the following precautions:

- If using high-voltage equipment (such as an arc lamp) with the camera system, turn the camera power on last and when powering down, power the camera off first.
- Use caution when triggering high-current switching devices (such as an arc lamp) near the system. The image sensor can be permanently damaged by transient voltage spikes. If electrically noisy devices are present, an isolated, conditioned power line or dedicated isolation transformer is highly recommended.
- Always leave one inch of space around the camera for airflow.
- Never open the camera. There are no user-serviceable parts inside the Retiga E CMOS cameras. Opening the camera voids the warranty
- Use only the interface card, cables and power supply designated for this camera system. Using non-Retiga E cables, interface cards or power supplies may result in unexpected errors or permanent damage to the system
- Do not use a C-mount lens with optics that extend behind the lens flange

## Environmental Requirements

The Retiga E CMOS cameras should be operated in a clean, dry environment. The camera system should not be operated without being attached to a lens or microscope without proper airflow around the camera. The camera system's ambient operating temperature is 0°C to 30°C with 80% relative humidity, non condensing.

## Storage Requirements

The CMOS sensor and other system electronics are extremely sensitive to electrostatic discharge (ESD). To avoid permanently damaging the system, please observe the following precautions:

## Microscopes, Lenses and Tripods

The camera has two standard mounting options and can be coupled to any optical system or microscope that accepts a standard C-mount adapter for the Retiga E. The camera also allows you to install any lens that is compatible with either of these threaded video mounts if its optics do not extend behind the flange of the lens. The Retiga E can be mounted to optical tables, tripods or custom stands using the 4X ¼-20 UNC threaded attachment points located near the front of the camera housing on all sides.

## Repairs

Please save the original packing materials so you can safely ship the camera to another location or return it for repairs if necessary. Retiga E CMOS camera systems contain no user-serviceable parts. Repairs must be done by Teledyne Photometrics. Should the camera system require repairs, please contact Teledyne Photometrics Customer Service.

**Note: Do not open the camera. Opening the Retiga E CMOS voids the warranty.**

## Cleaning

Clean the exterior surfaces of the camera with a dry, lint-free cloth. To remove stains, contact Teledyne Photometrics Customer Service. To clean the camera's imaging window, use only a filtered compressed-air source. Hand-held cans are not recommended as they may spray propellant onto the window. Do not touch the window.

## Chapter 2 – System Installation

**Note:** Carefully review the Precautions section in the previous chapter before performing any of the procedures outlined in this chapter. Using a different cable or interface card may result in permanent damage to the system

### Introduction

The Retiga E CMOS camera system includes the following hardware components:

- Retiga E (E7, E9 or E20) CMOS Camera
- 10V/5A DC power supply with international power cord set
- USB 3.1 interface card containing both USB C and A ports
- USB 3.1 Gen2 (USB 10 Gbps) cable, 3m
- 4x single-line MMCX trigger cables
- C-Mount lens cap
- USB memory device containing PVCAM library and drivers
- Quick Installation Guide

Retiga E CMOS cameras are linked using USB 3.1 Gen2 connectors and controlled by the host computer system. While it is recommended that the camera is operated via the provided USB interface card, the camera can also run on a PC's native USB 3.0 or above port. All these hardware components should be included with the shipment. Keep all the original packing materials so you can safely ship the camera to another location or return it for service.

If you have any difficulty with any step of the instructions, contact Teledyne Photometrics Customer Service.

### Software Compatibility

Unless there is a preferred version specified by a third-party software provider, the latest version of PVCAM is recommended for use with Retiga E cameras. The PVCAM SDK is available on the Teledyne Vision Solutions website.

### Host Computer Requirements

The host computer (PC) for a Retiga E camera must meet the following minimum requirements:

- Windows 10/11 64-bit operating system
- 2.0 GHz or faster Intel processor: either Xeon or Core i7
- >8 GB RAM
- >250 GB serial ATA (SATA) HDD and/or >512 GB solid state drive (SSD) for high-speed imaging and storage
- >512 MB slot-based ATI/NVIDIA video graphics card (i.e., not an "onboard/integrated graphics" adapter)
- USB port for use with USB memory devices
- Internet access to obtain the PVCAM library and interface drivers
- An open PCI-Express 4x (4 lane) interface slot or higher for use with the provided USB interface card

## System Installation

An appropriate Installation Guide is included as an insert with the camera. This guide provides step-by-step instructions for installing the camera interface software for Windows-based computers. Additional instructions are included for installing a USB interface card in the computer. The Teledyne Photometrics USB memory device contains the following files:

- Manuals Directory — contains user manuals in PDF format
- Customer Case Studies — application examples
- Imaging Software — a copy of the free open source software application, Micro-Manager
- Technical Notes — detailed background on advanced features
- For a 64-bit Windows OS, install PVCam64\_Setup\_X\_X\_X\_X.exe (latest version is on drive)
- Follow the Installation Guide insert for the version of Windows being used. Reboot the computer when the installation is complete.

## Installing the USB Interface Card



The USB 3.1 card included with Retiga E cameras ensures a stable connection and maximum data is able to be acquired from the camera.

**Note: The model of USB card shipped with the camera may differ from the one shown in the above photo. Please refrain from using other cards, as they may damage the camera.**

## Installing the USB Interface Card (cont.)

Before attempting to operate the camera, first install this interface card into the PC with the following steps:

1. Shut down the PC
2. Unplug the PC from power mains and ensure the camera is turned off
3. Open the side of the computer to access



4. Locate an available 4 channel or higher PCIe slot (marked x4). Refer to the PC's documentation to locate a suitable slot



5. Holding the USB card and (being careful not to touch the board components or PCIe bridge pins) insert it with the proper orientation into the open slot. The card should slide into place with minimal resistance and snap when fully inserted.

