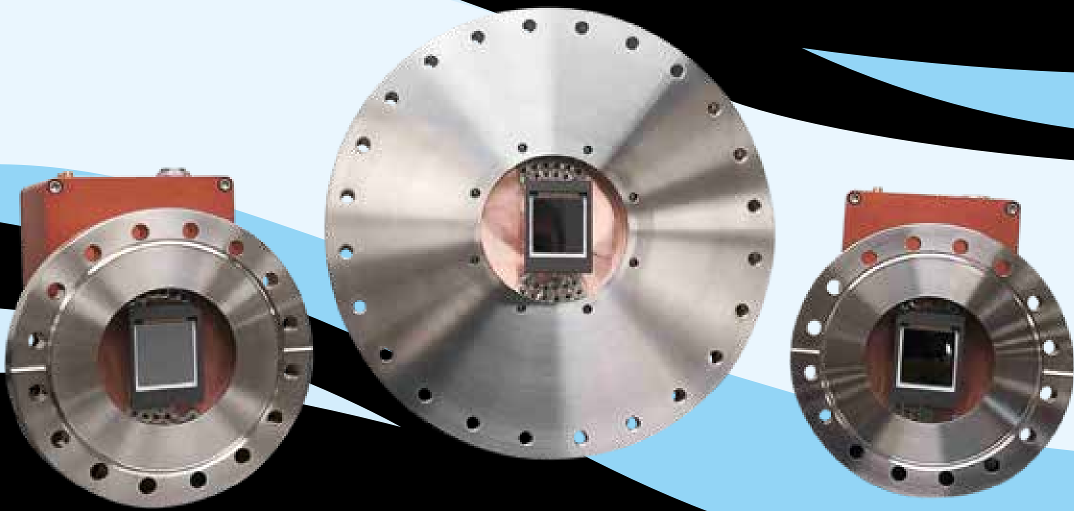
Raptor photonics



X- Ray & High Energy Solutions

Raptor Photonics is a leader in innovative, high performance camera solutions.

X-RAY 2019

Overview

Raptor Photonics offers a range of cameras for the detection of photons and high energy particles. Using high performance CCD sensors, from companies such as e2v, photon (or particle) energies from 1.2eV up to 20keV can be detected directly within the silicon. Higher energies are detected indirectly, by coupling a phosphor or scintillator screen onto the CCD sensor.

Raptor Photonics designs and builds a range of custom solutions for OEMs and National Laboratories around the world. Fusing advanced material science with the latest sensor technologies we deliver high performance camera designs with unsurpassed performance and reliability.

Direct or Indirect Detection?

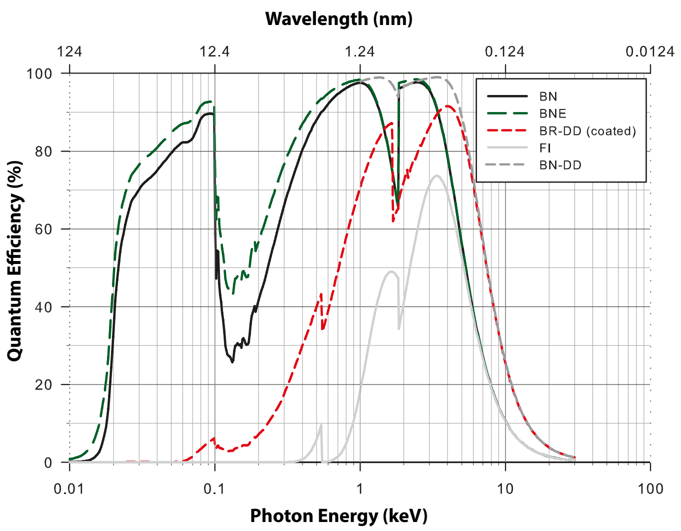
Direct Detection

When a photon (or particle) is absorbed within the silicon of a CCD sensor, its energy is used to create one or more electron-hole pairs. Photon energies below approximately 3.1eV will generate a single electron-hole pair within the device, whereas higher energies will produce multiple electron-hole pairs. When the photon energy is above approximately 10eV the number of electron-hole pairs (N_{e-h}) is given by the empirical relation:

