Frequently Asked Questions:

Princeton Instruments' eXcelon™ CCD and EMCCD Cameras

Updated: Sep 2010
Includes information on eXcelon™ Back-illuminated Deep Depletion Cameras

1. What is eXcelon™?
   eXcelon is a new CCD/EMCCD sensor technology jointly developed by Princeton Instruments, e2v and Photometrics. The technology is a significant enhancement to standard back illuminated (B) CCD/EMCCDs and back illuminated deep depletion (BR) CCDs It provides three significant benefits
   - **Improved sensitivity** – improved QE over broader wavelength region compared to the standard back illuminated (B) and deep depletion (BR) sensors
   - **Reduced etaloning** – significantly less etaloning or unwanted fringes in near infrared (NIR) region compared to standard counterparts
   - **No increase in dark current** – all this performance without increasing the dark current from their standard counterparts

2. What are the other advantages of eXcelon cameras™?
   In addition to significant improvements in sensitivity and lower etaloning, the eXcelon enabled PIXIS, Spec10 CCD cameras and ProEM EMCCD cameras provide the best all-around performance for low light level detection. The benefits include

   - Maintenance free operation with all-metal, vacuum seals (PIXIS, ProEM)
   - Deep cooling just with air/liquid (PIXIS, ProEM) or Liquid Nitrogen (Spec10)
   - Low noise readout electronics
   - Sub-electron read noise and precise EM Gain Calibration (ProEM)
   - Built-in mechanical shutter
   - Easy to use, powerful software interface including the latest LightField™ 64-bit software.

3. What wavelength range can the eXcelon™ cameras be used in?
   The eXcelon enabled cameras can be used over a broad wavelength range from below 200nm-1100nm. From the figure 1 below, one can notice that the eXcelon CCD cameras provide as much as 40% increase in QE over standard counterparts and broader wavelength coverage. Specifically, the new BR_eXcelon (Solid red trace) provides the highest QE over broad wavelength range than any CCD technology in the market today. All eXcelon sensors can be coated with special UV coating to enhance sensitivity below 350nm (dotted line on the left).