## Connecting the USB cable

Once the USB cable has been connected to the camera and host PC, the camera will power on. When using 3 meter active cables, it is important that proper USB cable orientation is used. Please refer to the QuickStart guide with the camera or the USB stick for the most up to date instructions.

## Chapter 3 – Theory of Operation

### Introduction

Backside-illuminated scientific CMOS (BSI sCMOS) sensors are a recent but rapidly maturing development in image sensor technology. Boasting near-perfect >90% quantum efficiency (QE), they are able to provide the highest levels of sensitivity. New cameras can now leverage these high-QE sensors to offer a combination of low read noise, high full well capacity, and fast readout rates that are ideal for modern low-light imaging.

### CMOS Image Sensor Structure

A major difference between traditional CCD sensors and CMOS sensors is the location where charge-to-voltage conversion of accumulated photoelectrons takes place. CCD sensors transfer the pixels accumulated signal in charge packets in “bucket brigade” fashion across the sensor to a common output node where charge is converted to a voltage. The voltage is then sampled using off-chip Analog-to-Digital Converters (ADC) and transferred to the PC as digital grey values.

While providing excellent quantitative photometry and very high image quality, the large number of transfers and sequential digitization of pixels results in low frame rates. This speed penalty increases with the number of pixels digitized.

CMOS sensors leverage many of the same analog signal concepts used in CCDs but place the output node circuitry inside each pixel. This eliminates the charge transfer process. To read the signal from a given row, the accumulated charge is converted to a voltage inside the pixel, then each pixel in the row is connected to the appropriate column voltage bus, where the on-chip ADCs convert the voltages to a 12-bit grey value. The parallel digitization of all pixels in a row provides CMOS devices with a tremendous speed advantage. Imagine a CCD with 2048x2048 pixels – and each pixel’s voltage is measured in 1  $\mu$ sec. To read a single row, 2048 voltage measurements are performed in serial fashion taking slightly longer than 2 ms, and when repeated for 2048 rows, the entire image takes over four seconds to be digitized.

On a CMOS device the entire ~2200 voltage conversions needed to digitize a row happen in parallel. In practice, the time saving is split between faster frame rates and slowing the rate of pixel measurement to reduce electronic noise. For example, if the time to measure a pixel was increased to 10  $\mu$ sec to lower noise, the image sensor can still be read in 10 ms (for a maximum 100 fps).

Of course, there are many challenges to obtaining the same analog performance from each of a Retiga E cameras 7 million or more pixels, whereas a CCD has a single, common output node resulting in a uniform response. The most common problems are pixel-to-pixel non uniformity in gain and offset, random telegraph noise (RTN), and defective pixels with abnormal noise or dark current characteristics (hot pixels). Often solutions to these challenges are found in the digital domain, where Retiga E’s advanced real time signal processing corrects each pixel for gain and offset variation using calibration at the factory. To address RTN and other pixel defects, real-time digital filters are used. These corrections are described further in this manual.

## Rolling and Global Shutter Readout

**Note: The Retiga E Family of CMOS camera contains a mix of rolling and global shutter readouts. The Retiga E7 has a true global shutter readout, while the Retiga E9/E20 have rolling shutter readout.**

Rolling Shutter and Global Shutter are the two primary operating modes of CMOS image sensors.

In Global Shutter readout, a global charge-clearing mechanism begins the exposure period for all pixels. Each pixel accumulates signal charge until the exposure period ends. At this point, the accumulated charge is transferred and converted to a voltage in the pixel's output node, ending the exposure.

The strength of the Global Shutter approach is that all pixels are exposed at the same instant in time – an important attribute when imaging fast-moving objects. The downside of this approach is that the sensor has two phases, an active image accumulation phase and a subsequent readout phase. As the phases do not overlap in time, the maximum achievable frame rate is lower.

In Rolling Shutter readout, exposure and readout are overlapped. This is accomplished by beginning the exposure one row at a time, then starting the readout one row at a time. The row being digitized “rolls” through the sensor, resulting in a much faster readout method.

The downside of Rolling Shutter readout is that changes in the scene on similar timescales are distorted, as each row samples the image at different times. This is the well-known “rubber band” effect. It can appear in fluorescence microscopy as shaded illumination when rapidly changing wavelengths.

To maintain the benefit of Rolling Shutter readout and eliminate rolling shutter artifacts, external illumination can be gated on when all rows are being simultaneously exposed, and off during the readout phase. This external triggering mode, used in combination with high-speed light sources (e.g., lasers, LEDs), achieves a pseudo global shutter effect. This triggering mode is described in the device synchronization section of this manual.

**Digital Binning**

CCD image sensors are capable of charge binning (combining adjacent pixels into one super pixel). This is accomplished as part of the charge transfer process and has the advantage of increasing signal to noise in read noise-limited situations, at the expense of spatial resolution.