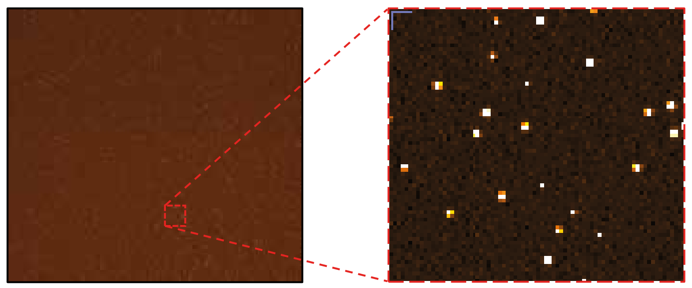
$$N_{e\text{-}h} = \frac{E_{ph}}{3.65}$$

Where Eph is the energy of the incident photon in eV.[1]

In the case of x-ray detection, this means that individual x-ray photons produce a signal within the CCD which is clearly distinguishable above the noise floor of the camera and therefore photon counting can be performed. However, the ability of a CCD to detect radiation is also strongly dependent on the absorption depth of the photon (or particle) within silicon. If the absorption depth is too long, the photon simply passes through the device undetected; whereas if the absorption depth is very short, such as for soft x-rays of energy less than a few hundred eV, the surface features of the device will limit / influence the detection efficiency. In the case of front illuminated (FI) sensors, photons must first pass through the electrode structures before having any possibility of detection. Back illuminated devices, with no AR coating (BN), eliminate this attenuation associated with the gate structures, however a small amount of attenuation will persist at very short absorption lengths, due to the surface treatment during the standard back thinning process. Devices are available with an 'enhanced' back thinning process (BNE) which minimizes the detection inefficiency at the back surface. The detection abilities of standard CCD devices are summarized in the Quantum Efficiency plots below.



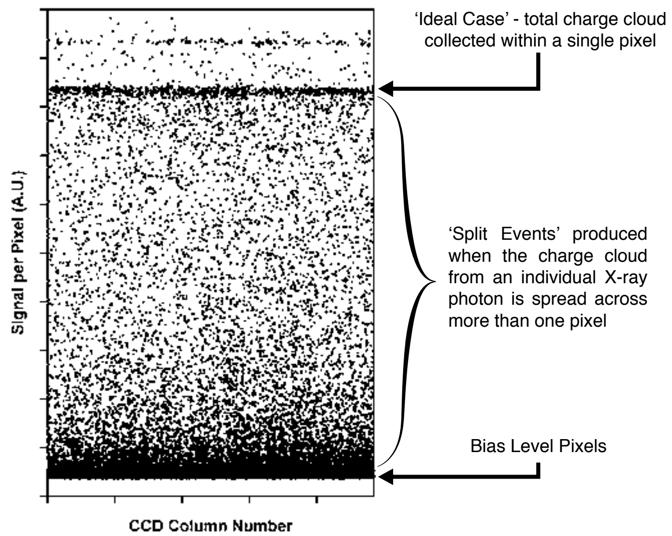
Therefore, provided absorption of the photon or particle occurs within the depleted region of the sensor, the photo-generated electrons will be confined within the potential wells of the sensor pixels and subsequently read out as a signal. In contrast the holes will be repelled towards the substrate and undergo recombination. A well designed and cooled camera system will minimize the noise components associated with both dark signal and read out noise. Combining this with excellent charge transfer efficiency (CTE) provides a system which has optimal energy resolution in low flux imaging conditions (i.e. <<1 x-ray photon/pixel/frame). Under these conditions 'starry night' images can be obtained as shown below.



