iXon^{EM}+ Back-illuminated EMCCDs

The Pioneering Scientific EMCCD that Continues to Set the Standards

www.andor.com

True 16-bit digitization

EM and Conventional Amplifiers

EMCAL™

Superior Quantitative Performance

Vacuum protection - no QE degradation

Lowest Read Noise

RealGain™

Enhanced Photon Counting Capability

-100°C TE Cooling

Lowest Clock Induced Charge

Longevity! Vacuum protection + Anti-Ageing

Highest EMCCD Sensitivity!

Highest Dynamic Range

Fastest Frame Rates

Baseline Stability since 2002!

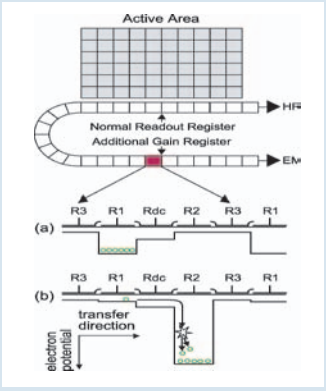
ANDOR™
TECHNOLOGY

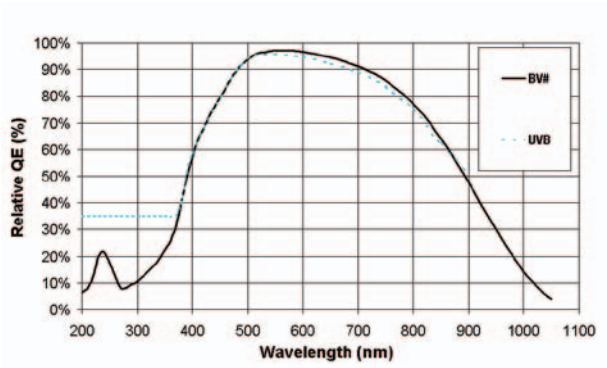
The EMCCD advantage...

Current trends in photon measurement are placing unprecedented demands on detector technology to perform at significantly higher levels of sensitivity and speed. Electron Multiplying CCD (EMCCD) technology has been designed to respond to this growing need, unlocking new and innovative experimental prospects.

EMCCDs operate by amplifying weak signal events (down to single photons) to a signal level that is well clear of the read noise floor of the camera, at any readout speed. Importantly, this 'on-chip' amplification process is realized without sacrificing the photon collection capability of the sensor, with back-illuminated sensors offering up to 95% Quantum Efficiency (QE).

With the back-illuminated iXon^{EM}+, Andor have delivered a dedicated, truly high-end, ultra-sensitive scientific camera platform, designed specifically to get the absolute best from Electron Multiplying CCD (EMCCD) technology across all critical performance specs and parameters.



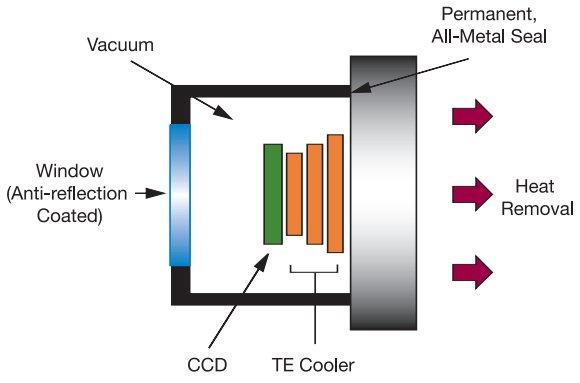


iXon^{EM}+ Back-illuminated QE curves

Permanent Vacuum Head – A back-illuminated EMCCD *must*

It is fundamental that a back-illuminated sensor is housed in a hermetically sealed permanent vacuum head with minimized out-gassing, otherwise both cooling performance and the sensor QE will steadily degrade. It is this compelling reason that drove Andor to develop UltraVac™.
Andor's proprietary UltraVac™ process has a proven track record of field reliability, accumulated over more than 10 years of shipping high-end vacuum cameras. UltraVac™ also enables use of only one input window, improving photon-throughput by 8%.

- No QE degradation
- Sustained deep TE cooling.
- One input window
- No condensation



EMCCD Pioneers

Andor Technology pioneered the world's first scientific EMCCD cameras, shipping the initial cameras back in 2000 and winning the Photonics Circle of Excellence award for our achievements in January 2001.