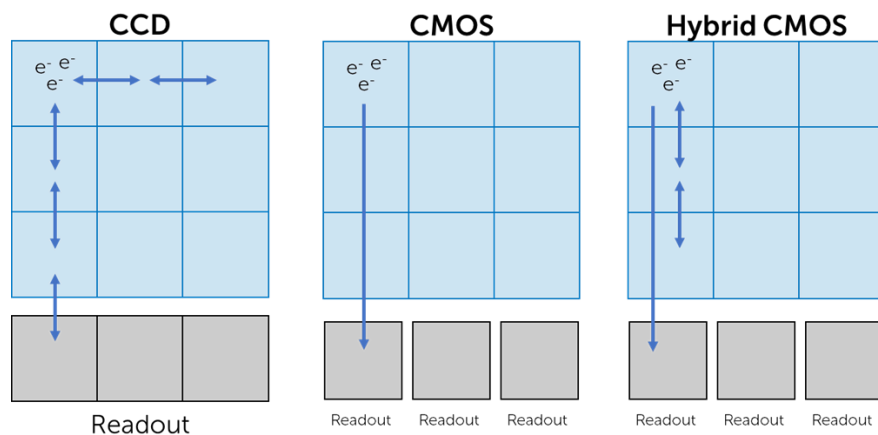
The lack of a charge transfer process in CMOS devices means true charge binning was not available in currently available sCMOS sensors, including the Retiga E9 and Retiga E20. For these cameras, binning pixels is a convenient means to reduce image data or increase signal by 4x and improve SNR by 2x as the noise from each pixel adds in quadrature. The Retiga E20 can be binned 2x2 or 3x3, and the Retiga E9 can be binned 2x2, 4x4, 8x8 or 16x16, all on-camera digital simulated binning, done on the FPGA. This mathematically combines signal from adjacent pixels and adjusts the sum so that the bias offset is only added one time.

However, the Retiga E7 is different to typical CMOS devices in that it can perform standard digital binning 2x2 and 4x4 (as the Retiga E9/E20 do), but the Retiga E7 can also perform 2x1 charge domain (on chip) binning, similarly to a CCD. This is termed 'hybrid binning'.

**Hybrid Binning (Retiga E7 only)**

Hybrid binning offers the best of both worlds between CCD and CMOS binning. Hybrid CMOS sensors, such as the one in the Retiga E7, have electric connections between pixels, typically along the same column. This provides CCD-like charge accumulation without extra noise for pixels in columns, only adding noise when combining with the adjacent row. With a hybrid 2x2 bin on the Retiga E7, pixel columns are combined before readout (CCD style) and pixel rows are combined after readout (CMOS style). This provides the same 4x increase in signal as always, but now with less noise increase than typical CMOS, resulting in an overall 2.8x increase in SNR (compared to 2x in typical CMOS).

Hybrid sensors also receive a speed benefit from binning, similarly to CCD. With a 2x2 bin the Retiga E7 doubles in speed, meaning that it can acquire at 51 fps across the full frame unbinned, and 102 fps with a 2x2 bin. This increase in both speed and sensitivity mirrors a CCD bin, but with the much higher base speeds of a CMOS.



## Sensor Clearing

In order to capture the highest signal-to-noise ratio possible, it is important that scientific cameras minimize any signal that's not derived from the sample. One contribution to this background signal is the buildup of charge prior to an exposure, which includes any light still reaching the sensor as well as thermally generated sensor dark current. To eliminate this pre-acquisition charge accumulation, most CCD and CMOS cameras clear the sensor one or more times prior to exposing the sensor to light. This can be done using a "fast" readout that is subsequently discarded.

Unlike CCDs, there is limited benefit to performing multiple pre-exposure clearing cycles with CMOS, because each pixel is reset as part of the normal readout process, and the charge transfer registers that can hold residual signals are not present.

## Bias Offset Settings

Scientific cameras produce a fixed artificial signal offset known as bias offset. This grayscale offset is present in all pixel values, even when no light is falling on the sensor and the exposure time is set to zero. Bias offset prevents clipping of the camera read noise and preserves quantitation even down to signals of a few electrons per pixel.

If supported by the software application being used, the bias level can be altered. However, we do not recommend changing this value because the preset values for the Despeckle Pixel Noise Filters are set with this value.

For quantitation, many users subtract an average bias image, calculated at the start of each experimental run. This can also be used to monitor light leaks and other systematic effects that can impact experimental results.

- For the Retiga E7/E20, the bias offset is set to 100 ADU
- For the Retiga E9, the bias offset is set to 400 ADU

## Pixel Noise Filters

**Note: Retiga E cameras ship with an optimized default setting for real-time Pixel Noise Filtering. Normally these values do not need to be adjusted. Additionally, the features described in this section may or may not be controllable in the software application of choice.**

In the CMOS sensor section, it was noted that a drawback to current CMOS sensors is variability in pixel-to-pixel response. This variability falls into two categories, static variation in gain and offset and dynamic fluctuations that require real-time Pixel Noise Filters, also known as "Despeckling".

The static variation in gain and offset is measured and a correction factor is determined for every pixel. This fixed pattern noise is measured during manufacture and the corrections are stored in the camera. These corrections are then applied in real-time to each image.

The dynamic fluctuations must be detected and corrected in real-time. The Retiga E cameras have several noise filters for this purpose. Defect detection is based on the use of a conditional median filter: The 3x3 neighborhood surrounding a pixel is examined, and if the pixel's value exceeds or falls below the median by a given amount, its value is replaced by the median. Four filters are available.

**Pixel Noise Filters  
(cont.)**

Real-time Filters for Random Telegraph Noise:

1. Despeckle Dark Low
2. Despeckle Bright Low

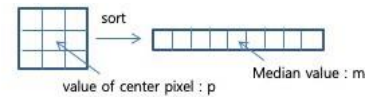
Real-time Filters for Bright (Hot) or Dark Pixels:

3. Despeckle Dark High
4. Despeckle Bright High

“Dark” filters work on the low side of the local median, while “Bright” filters work on the high side of the local median. The filter is only applied if the pixel’s value exceeds (or is below) a threshold expressed as a % of the local median x100.