Typical 'Starry Night' Image - the spikes in the image are produced by the detection of Individual X-ray photons

Zoomed in selection of image shows Bias Level Pixels, Detection of X-ray photons within a single pixel and Split Events

Analysis of such images can provide the user with information on the energy / energies of the x-ray photons striking the detector. Conversely, if the source provides x-rays of a known energy, then a wealth of information regarding the camera performance can be extracted by determining the conversion factor, in electrons per DN. This figure will allow the user to calculate parameters such as read noise, dark current and pixel well depth in absolute units. Visual inspection of these images, in addition to some simple data processing, can give the user qualitative information on the Charge Transfer Efficiency of the camera in both horizontal and vertical directions. The expanded section of the image shows individual pixels from a small subsection of the main image – the bright spikes / spots in the image are produced by the detection of single x-ray photons within the silicon of the CCD sensor, whereas the darker pixels can be used to provide information on the read noise and dark signal of the camera. Single bright pixels are the 'ideal case' where the entire charge cloud produced by the detected x-ray is confined within a single pixel, however the more likely scenario is that the charge cloud is shared between two or more neighbouring pixels (often referred to as 'split events'). Plotting the pixel values for the entire image, as shown below, also allows the user to qualitatively check the system for gross charge transfer inefficiency which would be visible as a slope / broadening of the line attributed to the 'Ideal Case'.



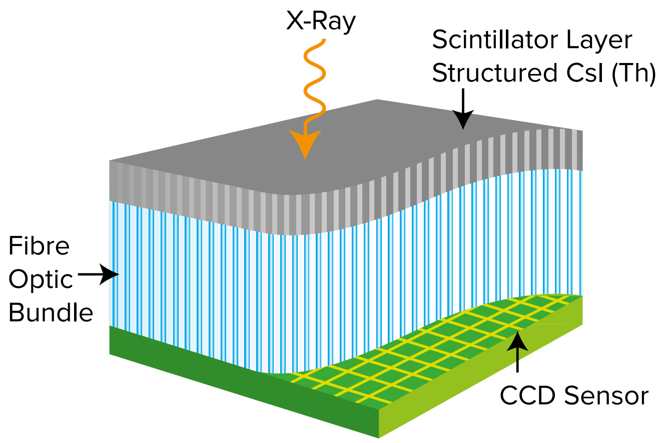
Direct detection offers excellent spatial resolution in addition to single photon sensitivity, however the deposition of energy (by either photons or particles) in the CCD sensor will introduce changes to the silicon structure of the sensor; principally affecting the oxide layers next to the electrode structures. Back illuminated devices are therefore more tolerant to irradiation as these oxide layers are somewhat 'shielded' from the incident photons by the silicon of the device itself. X-ray damage will manifest as both an increase in dark charge and an increase in the number and severity of trap defects. The increase in dark charge will depend on the accumulated X-ray dose, which when used under typical photon counting conditions, should not become problematic until after many years usage. However, if a device is repeatedly illuminated with high levels of radiation the effects can become apparent very quickly.

The use of a silicon based CCD sensor for direct detection is best suited to photon (or particle) energies below 20keV (see QE plots). Standard IMO (or MPP) devices provide useable detection efficiency up to approximately 10keV, whereas the thicker depletion region in 'deep depletion' devices extends this range out to approximately 20keV. Employing back illuminated devices, without an AR coating on the sensor surface, can deliver excellent peak QE values approaching 100% for some photon energies.

