# Frequently Asked Questions: eXcelon Back Illuminated CCD/EMCCD Cameras

1. What is eXcelon?

eXcelon is a new CCD/EMCCD sensor technology jointly developed by Princeton Instruments, e2v and Photometrics. It provides three significant benefits

- **Improved sensitivity** – improved QE over broader wavelength region compared to back illuminated sensors
- **Reduced etaloning** – up to 10 times lower etaloning or unwanted fringes in near infrared (NIR) region compared to standard back illuminated CCDs/EMCCDs
- **Lower dark current** – similar to back illuminated CCDs or 100 times lower than the deep depletion CCDs.

2. 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. The sensors can be coated with special UV coating to enhance sensitivity below 350nm (dotted line below). The eXcelon CCD cameras provide as much as 15% increase in QE in NIR and as much as 20% in UV region compared to standard back illuminated (BI) cameras.

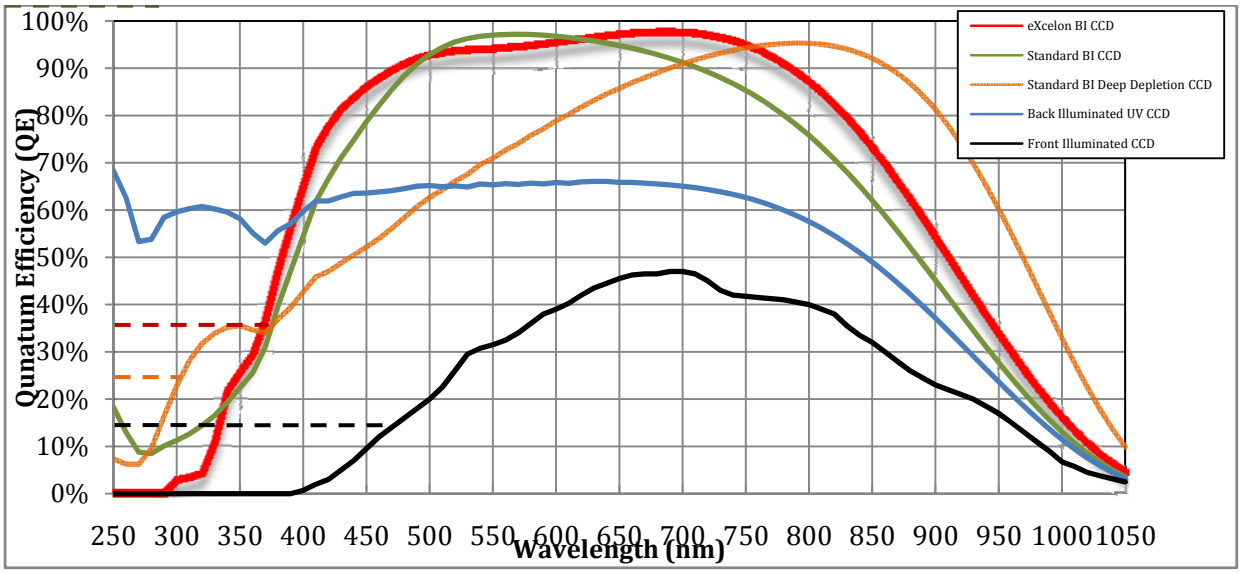


Figure 1: QE comparison of eXcelon and standard Back Illuminated CCD technologies (Data at +25°C)

3660 QUAKERBRIDGE ROAD
TRENTON, NJ 08619 USA
TEL: 609 587 9797 | FAX: 609 587 1970

3. How is the improved performance of these detectors achieved?

While the exact details behind the breakthrough technology are proprietary, it involves cutting-edge sensor manufacturing and processing that achieves such performance. We have worked on this for over 18 months in order to optimize and perfect the manufacturing of these sensors and cameras.

4. What are the other advantages of eXcelon cameras?

In addition to significant improvements in sensitivity the eXcelon enabled PIXIS, Spec10 CCD cameras and ProEM EMCCD 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

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 Spec10 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 |
|---|---|---|
| ProEM: 512B_eXcelon | 512x512 | 16 um |
| ProEM: 1024B_eXcelon | 1024x1024 | 13 um |

**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.*

| Model Name | CCD Format (Full frame) | Pixel Size |
|---|---|---|
| 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 |
|---|---|---|
| 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.

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.