For example, a Despeckle Dark Low threshold of “97” indicates that a pixel that is 3% below the local median will be replaced with the local median. A Despeckle Bright High threshold of “300” indicates that a pixel that is 200% brighter than the local median will be replaced.

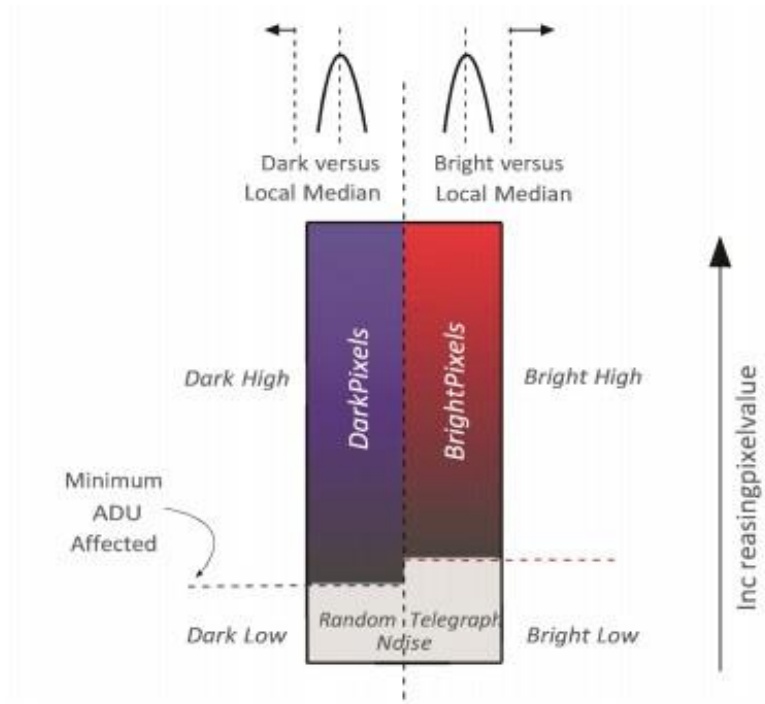
The intensity range where each filter operates can be set by a value known as “Minimum ADU Affected”. Take the “Dark” filters for example – pixel values that fall below the Minimum ADU Affected will be operated on using Despeckle Dark Low, and pixel values that lie above the Minimum ADU Affected will be operated on using Despeckle Dark High settings.



Reset All Values to Default	
<b>DESPECKLE BRIGHT LOW</b>	
ENABLED	<input checked="" type="checkbox"/>
THRESHOLD	<input type="range" value="140"/> 140
	$\text{If} ( p > m ) \ \&\& \ ( p > m * 1.4 ) \ \&\& \ ( m \leq 200 )$
	{
	$p = m;$
	}
<b>DESPECKLE BRIGHT HIGH</b>	
ENABLED	<input checked="" type="checkbox"/>
THRESHOLD	<input type="range" value="120"/> 120
MIN ADU AFFECTED	<input type="range" value="200"/> 200
	$\text{If} ( p > m ) \ \&\& \ ( p > m * 1.2 ) \ \&\& \ ( m > 200 )$
	{
	$p = m;$
	}
<b>DESPECKLE DARK LOW</b>	
ENABLED	<input checked="" type="checkbox"/>
THRESHOLD	<input type="range" value="66"/> 66
	$\text{If} ( p < m ) \ \&\& \ ( p < m * 0.66 ) \ \&\& \ ( m \leq 200 )$
	{
	$p = m;$
	}
<b>DESPECKLE DARK HIGH</b>	
ENABLED	<input checked="" type="checkbox"/>
THRESHOLD	<input type="range" value="74"/> 74
MIN ADU AFFECTED	<input type="range" value="200"/> 200
	$\text{If} ( p < m ) \ \&\& \ ( p < m * 0.74 ) \ \&\& \ ( m > 200 )$
	{
	$p = m;$
	}

**Pixel Noise Filters  
(cont.)**

Given the new terminology – a simplified way to visualize the region in which each filter operates is shown below:



Generally, the optimal values for these filters are set at the factory. However, some experimental approaches utilize much better postprocessing noise-reduction algorithms than can be implemented in-camera. Should you find the need to alter the filter strength, the general principle for setting the pixel noise filters is to use as little filtering as possible.

Often the best way to determine this is by viewing a real-time histogram with log scaling of the frequency. For setting “Dark Low” and “Bright Low,” block any light from reaching the sensor and examine the bias histogram. This allows viewing of the histogram’s tail, where the effect of the filters can be seen. Adjust the filters to trim the non-Gaussian tails from the distribution.

For “Dark High” and “Bright High,” observe the image with flat, even illumination in the expected range to be observed. Adjust “Bright High” to eliminate most of the bright speckles and adjust “Dark High” to eliminate any dark speckles that might appear.

Although they can be set independently, we do not recommend changing the Minimum ADU Affected. This value will have been set at the factory to approximately 1.5x the bias level to ensure the “Low” filters are operating on RTN noise.

## Chapter 4 – Operating Features

### Readout Modes and Gain States

Retiga E CMOS cameras differ in their modes and gain states depending on the model, this section will be split by each of the Retiga E cameras.

#### Retiga E7

The Retiga E7 has 3 modes:

- Speed
- Long Exposure
- Extended Dynamic Range (EDR)

Speed mode is a 12-bit mode focusing on maximizing speed, operating at 51 frames per second (fps) across the full frame, this can be increased by establishing a region of interest (ROI) therefore decreasing the number of rows to be digitized, and can be limited by using a digital interface older than USB 3.1 Gen2 provided.