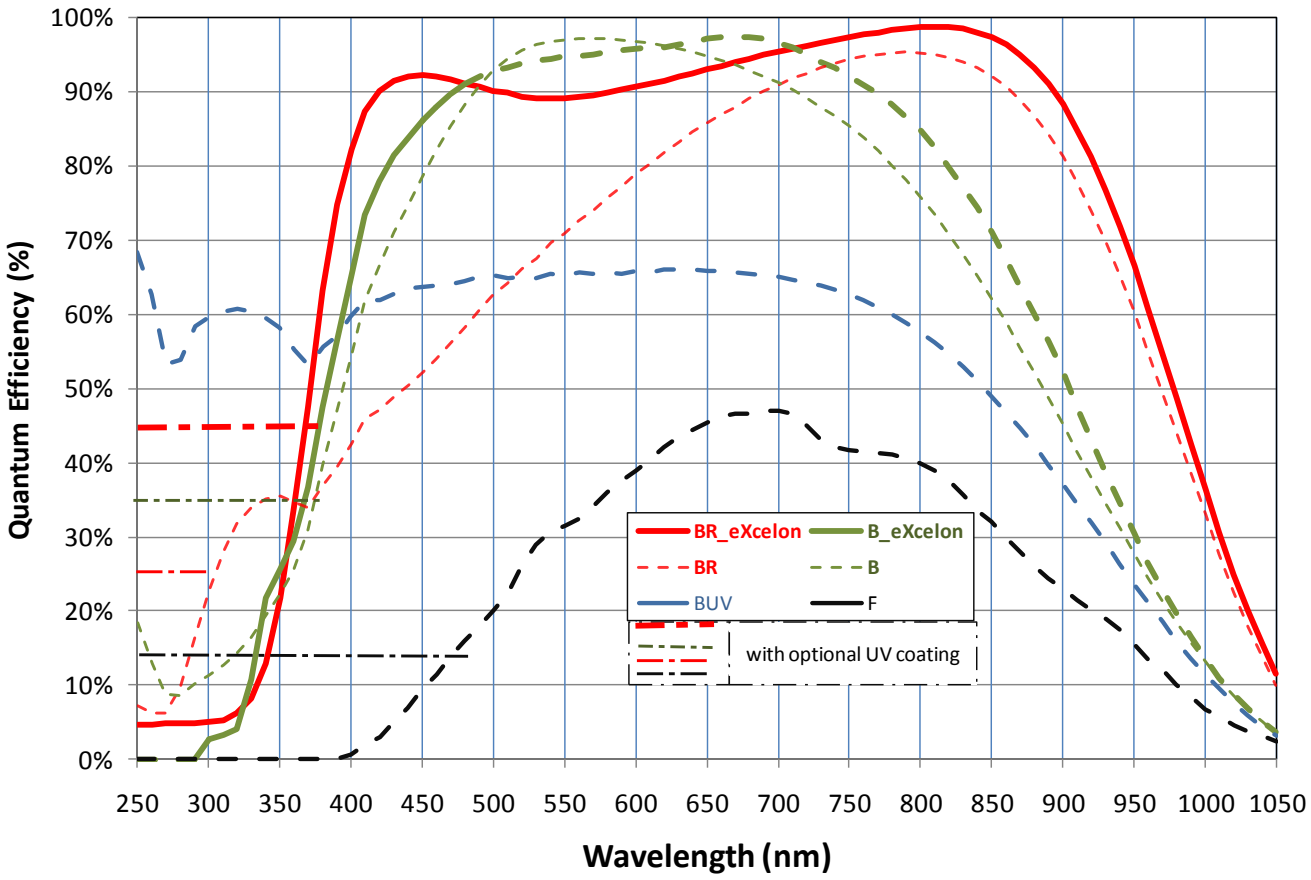

Figure 1: QE comparison of eXcelon and standard Back Illuminated and deep depletion CCD technologies (Data at +25°C)

4. How is the improved performance of the eXcelon™ detectors achieved?
   While the exact details behind the patent-pending eXcelon technology are proprietary, it involves cutting-edge sensor manufacturing and processing to achieve such performance. We have worked on this for over 2 years in order to optimize and perfect the manufacturing of these sensors and cameras.

5. Where can I get eXcelon™ enabled cameras?

As of this write-up, Princeton Instruments launched several models of CCD and EMCCD cameras using the breakthrough technology. The following cameras are available in the already popular PIXIS, ProEM and Spec-10 camera platforms. For more information, please contact your local Princeton Instruments' representative or visit www.princetoninstruments.com .

ProEM (TE Air/Water cooled EMCCD cameras)

ProEM EMCCD cameras are the first EMCCD cameras to feature ultra low noise readout electronics, built-in light source for precise EM gain calibration (OptiCAL™), Gigabit Ethernet interface for reliable, high speed data throughput. They also come with all metal seals and lifetime vacuum guarantee –only such in the industry. The deep cooling below -90°C is achieved via air, water or a combination thereof.

Model Name	CCD Format (Frame Transfer)	Pixel Size	Description
Back Illuminated, EMCCD (B_eXcelon)			
ProEM: 512B_eXcelon	512x512	16 um	Single photon sensitivity at high speed
ProEM: 512BK_eXcelon	512x2, 512x410 (on-chip mask)	16 um	>1 million fps in burst mode with on-chip mask; single photon sensitivity
ProEM: 1024B_eXcelon	1024x1024	13 um	Single Photon sensitivity and large field of view

PIXIS (TE Air/Water cooled CCD cameras)

PIXIS CCD cameras offer the lowest read noise and readout speed combination for low light imaging and spectroscopy. They come with all metal seals and lifetime vacuum guarantee –only such in the industry. The deep cooling below -90°C is achieved via air or water cooling. Ideal for applications requiring extended integration times.

Model Name	CCD Format (Full frame)	Pixel Size
Back Illuminated, Deep depletion CCD (BR_eXcelon)		
PIXIS: 100BR_eXcelon	1340x100	20 um
PIXIS: 400BR_eXcelon	1340x400	20 um
PIXIS: 1300BR_eXcelon	1340x1300	20 um
PIXIS: 1024BR_eXcelon	1024x1024	13 um
Back Illuminated (B_eXcelon)		
PIXIS: 100B_eXcelon	1340x100	20 um
PIXIS: 400B_eXcelon	1340x400	20 um
PIXIS: 1300B_eXcelon	1340x1300	20 um
PIXIS: 2KB_eXcelon	2048x512	13.5 um
PIXIS: 512B_eXcelon	512x512	24 um
PIXIS: 1024B_eXcelon	1024x1024	13 um
PIXIS: 2048B_eXcelon	2048x2048	13.5 um

Spec-10 (Liquid Nitrogen cooled CCD cameras)

When ultra-low light performance demands minutes to hours of integration time, liquid nitrogen is still the best with cooling down to -120°C. Spec-10 LN CCD cameras have the lowest dark noise and read noise combination in the industry for slow scan applications.