Andor even coined the term 'Electron Multiplying CCD (EMCCD)', which has now been adopted industry-wide! Since then, Andor have consistently set higher and higher EMCCD performance standards with our deep-cooled, vacuum-sealed iXon^{EM} & iXon^{EM}+ quantitative camera range.

For example, we introduced the world's first back-illuminated EMCCDs in January 2002, alongside our unique baseline clamp solution for enhanced quantitative performance. Andor's method for achieving industry-lowest Clock Induced Charge was introduced in early 2003 and our much revered quantitative and linearized EM gain control (RealGain™) was innovated in January 2006.

Andor's flexible EMCCDs allow EM Gain to be completely turned off under brighter conditions, enabling multiplicative noise to be circumvented and S/N to be optimized at any readout speed

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iXon^{EM}+ Back-illuminated Range

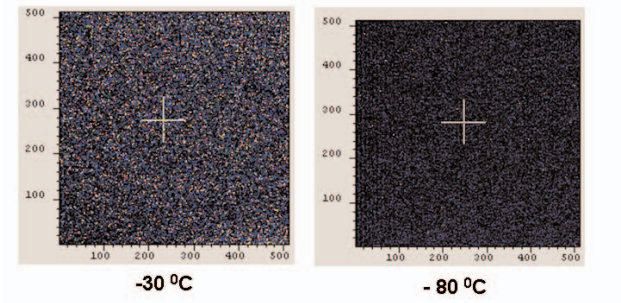
Camera	Key Features	Sensor Format	Pixel Size	Frame Rate
DU-897	**'Ultimate Sensitivity'** The Photon Counting Choice	512x512	16 µm	34.5 fps
DU-860	**'Lightning Speed & Sensitivity'**	128x128	24 µm	>500 fps
DU-888	**'Field of View & Sensitivity'**	1024x1024	13 µm	9 fps

iXon^{EM}+ offers choice of both EMCCD and Conventional CCD amplifiers - DU-897 and DU-888 models

Deep Thermoelectric Cooling

Single thermal electrons are amplified by the EMCCD gain mechanism. Deep vacuum TE cooling is critical to optimize the sensitivity performance of back-illuminated EMCCD sensors, otherwise the raw sensitivity will be compromised, even under conditions of short exposures!

- Cooling down to -100°C
- Lowest EM-amplified darkcurrent
- Fewer pixel blemishes (hot pixels)
- Low power consumption (finesse cooling)

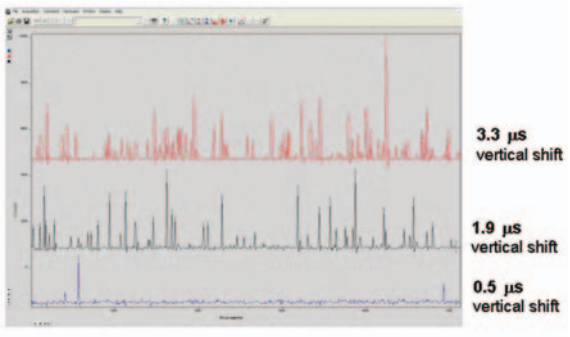


iXon^{EM}+ DU-897 Dark Images taken with x1000 EM gain at different cooling temperatures, 29ms exposure time, same scaling. -30°C shows elevated levels of EM-amplified dark-current. -80°C shows a very clean noise floor.

Minimized Clock Induced Charge – finesse charge clocking

After having minimized darkcurrent through deep cooling, the remaining detection limit in back-illuminated EMCCDs is given by the number of Clock-Induced Charge noise events. Andor's industry-exclusive combination of high resolution clocking parameters and sub-microsecond vertical (parallel) shifts are fundamental to minimizing CIC, enabling truly 'high-end' EMCCD sensitivity to be claimed.

- Industry-lowest CIC
- Fastest vertical shift speeds



Line intensity profiles generated from iXon^{EM}+ DU-897. Dark Images taken at x1000 EM gain at 29ms exposure time, showing CIC contribution for different vertical shift speeds. Cooling temperature was -85°C to ensure minimal darkcurrent contribution. Faster vertical shift speeds result in significantly fewer CIC events.

A back-illuminated EMCCD camera is chosen specifically with highest sensitivity in mind. Darkcurrent and Clock Induced Charge (CIC) noise sources must be minimized to ensure absolute detector sensitivity. iXon^{EM}+ is the only EMCCD camera to combine both deep vacuum TE cooling and effective CIC-minimization.