Long Exposure mode is a 12-bit mode that makes use of the ultra-low dark current of the Retiga E7 thanks to Teledyne's advances in thermal control. With a dark current of 0.001 e<sup>-</sup>/p/s, in this mode the Retiga E7 has a maximum exposure time of 1 hour (120 seconds in Speed mode). While this limits the speed of the camera to 3.2 fps, it allows for applications beyond a typical CMOS camera (which have traditionally limited exposure times due to high dark currents).

EDR mode is a 16-bit mode, similar in principle to Long Exposure mode, but instead of a single exposure EDR mode combines two exposures of equal time, but different gain modes. As an example, setting the exposure to 60 minutes will require 120 minutes of acquisition. This further limits the speed to 1.6 fps but as described, results in greatly enhanced dynamic range.

#### Retiga E9

The Retiga E9 has 3 modes, all 16-bit:

- Full Well
- Balanced
- Sensitivity

Full Well mode focuses on maximizing the full well capacity of the Retiga E9, allowing for capture of intense signals thanks to a large dynamic range. However, the read noise is increased compared to other modes at ~3.4 e<sup>-</sup> average.

Moderate mode strikes a balance between other modes, featuring a large full-well capacity and low read noise, but prioritizing neither.

Sensitivity mode focuses on minimizing noise, operating with sub-electron read noise levels of ~0.8 e<sup>-</sup> average. These ultra-low noise levels allow for the capture of the faintest signals but result in a limited full well capacity of 2000 e<sup>-</sup>.

## Modes and Gain States (cont.)

### Retiga E20

The Retiga E20 has 1 mode:

- Standard

Standard mode is a 12-bit mode, and the only available readout mode on the Retiga E20, featuring low noise levels and high speeds.

## Regions of Interest (ROIs)

Regions of Interest (ROIs) are image subregions selected by the user to be captured and delivered to the host PC in place of the full image. This can substantially increase frame rates and lower the amount of data that needs to be processed.

For the Retiga E7/E9, the acquisition frame rate increases as the number of rows contained in the ROI decreases. By reducing this number of rows, frame rates above 1000 fps are achievable with small ROIs. As a result of the scientific CMOS sensor architecture, if any pixel in a row is part of the ROI, the entire row is digitized. Reducing the number of columns in the ROI does not improve the frame rate of the camera but it does reduce the amount of data acquired, saving computer resources and processing time.

For the Retiga E20, the sensor does not allow windowing and the frame rate does not increase when establishing a ROI, the speed will be the same as full frame (19.8 fps).

## Device Synchronization (Triggering)

Retiga E cameras offer several methods of integrating with external hardware devices. Each camera has four MMCX connectors on the back of the camera for trigger input/output operations. The signals provided to the user are:

- Trigger In (TRIG IN): Inputs initiate an exposure or sequence
- Trigger Ready Out (TRIG RDY): Status indicating if the camera can accept another trigger
- Read Out (RD OUT): Status indicating the camera is currently digitizing
- Expose Out (EXP OUT) Output for controlling illumination source 1

Single line microminiature co-ax (MMCX) cables are included with the camera to access these functions. Each signal requires a cable that can be read with an oscilloscope or signal analyzer

Retiga E cameras support four trigger modes and expose out behaviors, as detailed in the next section.

## Trigger Modes

### Timed Mode (Internal)

Internal Mode is the default triggering mode for Retiga E cameras. The start of a sequence of acquisitions is initiated by the software/application. Once initiated, each frame captured in the sequence is controlled by the internal timing generators of the camera. Camera settings, expose out behavior, and sequence size are set in the software application prior to acquiring the sequence. Internal Mode is used when synchronization with other devices is either not required or is controlled independently through the software.

### Trigger-First Mode

Trigger-First Mode is similar to Internal Mode but requires a hardware trigger from the I/O connector. Hardware triggers enable a higher precision of acquisition timing than software triggers. The rising edge of an external trigger initiates the start of a sequence of acquisitions. Once initiated, each frame capture in the sequence is controlled by the internal timing generators of the camera. Camera settings, expose out behavior, and sequence size are set in the software application prior to acquiring the sequence.

### Edge Mode

Like Trigger-First Mode, Edge Mode requires a hardware trigger but for every frame. The rising edge of the external trigger initiates capture of a single frame. Each frame requires an external trigger from the I/O connector. Camera settings, expose out behavior, and sequence size are set in the software application prior to acquiring the sequence.

### Level Trigger Mode

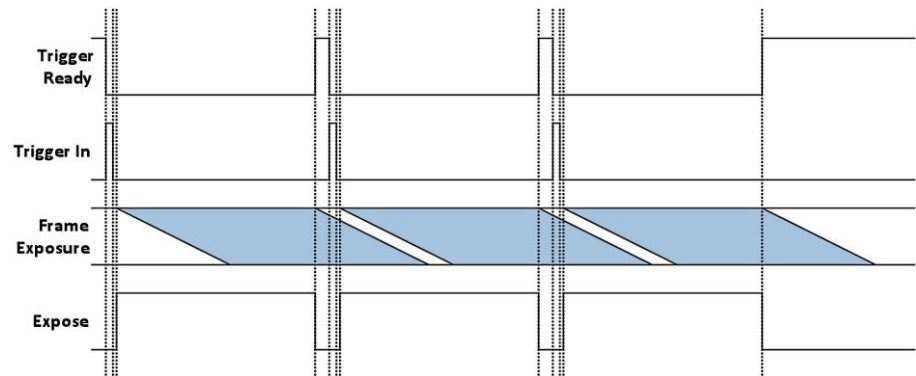
Level Trigger Mode uses the duration of the trigger-in high signal (+5 V) to define the exposure time. This offers flexibility to control the exposure time for each frame. In Level Trigger Mode, the beginning of the next frame cannot happen until all the rows have read out so that the frame-to-frame time is the sum of the trigger high duration plus the product of the number of rows x the line time.