Model Name	CCD Format (Full Frame)	Pixel Size
Back Illuminated, Deep depletion CCD (BR_eXcelon)		
Spec10: 100BR_eXcelon	1340x100	20 um
Spec10: 400BR_eXcelon	1340x400	20 um
Back Illuminated (B_eXcelon)		
Spec10: 100B_eXcelon	1340x100	20 um
Spec10: 400B_eXcelon	1340x400	20 um
Spec10: 2KB_eXcelon	2048x512	13.5 um

6. Can the eXcelon performance be offered for EMCCDs (electron multiplication CCDs) also?
   Yes, the eXcelon EMCCD cameras also offer better response, reduced etaloning, and lower dark current in addition to EMCCD's inherent ability to deliver sub electron read noise. The ProEM EMCCD camera supports 512x512 and 1024x1024 format eXcelon sensors and is considered the reference standard in the industry.

7. What is etaloning? Why is it an issue in near infrared (NIR) imaging and spectroscopy?
   Etaloning is unwanted fringe pattern that appears primarily in back illuminated sensors when illuminated with NIR (>700nm) light. It is as a result of constructive and destructive interference. Due to the fact, etaloning structure can change with wavelength and angle of incidence; it is hard to eliminate using typical background or flat field correction techniques.

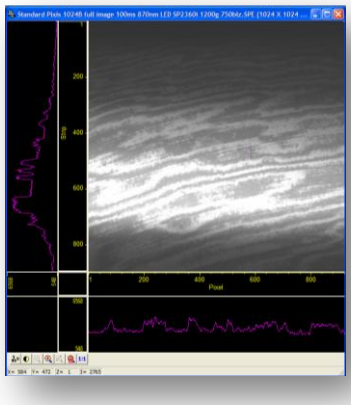

Figure 2: An example of etaloning in standard Back illuminated CCDs (Image taken with 870nm illumination)

8. How is the eXcelon performance different from that of standard back illuminated and deep depletion sensors?

The differences are outlines in the table below. Briefly, the eXcelon sensors provide broader and better sensitivity and reduced etaloning compared to standard back illuminated sensors; and 100x lower dark current compared to deep depletion sensors

Feature / Performance	eXcelon BI (B_eXcelon)	Standard BI (B)	eXcelon BI Deep Depletion (BR_eXcelon)	Standard BI Deep Depletion (BR)
QE Range	**<200*-1100nm**	<200*-1100nm	<200*-1100nm	<200*-1100nm
Peak QE*	**~95% @ 550nm**	~95% @ 700nm	>95% @ 850nm	~95% @ 800nm
Etaloning in NIR	**Low**	High	Lowest	Lower
Dark current	**Low**	Low	High (Similar to BR)	High (50x - 100x of BI)

*Data at +25C. ** With optional UV coating

9. Does Princeton Instruments offer standard back illuminated and deep depletion sensor options?

Yes, Princeton Instruments also offers standard BI (B) and BI DD (BR) sensors in most of their platforms.

10. What level of etaloning reduction is expected from eXcelon detectors?

The exact reduction depends on the type of light source and wavelength of light being used, the one-to-one comparison tests, as much as 10-times lower peak-to-peak fringes are seen in eXcelon compared to the standard back illuminated cameras. It is illustrated with the side-by-side comparison of eXcelon image taken at the same conditions as the image in figure 2 above.