[1] Janesick, James R. (2001). Scientific Charge-Coupled Devices. Bellingham, WA: SPIE Press

Indirect Detection

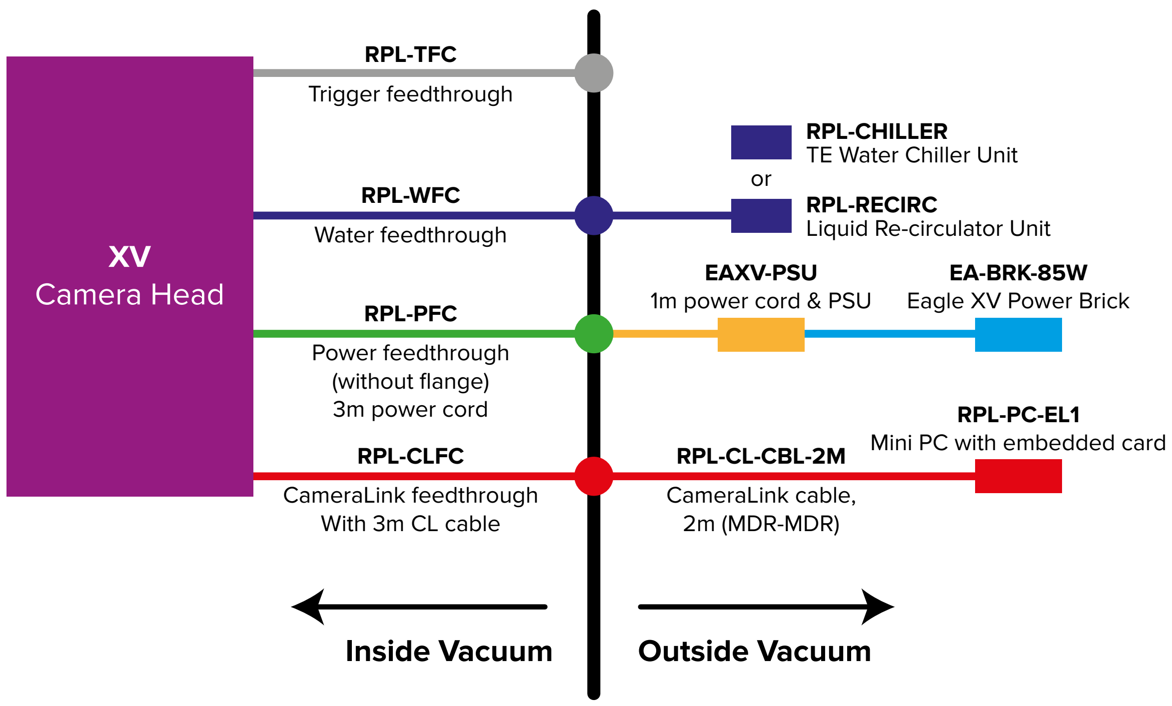
At energies of >20keV the photon absorption length is much larger than the depletion depth in deep depletion CCDs, therefore most of the photons are not detected by the sensor. For these higher energies indirect detection is more appropriate.



Indirect detection uses a phosphor or scintillator to absorb the incident high energy photons and re-emit this energy in the form of visible (usually 'green') photons. The CCD sensor then detects these visible photons, thereby detecting the x-rays 'indirectly'.