## Expose Out Modes

The settable Expose out behaviors provide flexibility in different experimental scenarios.  
**Note: All timing diagrams below are shown with Edge triggering mode.**

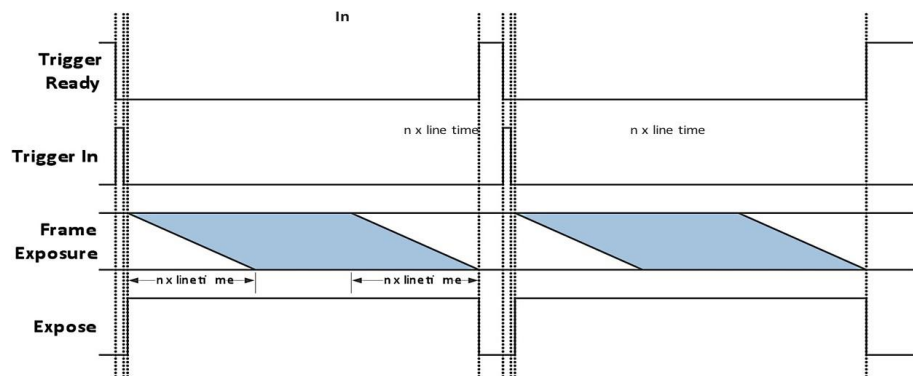
### First Row

Internal Mode is the default triggering mode for Retiga E cameras. The start of a sequence of acquisitions is initiated by the software/application. Once initiated, each frame captured in the sequence is controlled by the internal timing generators of the camera. Camera settings, expose out behavior, and sequence size are set in the software application prior to acquiring the sequence. Internal Mode is used when synchronization with other devices is either not required or is controlled independently through the software.



### Any Row

The “Expose Out” I/O signal leaving the camera is high when any row in a single frame is exposing. The length of the Expose Out signal is equal to the time between the start of the first row’s exposure and the end of the last row’s exposure. Each line exposes for the same amount of time which is equal to what is set in the software application. Maximum camera frame rates are not possible in this mode but this does avoid frame overlaps.

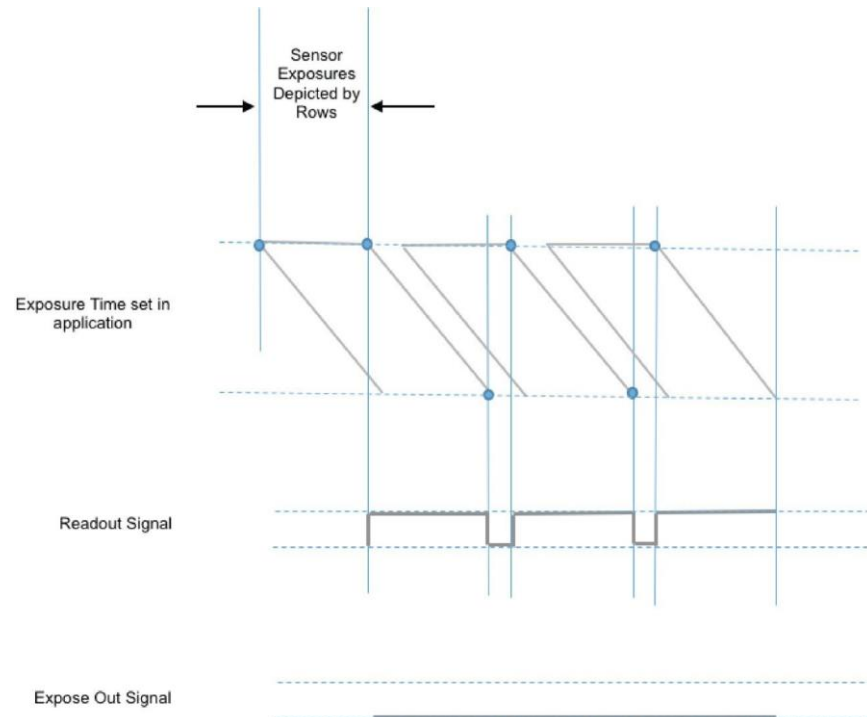


## Expose Out Modes (cont.)

### Rolling Shutter Mode

The Rolling Shutter Expose Out Mode is similar to First Row Mode, except that the Expose Out signal is high only when all rows are exposing.

When Exposure time is less than readout time:



## Fan Speed Control

Fans are often used to remove heat from the camera due to their convenience. However, under demanding conditions, fan vibration isolation is insufficient for single molecule localization, high magnification imaging or use with micromanipulators.

Retiga E cameras solve this problem in two ways. First, a new, innovative fan mounting system was developed that isolates fan vibration from the rest of the camera. Side by side testing with competing products indicated that Retiga E outperform alternatives in terms of vibration isolation.

Secondly, the fan has variable speed control. The lower the fan speed, the lower the vibration transferred. Retiga E cameras provide three fan speeds, and even on the lowest setting, it can still reach nominal -25 °C sensor cooling in a 23 °C ambient.