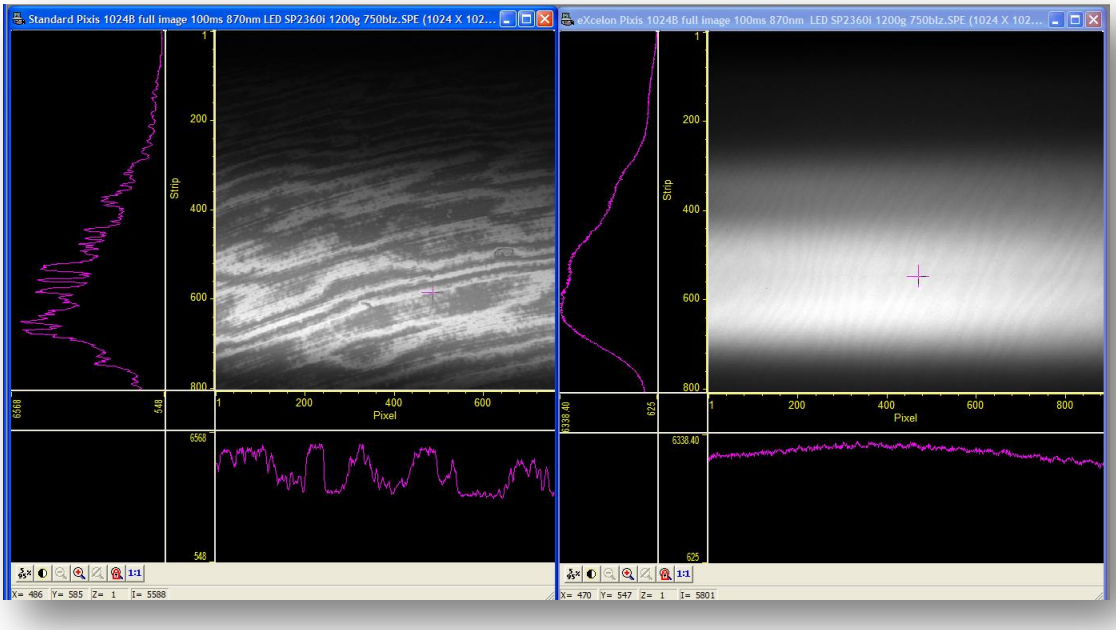

Figure 3: Comparison of images captured with standard BI (left) and new eXcelon BI CCD cameras (right) at 870nm. The cross sectional data shows excellent fringe suppression provided by eXcelon sensor

11. Do eXcelon CCD detectors improve QE?
    Yes, one of the benefits of eXcelon CCD sensors is improved QE over most of the detection range of 200-1100nm compared to the standard Back illuminated (B) and deep depletion (BR) sensors. While there is a small (2%-3%) reduction around 500nm, for most applications, the broader wavelength coverage coupled with lower etaloning, eXcelon enabled cameras prove beneficial.

12. Can the response in UV (<350nm) be further improved?
    Yes, similar to the standard back illuminated and deep depletion sensors eXcelon sensors can also be coated with special UV phosphor layers that improves QE in deep UV region. The estimated UV response with these coatings is shown in figure 1.

13. Where can I get the performance data for eXcelon cameras?
    Please visit www.princetoninstruments.com and download datasheets for PIXIS, ProEM and Spec10 cameras for detailed specifications.

14. My research requires a camera with broadband response with minimal fringing in the near infrared red (>700nm) region. Is eXcelon the right choice?
    Yes, if you considered back illuminated detectors in the past, eXcelon detectors provide much superior performance in terms of increased sensitivity and reduced etaloning. If the application requires >800nm wavelength for minimal etaloning and the dark noise is not a limitation, eXcelon (BR_eXcelon) deep depletion cameras provide the highest performance.

15. What applications can take advantage of eXcelon's improved performance?
    The eXcelon cameras find wide applications from Bose Einstein Condensate (BEC) imaging to Raman spectroscopy. For example, solar cell imaging, plasma diagnostics, fluorescence imaging, and astronomy imaging or spectroscopy applications can benefit greatly by taking advantage of the improved QE response. Any application requiring broad wavelength coverage with minimal etaloning in NIR would benefit from the new technology.

16. Can you help me make choose the right detector for my application?
    Princeton Instruments' experienced application and sales engineers world-wide will be happy to assist you with choosing the right detector. Please visit www.princetoninstruments.com to find your local PI representative.