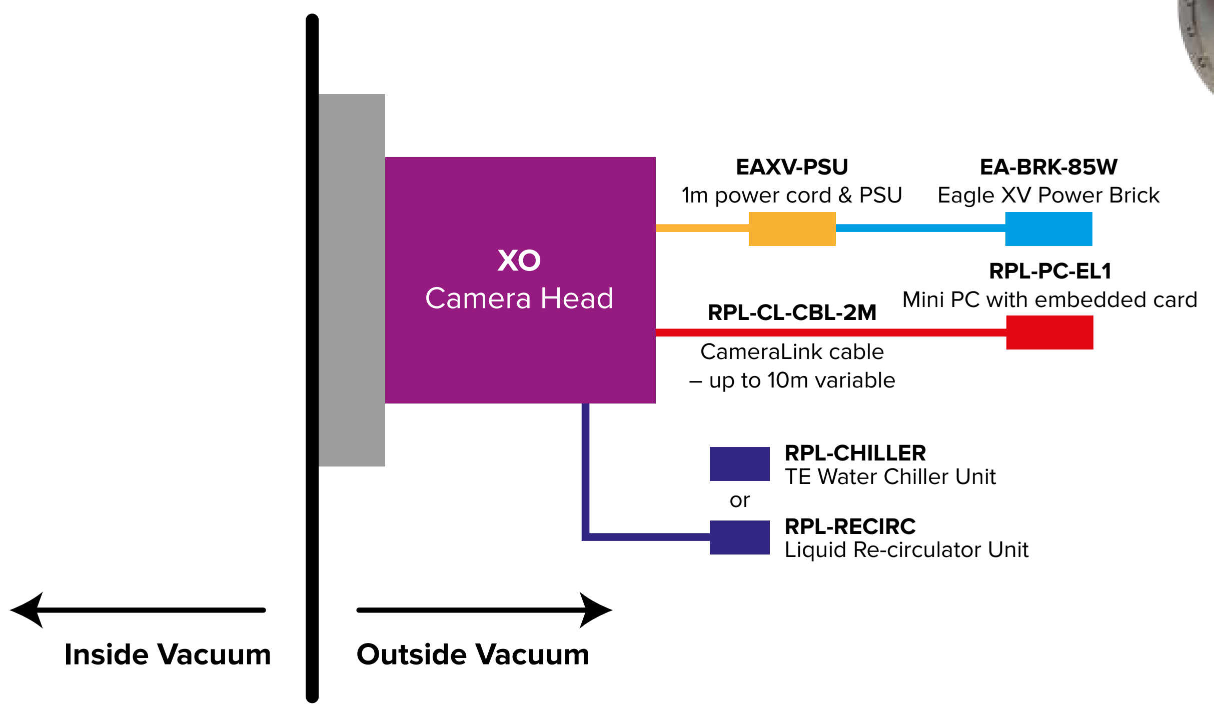
The most commonly used materials are Terbium activated Gadox (Gd_2O_2S:Tb) and Thallium activated Cesium Iodide (CsI:Th) both of which convert approximately 13% of the absorbed photon energy into visible photons. These photons are emitted into 4π and so only a small fraction will actually reach the CCD for detection. Typically, a fibre-optic bundle is used to maximize the collection efficiency of these visible photons and transfer them to the CCD. This method can also protect the CCD from damage caused by photons which have not been absorbed within the phosphor/scintillator and prevent images being acquired which contain both direct and indirectly detected photons.

Direct X-Ray - In Vacuum - XV



Cooling Options	Uncooled Cooled to -70°C
*** Resolution Options**	**CCD42-40** – 2048 x 2048, 13.5µm pixels; **CCD47-10** – 1024 x 1024, 13µm pixels; **CCD42-10** – 2048 x 512, 13.5µm pixels; **CCD30-11** – 1024 x 255, 26µm pixels
Sensor Type Options	**FI** – Front illuminated **BN** – Back illuminated uncoated **BN-DD** – Back illuminated uncoated deep depleted

Direct X-Ray - Open Front - XO

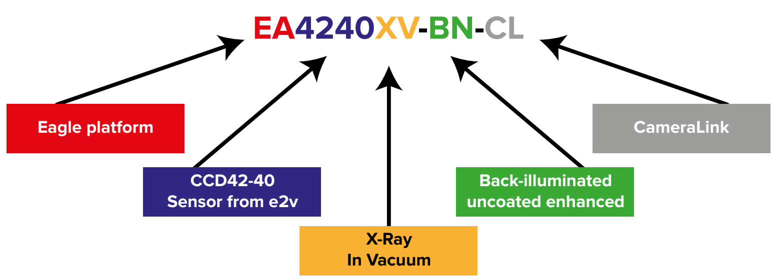


Cooling Options	Uncooled and Cooled to -70C. (Other cooling options available upon request)
*** Resolution Options**	**CCD42-40** – 2048 x 2048, 13.5µm pixels; **CCD47-10** – 1024 x 1024, 13µm pixels; **CCD42-10** – 2048 x 512, 13.5µm pixels; **CCD30-11** – 1024 x 255, 26µm pixels
Sensor Type Options	**FI** – Front illuminated **BN** – Back illuminated uncoated **BN-DD** – Back illuminated uncoated deep depleted
Flange Option	**6" CF Flange** (CF152) As standard, other options on request