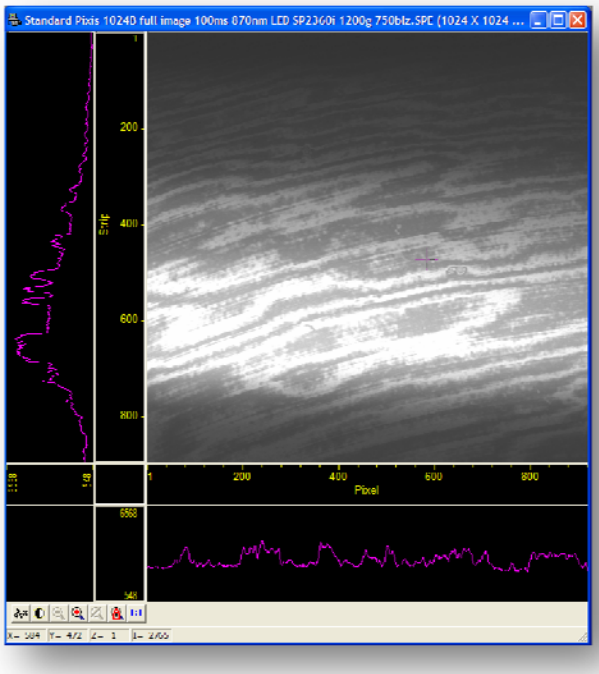


**Figure 2: An example of etaloning in standard Back illuminated CCDs (Image taken with 870nm illumination)**

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) | Standard BI Deep Depletion (BR) |
|---|---|---|---|
| QE Range | **<200*-1100nm** | <200*-1100nm | <200*-1100nm |
| Peak QE* | **~95% @ 550nm** | ~95% @ 700nm | ~95% @ 800nm |
| Etaloning in NIR | **Lower** | High | Lowest |
| Dark current | **Low** | Low | High (100x 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 and BI DD 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.

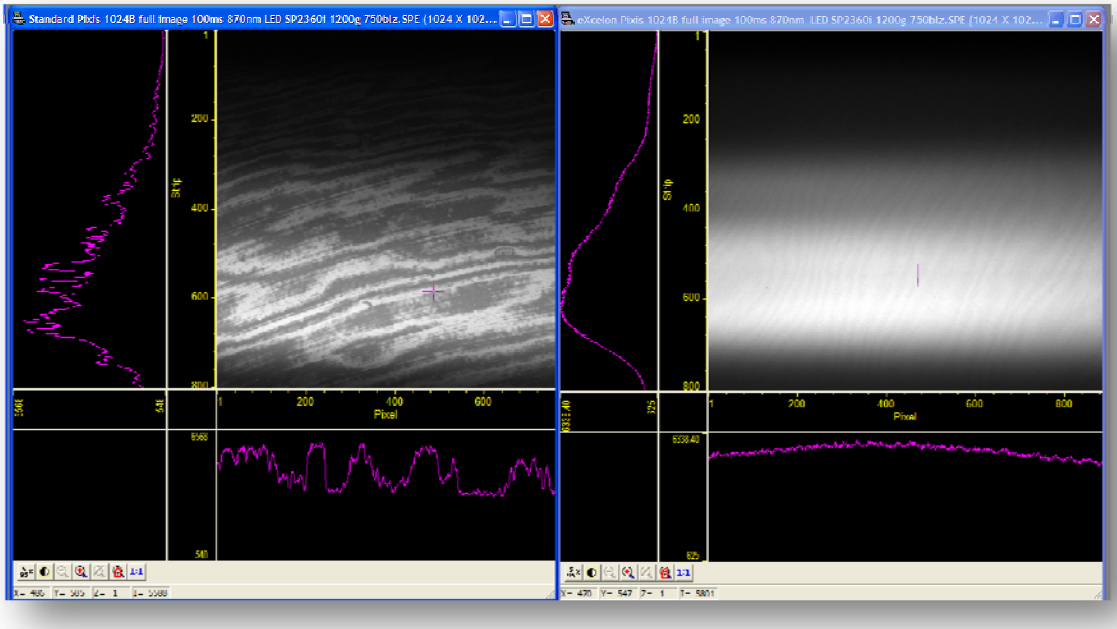


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Figure 3: Comparison of images captured with standard BI (left) and new eXcelon BI CCD cameras (right) at 870nm. The cross sectional data shows excellent fringe suppression of eXcelon

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 BI 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 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, you could also consider deep depletion (BR) sensors.

15. What applications can take advantage of eXcelon's improved performance?
    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 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.

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 300-1100nm range.**

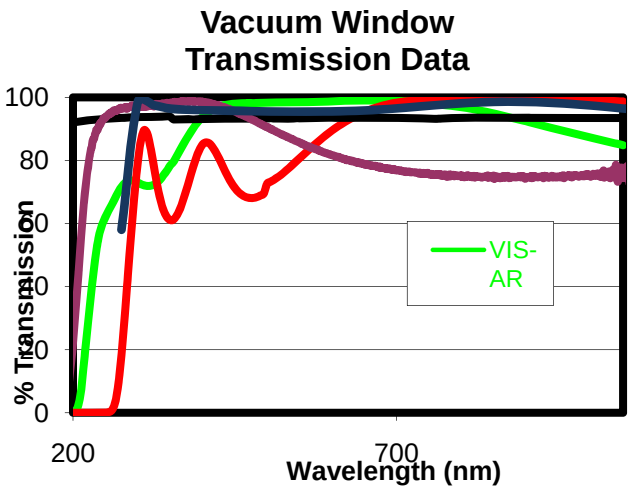


Figure 4. Princeton Instruments Window AR coating options.

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 is demonstrating the new 64-bit application software with the new intuitive user interface and acquisition performance with PIXIS and ProEM. Please visit our website for the updates on the release of that software

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

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