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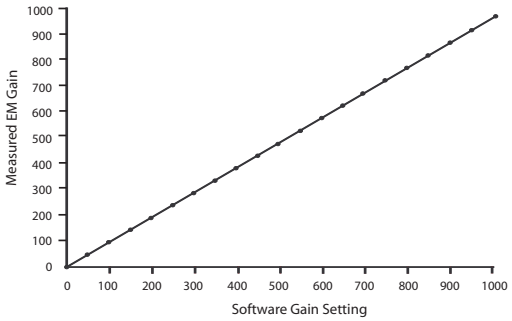
RealGain™, Anti-Ageing and EMCAL™

With the launch of the next generation iXon^{EM}+ in early 2006, Andor once again raised the bar by introducing some significant new technology innovations. These particular pioneering steps were to set new high standards in quantitative EMCCD usage and general EMCCD longevity expectations.

- **RealGain™** – Select absolute EM gain direct from a linear and directly quantitative software scale, x1 to x1000. No more arbitrary EM gain units. The EM gain you ask for is the EM gain you get!
- **Anti-Ageing** – Internally configured to significantly inhibit saturation-induced decay of EM Gain*.
- **EMCAL™** - Innovative user-initiated auto-recalibration of EM gain, utilizing a proprietary method of automated EM gain assessment and Andor's unique Linear and Real Quantitative Gain implementation.



RealGain™ *calibration in the iXon^{EM}+.*

Temperature-compensated: *The same linear relationship holds across all cooling temperatures.*

* **Tech note from E2V, the sensor manufacturers:**
http://www.e2v.com/module/page-357/l3-visiondatasheets.cfm
'An Overview of the Ageing Characteristics of L3Vision™ Sensors'

iXon^{EM}+ back-illuminated EMCCDs can be read out at either 10, 5, 3 or 1MHz speeds, offering extensive flexibility to balance dynamic range vs frame rates.

Why choose Andor's optimized iXon^{EM}+ back-illuminated EMCCD?

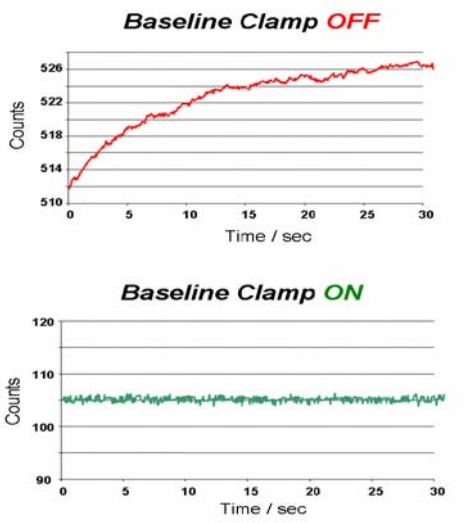
The principal reason for making use of Andor's vacuum-housed iXon^{EM}+ Electron Multiplying CCD (EMCCD) technology is to ensure the absolute **highest sensitivity** from a **quantitative** scientific digital camera, particularly under **dynamic measurement** conditions (faster frame rates). Furthermore, Andor's vacuum-housing is critical to ensure complete **protection** of the back-illuminated sensor, such that it will not suffer QE performance degradation.

The architecture of EMCCD sensors also render them extremely **flexible**. When harnessed effectively in the iXon^{EM}+, EMCCD technology can be applied in an entirely quantitative fashion to meet a wide variety of experimental requirements, ranging from single photon counting experiments through to slower scan, true 16-bit dynamic range measurements.

The iXon^{EM}+ is also equipped with patented, pioneering technology that will ensure the **longest quantitative service** life of any EMCCD, offering ultimate anti-ageing protection of the sensor and automated user-initiated recalibration of EMCCD gain.

Quantitative Stability since 2002!

The back-illuminated iXon^{EM}+ is well regulated in terms of both Baseline (bias offset) rigidity and EM Gain Stability, lending for **enhanced quantitative reliability** throughout and between measurements.



iXon^{EM}+ Baseline Clamp ensures stable baseline value across a kinetic series and across different EM gain settings.

iXon^{EM}+ offers the lowest read noise specifications available for back-illuminated EMCCD sensors. This translates into a higher S/N when not using EM gain and a higher available dynamic range.