Ordering information for Eagle XV

Minimum Order Requirements	
Camera Head ** see resolution options*	EA_ _ _ _XV-_ _-CL
Power Supply	EAXV-PSU
Brick	EA-BRK-85W
Power Feedthrough	RPL-PFC
CameraLink Feedthrough	RPL–CLFC
Additional Peripherals and Accessories	
Water Feedthrough	RPL-WFC
Trigger Feedthrough	RPL-TFC
TE Water Chiller	RPL-CHILLER
Liquid Recirculator	RPL-RECIRC
CameraLink Frame Grabber	RPL-EB1
CameraLink cable	RPL-CL-CBL-2M
Mini PC with embedded card	RPL-PC-EL1

XV Camera example ordering



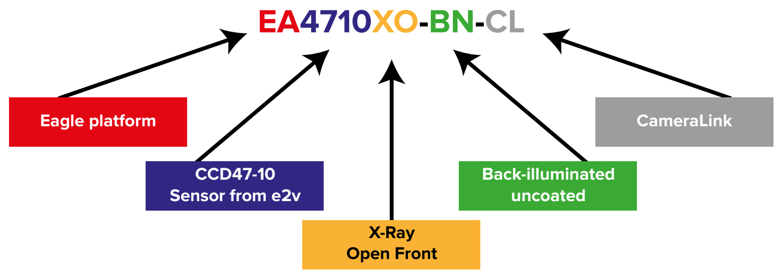
RPL-PFC

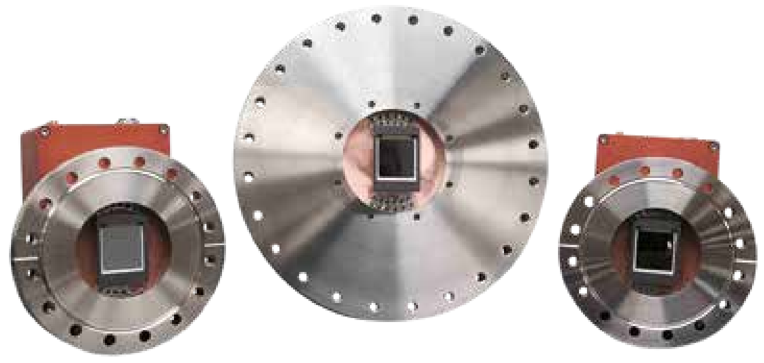
RPL-CLFC

Ordering information for Eagle XO

Minimum Order Requirements	
Camera Head ** see resolution options*	EA_ _ _ _XO-_ _-CL
Power Supply	EAXV-PSU
Brick	EA-BRK-85W
Additional Peripherals and Accessories	
TE Water Chiller	RPL-CHILLER
Liquid Recirculator	RPL-RECIRC
CameraLink Frame Grabber	RPL-EB1
CameraLink cable	RPL-CL-CBL-2M
Mini PC with embedded card	RPL-PC-EL1