17. What is the advantage of single window design?
    All Princeton Instruments cameras are designed with single vacuum window in the optical path. Any protective window that might be on the window is removed prior to installation. This will allow them to offer 6%-8% more photon throughput. Furthermore, the window can be coated with anti-reflective coating to optimize the response. For imaging with coherent light sources such as lasers, wedge window option is also available. Princeton Instruments uses highly reliable "glass-to-metal" brazing process to attach the windows to the vacuum chamber. This is in contrast to standard epoxy (glue) used on most other camera designs which will degrade and/or out-gas over time reducing the cooling performance.

Princeton Instruments backs this up by giving "Lifetime" vacuum guarantee on our cameras using the XP cooling technology –only such guarantee in the industry.

18. What anti-reflective (AR) coatings are available for eXcelon detectors?

For best performance in low light level applications, it is important to optimize every aspect of light transmission and detection. The AR coatings on the vacuum window provide >99% transmission in the wavelength of interest. They also reduce reflections from CCD-to-window and window front and back surface for the best possible fringe and glare suppression. Princeton Instruments custom designed a choice of AR coatings –BBAR, UVAR, VISAR and NIR-AR coatings on the windows. It is important to note, that while these coating improve the transmission over the specified wavelength, their performance could be worse than an uncoated window outside their design region. So, it is important to select the best coating when ordering the camera. **For most applications broadband AR (BBAR) coating offers balanced transmission over 400-1100nm range.**

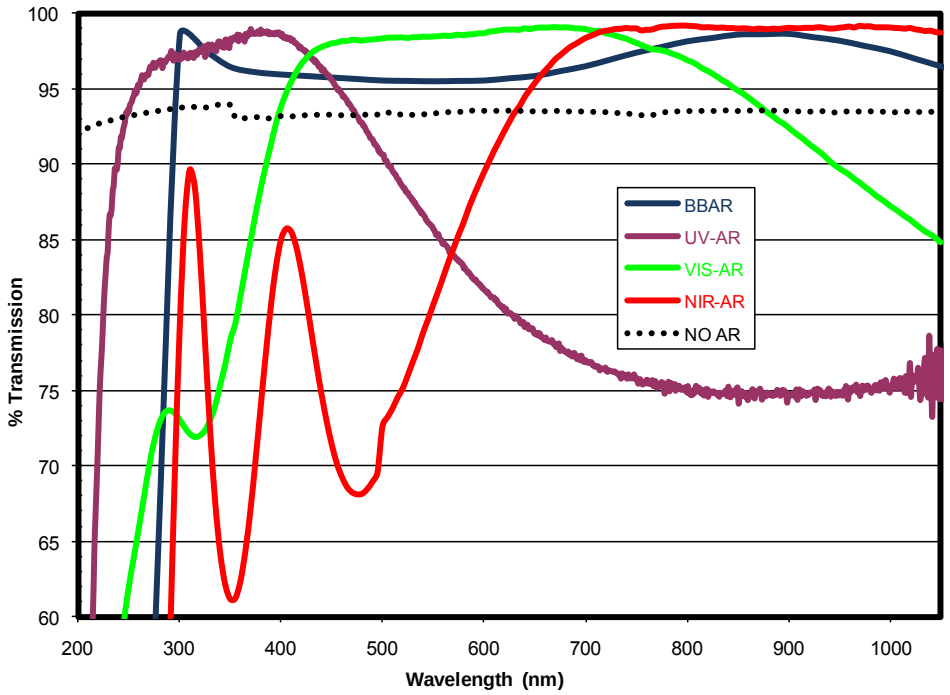

Figure 4. Princeton Instruments uses Single Vacuum window in the optical path. Standard AR coating transmission curves shown above. Custom AR coatings are available for specific applications. Please contact factory

19. What software programs support eXcelon cameras?

All PI cameras including eXcelon cameras are supported by WinView/Spec under Windows XP/Vista/7 (32-bit). The renowned applications support both camera and spectrographs for easy integration. For customization, LabView SITK™ with pre-written vis or PVCAM acquisition libraries. Any software written to drive PIXIS, ProEM and Spec10 detectors in the past will readily be able to run eXcelon counterparts. **In addition, Princeton Instruments launched the new LightField™ 64-bit application software with the new intuitive user interface and acquisition performance with PIXIS and ProEM.** Please visit our website for more information on LightField.

20. Where can I find more information on eXcelon cameras and technology?

Please visit www.princetoninstruments.com or www.eXcelonCCD.com or www.eXcelonEMCCD.com for more information.

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