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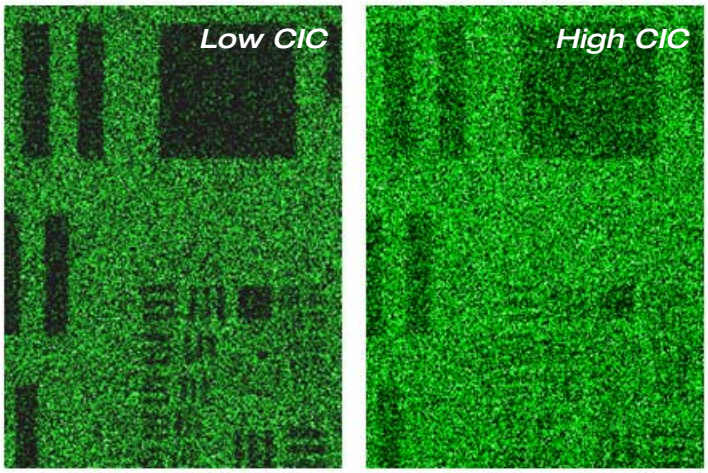
Photon Counting - with the low-noise iXon^{EM+}

To successfully photon count with EMCCDs, there has to be a significantly higher probability of seeing a 'photon spike' than seeing a darkcurrent/CIC 'noise spike'.

The iXon^{EM+} DU-897 has the lowest darkcurrent/CIC performance on the market, yielding both lower photon counting detection limits and higher contrast images. Furthermore, the superior frame rate capability enables a higher linear dynamic range of photon counting.



Photon Counting of a weakly illuminated resolution chart with:

Low Clock Induced Charge - LHS

vs

High Clock Induced Charge - RHS

Unlike other EMCCDs, the Andor iXon^{EM+} offers 16-bit digitization from a linear, scientific grade A/D converter (no internal noise), utilized when actual dynamic range exceeds 14-bits.

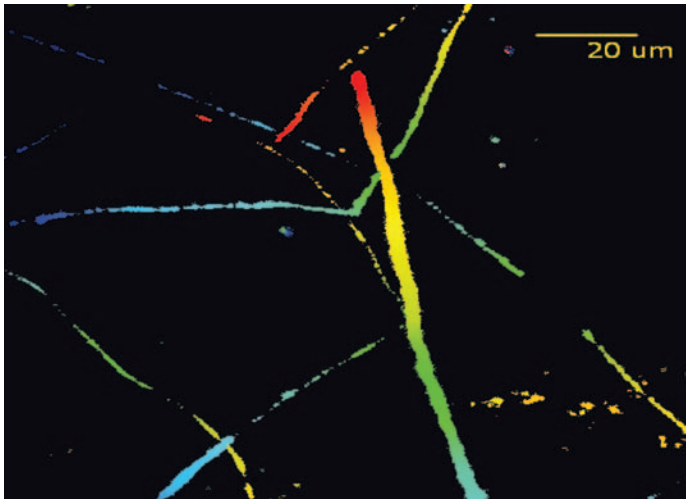
Fastest Frame Rates

iXon^{EM+} industry fastest vertical shift speeds result in faster frame rates and reduced smearing. Significantly faster under commonly employed conditions of sub-array/binning.

- Fastest Full Frame Rates
- Up to 60% faster than closest competing EMCCDs under conditions of sub-array/binning
- Minimized smearing
- Higher photon counting dynamic range

	iXon^{EM+} DU-897	Competing EMCCD 1	Competing EMCCD 2
512x512 / 1x1 binning	**34.5**	**31.5**	**31.9**
256x256 / 2x2 binning	**132**	**100.9**	**107.1**
128x128 / 2x2 binning	**248**	**155**	**172.4**
128x128 / 4x4 binning	**439**	**233**	**253.9**

Frame rate comparisons under various combinations of sub-array/binning: iXon^{EM+} DU-897 vs. principal competing EMCCDs utilizing the same 512x512 back-illuminated sensor.