XO Camera example ordering



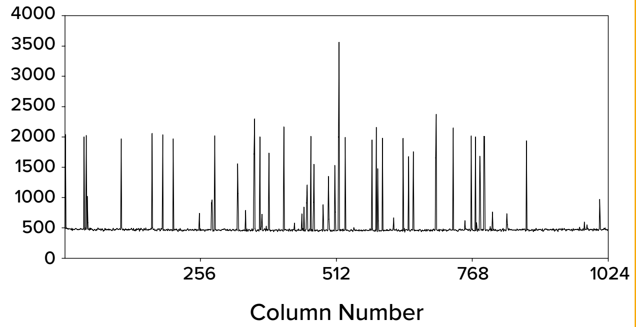


Range of CF Flanges

Applications / Case Studies

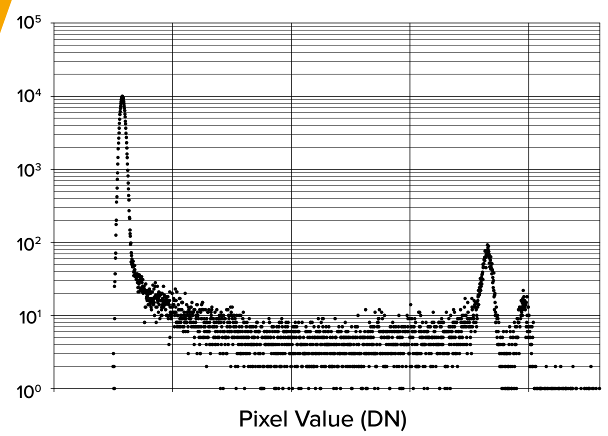
X-Ray Diffraction and X-Ray Fluorescence (XRD/XRF) – Toucan OEM

Raptor designed a new custom camera solution for incorporation in a global OEM's instrument used for XRD/XRF applications. Users get ultra-fast analysis for full compound identification of major, minor and trace components within mining and ores, petrochemical, fast HAZMAT ID and pharmaceuticals industries. Using a specifically developed direct detection CCD camera, the solution is able to collect X-ray photon data for both X-ray diffraction and X-ray fluorescence simultaneously. The solution was based on the Toucan spectroscopy platform using a CCD30-11 sensor cooled to -40C and USB2.0 interface. The cameras include an integral Beryllium window acting as a visible light barrier.



High Energy Electron Detection

A key national lab commissioned Raptor to design a 1MP back-illuminated CCD (CCD-42-10) to directly measure resolution test-chart images formed by 14keV electrons. The Eagle XO is an open front detector with CF mounting flange. The sensor resolution is 2048 x 512 pixels.



Remote In-Vacuum Direct Detection

A European national lab commissioned Raptor to design and build a series of uncooled in-vacuum cameras with a 200m fibre optic connection to provide maximum immunity from electrical interference for remote in-vacuum direct X-Ray experiments.

High Energy In-Vacuum Direct Detection

Raptor won a contract to design and build both 1MP (CCD47-10) and 4MP (CCD42-40) deep-cooled in-vacuum cameras for use in key national lab to support a wide-ranging programme in fundamental physics and advanced applications.

Other Raptor X-Ray Solutions

Beryllium Window

Raptor offer a range of Beryllium (Be) Window options

Custom Interfaces

Raptor offers a selection of interfaces including:

- CameraLink
- Fibre Optic Comms
- GigE
- USB2/3

Indirect X-Ray options

Raptor offers a selection of Fibre Optic input plates, phosphors (Gadox) and CsI(Th) and scintillators

Direct X-Ray

Raptor offers a range of custom options for both direct and indirect detection including:

About Us / Capabilities

Raptor develops, manufactures and markets a range of high quality CCD, EMCCD and InGaAs cameras targeting the global Scientific and Surveillance imaging markets, specifically for OEMs and instrumentation manufacturers. We design and build a range of custom solutions for OEMs and National Laboratories around the world. Fusing advanced material science with the latest sensor technologies we deliver high performance camera designs with unsurpassed performance and reliability.

Total Solutions

And if you want a total "plug and play" solution, Raptor can provide everything you need, including the camera, lens, fibre optics, scintallators, flanges, frame grabber, cables, leads, software, laptop / PC all packaged up in a sturdy Peli case for easy transport and shipping.

Customer Support

Understanding your instrumentation solutions, your product roadmap and your business model will enable us to offer you the best camera solution. We would be delighted to hear from you.

For further information, datasheets or to schedule a demo of any of our cameras please refer to our website, contact your local distributor or reach out to us directly:

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