Speed settings include:

1. High (Sensor set point adjusts to -25 °C)
2. Medium (Sensor set point adjusts to -25 °C)
3. Low (Sensor set point adjusts to -25 °C)

## Time Stamps

Retiga E cameras are able to output “metadata” that describes data associated with each frame. Metadata contains useful information like the exposure time, ROI location and time stamps. Metadata is inserted directly into the frame buffer and transferred together with the image data.

Time stamps are particularly useful. Retiga E cameras generate Driver Generated Timestamps (for legacy support) in the host PC and Hardware Timestamps generated in the camera. The accuracy of Retiga E’s Hardware Timestamps is approximately 20  $\mu$ sec, one row read time from the sensor. This is far better than the 1 ms accuracy of Driver Generated Timestamps. Hardware Timestamps are given in units of 1 ns.

To display Hardware Timestamps in the Micro-Manager application, metadata must be enabled for Retiga E cameras in the Device Property Browser. When acquiring a sequence, Hardware Timestamps will be displayed in the metadata tab with the prefix “FMD” (for Frame metadata).

**Note: Retiga E cameras have timestamps for “Bof” for “Begin of Frame” and “Eof” for “End of Frame” events, which differ by approximately 10 ms, which was the preset exposure time.**

NAME	VAL
PVCAM-FMD-ExposureTimeNs	9993600
PVCAM-FMD-FrameNr	11
PVCAM-FMD-TimestampBofNs	254157974400
PVCAM-FMD-TimestampEofNs	254167804800

## Chapter 5 – Troubleshooting

**Note:** For difficulty in troubleshooting or if the symptoms are not listed here, contact Teledyne Photometrics Customer Service.

### System Does Not Boot Normally

If the operating system does not boot normally after the interface card is installed, try reseating the USB card. If this is unsuccessful, try installing the new card in another open PCIe 4x or higher slot. If this does not work:

1. Turn off the computer and remove the newly installed interface card.
2. Turn the computer on. If the system boots normally, there is probably an interrupt conflict between a previously installed device

If you need assistance resolving the interrupt conflict, contact Teledyne Photometrics Customer Service.

### 'New Hardware Found' Dialog Does Not Appear

If the 'New Hardware Found' dialog box does not appear after installing a new interface card:

1. Make sure the new interface card is inserted in an expansion slot according to the computer manufacturer's instructions
2. Wait for the LED on the rear of the camera to stop blinking before checking for "New Hardware Found" and the application.

If the New Hardware Found dialog box still does not appear, contact Teledyne Photometrics Customer Service.

### Images Not Displayed

If no images appear:

1. Confirm the camera switch is set to on.
2. Confirm that the Retiga E camera is selected in the imaging software application.
3. Power off the camera and the host computer and check all system connections (particularly the data and power cables), then restart.
4. Confirm the camera is operational by taking an image with a standard C-mount lens attached to the camera. Using normal room lighting, place the camera on a table about three meters away from an object and acquire an image.

If the problem persists, contact Teledyne Photometrics Customer Service.

### **Camera Running Too Warm**

It is normal for the camera to be slightly warm to the touch while in operation. However, if it is more than slightly warm to the touch (and at least one inch of space has been left around the external cooling fins for airflow), switch off the camera immediately and contact Teledyne Photometrics Customer Service.

### **PVCAM Error Message Appears**

If a PVCAM error message appears, note the message's number code and contact Teledyne Photometrics Customer Service

### **Lengthy Pauses During Imaging**

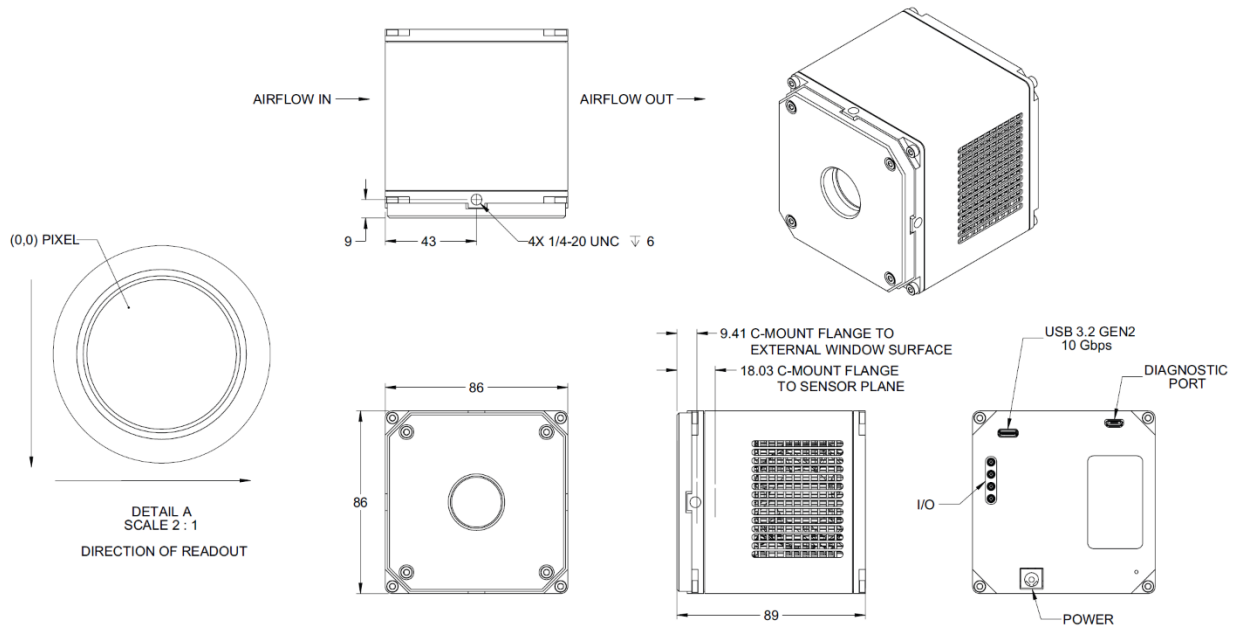
If you notice lengthy pauses marked by a lot of disk activity while imaging:

1. Close any other programs that may be running.
2. Install more physical memory (RAM) in your computer system.

## Chapter 6 – Basic Specifications

### Retiga E Camera Dimensions

The Retiga E7, E9 and E20 all have the same dimensions as shown in the diagram below. All units are in millimetres.