Quantum dots are immuno-linked to dynein molecules, which carry their cargo along extra-cellular microtubules (not visible here). Using Andor iQ and back-illuminated EMCCD, 4000 frames were acquired with 30 ms exposure in frame transfer mode and simultaneously displayed and streamed to hard disk at 30 fps using iQ's ImageDisk functionality. The data has been processed by maximum intensity time encoding, in which each pixel is replaced by the time value when it was brightest and then pseudo-colored. Red pixels are the latest in time, while blue are the earliest, giving a map of the rate and direction of transport. Courtesy Dr Stefan Diez, MaxPlanck Institute, Dresden, Germany.

Andor's EMCCD technology is available coupled to a fiberoptic, ideal for use with large area demagnifying tapers: Enquire for further details.

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iXon^{EM}+ - The Microscopist's Choice

Since its pioneering introduction in 2000, Andor's EMCCD technology has been widely and highly successfully employed by microscopists throughout the world, resulting in an outstanding level of representation in high-profile publications.

In applications such as single molecule microscopy, live cell microscopy (including confocal), calcium signaling, transport/motile imaging and intracellular bioluminescence, where weak, rapidly changing fluorescent signals from cells must be dynamically imaged, Andor's iXon^{EM}+ technology offers an ideal detection solution. Ultra-sensitive detection capability in fluorescence microscopy also facilitates use of lower excitation powers (thereby reducing photobleaching and phototoxicity) and lower dye concentrations.

iXon^{EM}+ - The Physical Scientist's Choice

The unique high-performance specifications of the optimized iXon^{EM}+ have been serving the physical scientist and astronomer in scenarios that demand more than simply an EM sensor in a camera!

Andor have worked with numerous scientists to deliver solutions that work for their particular application requirements, such as providing effective charge purging immediately prior to acquisition, specific coatings, coupling to fiber optic scintillators and also specific interface requirements. As such, the iXon^{EM}+ has been prevalent across a variety of demanding applications, such as photon counting, lucky astronomy, adaptive optics, Bose Einstein condensation (BEC) / ion trapping, single molecule detection / nanotechnology, neutron tomography, X-ray/Gamma tomography, plasma diagnostics, Raman detection and sono- / thermo-luminescence detection.

Andor Solis

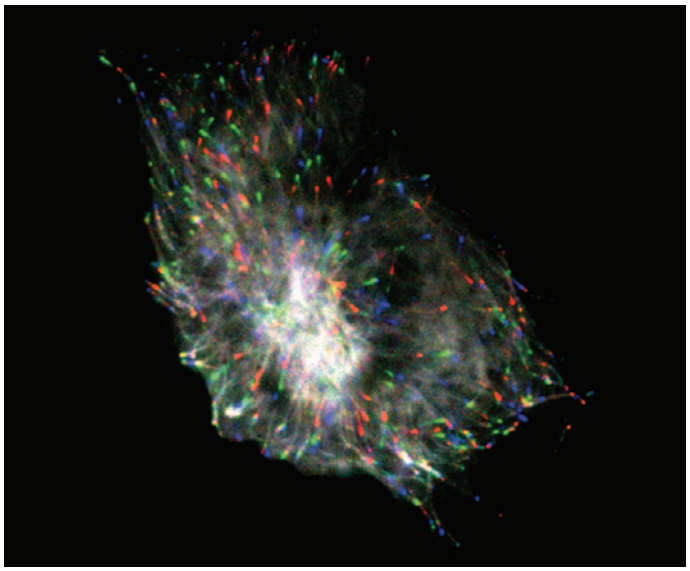
Andor Solis (**SOL**utions for **I**maging and **S**pectroscopy) is Andor's camera control and analysis software platform, with versions specifically designed for imaging.
It is easy to install and provides state of the art acquisition, display and processing capabilities.

Andor iQ

Andor iQ is our flagship live cell imaging software, designed with flexibility and power in mind. iQ – **i**mage and **Q**uantify – occupies a central role in our Revolution product range and provides optimized control of Andor's award winning iXon^{EM}+ EMCCD cameras and automation hardware for a range of bioimaging applications.

Third Party Support

Andor has worked with several 3rd party imaging software companies to include support for the Andor range of cameras.



Composite triple color image of a microtubule protein (EB1-GFP) imaged with objective-type TIRFM (60x 1.45NA), using the iXon back-illuminated 897 model. The different colors reveal the dynamics of the microtubules over time: frame 1 = red; frame 10 = green; frame 20 = blue. Courtesy of Dr Derek Toomre, CINEMA laboratory, Dept. Cell Biology, Yale University.

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