### Camera Weight

The Retiga E7, E9 and E20 all have the same weight: 0.8 kg, 1.76 lbs

### Power Supply Specifications

Voltage Input	100-240 V~ @ 50-60 Hz
Current Input	5 A (110V nominal)
Voltage Output	+12V @ 8 A
Maximum Power Output	140 W
Supply Cable Length	4 ft. / 1.22 m
Certifications	CE, UL, CUL, FCC, PSE Efficiency level VI

**Note:** CE certification applies to Retiga E cameras only when the camera system operates with a CE-approved power supply

## Sensor Specifications

### Retiga E7

Window	UV grade fused-silica Broadband MgF2 anti-reflective coating on both surfaces
<b>sCMOS Sensor Array</b>	
Sensor	Sony IMX428 CMOS sensor
Sensor Process	Front illuminated scientific CMOS
Resolution	3200 x 2200 (7.1 megapixels)
Pixel Size	4.5 $\mu\text{m}$ x 4.5 $\mu\text{m}$
Peak QE	73%
Shutter Format	True Global Shutter

### Retiga E9

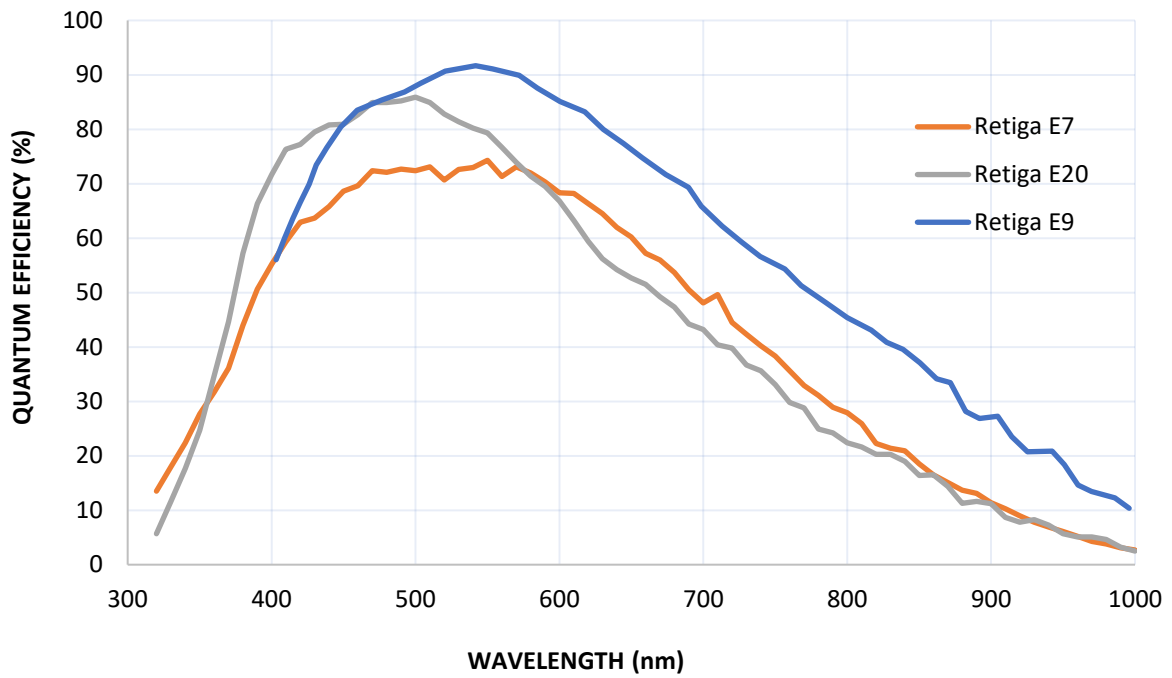
Window	UV grade fused-silica Broadband MgF2 anti-reflective coating on both surfaces
<b>sCMOS Sensor Array</b>	
Sensor	Sony IMX533 CMOS sensor
Sensor Process	Back illuminated scientific CMOS
Resolution	3000 x 3000 (9 megapixels)
Pixel Size	3.76 $\mu\text{m}$ x 3.76 $\mu\text{m}$
Peak QE	90%
Shutter Format	Rolling Shutter

### Retiga E20

Window	UV grade fused-silica Broadband MgF2 anti-reflective coating on both surfaces
<b>sCMOS Sensor Array</b>	
Sensor	Sony IMX183 CMOS sensor
Sensor Process	Front illuminated scientific CMOS
Resolution	5472 x 3648 (20 megapixels)
Pixel Size	2.4 $\mu\text{m}$ x 2.4 $\mu\text{m}$
Peak QE	85%
Shutter Format	Rolling Shutter

**Retiga E Quantum Efficiency Comparison**

As the Retiga E7, E9 and E20 each use a different sensor the quantum efficiency (QE) curve response across different imaging wavelengths differs, as shown in the graph below.





Teledyne Photometrics

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