

RealGain™ Anti-Ageing™ & EMCAL™

Technical Article

In 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, which others in the industry are only now beginning to adopt.

Part 1: RealGain™, Anti-Ageing and EMCAL™

RealGain™ Linear - In response to considerable demand from our customers, Andor have set about a detailed analysis of the EM voltage dependence, and have successfully converted the non-linear relationship between EM gain and the EM software setting into a linear one. Real - Importantly, the true EM gain (i.e. the absolute signal multiplication factor) is selected directly from the software linear gain scale, as shown in Figure 1. No more guesswork with arbitrary gain units across a non-linear scale - the gain you ask for is the gain you get. Select the best gain to overcome noise and maximize dynamic range.

Temperature Compensated

Although EM gain is temperature dependent, Andor's real/linear gain calibration extends to any EMCCD cooling temperature. Selecting x300 gain software setting at -50°C, or at -

100°C gives the same x300 true EM gain. Importantly, this means that there is no need to recalibrate EM gain on each use in multi-user laboratories and facilities.

Anti-Ageing of EM gain

It has been observed that EMCCD sensors, more notably in cameras that incorporate L3Vision sensors from E2V, are susceptible to EM gain fall-off over a period of time. This phenomenon has been documented by E2V and can be viewed on their web site. All back-illuminated EMCCD sensors are of this brand and therefore all are susceptible to EM gain ageing.

It is important to note that the ageing effect applies to any EMCCD camera, by any manufacturer, that incorporates these L3Vision sensors. In Andor's iXon range, this corresponds to the iXon3 860 model and the iXon Ultra 897 and 888 models. If left unchecked, this ageing phenomenon has the potential to significantly compromise the long-term quantitative reliability of EMCCD cameras. Fortunately, if these highly sensitive sensors are integrated into intelligently designed camera electronics, ageing can be minimized and should not present any real problem to the user.

Andor have recognized the ageing issue and have been busy implementing innovative measures to stabilize the EM gain on these sensors, ensuring that this ground-breaking ultra-sensitive technology can deliver a prolonged quantitative service to the user. iXon cameras have been internally configured to ensure that the rate of EM gain fall off is significantly reduced under standard operation. Part of the measures taken has been to invoke real EM gain limits, coupled with signal intensity feedback warnings (after EM amplification) to ensure that the user is more restricted in his/her ability to apply excessive EM gain and/or signal. The EM gain scales offered are more than sufficient to render the read noise floor as negligible for a given signal intensity and readout speed. These tight user restrictions significantly reduce the rate of EM gain fall off.

EMCAL™ Andor have developed a unique and patented method of user-initiated EM gain self-recalibration. Even after exercising due care during usage and availing of the above anti-ageing restrictions, the EM gain may deplete over an extended period of time. The EMCAL™ selfrecalibration process is very easily initiated by the user. At the touch of a button, a routine is triggered that measures EM gain and uses the iXon in-built temperature compensated RealGain™ scales to reset the EM gain calibration (if required), to deliver the true values requested on the software scale – i.e. resetting the factory calibration. EMCAL™ stands to markedly prolong operational lifetime and quantitative reliability of the technology, and circumvents the need to return the camera to the factory for recalibration.

Part 2: Longevity

How extensively can Andor's back-illuminated EMCCDs be used before they can no longer be recalibrated (EMCAL™) to factory EM gain settings?

One common concern associated with EM gain ageing phenomenon and the associated EMCAL™ recalibration fix is that of longevity. The clock voltage setting, which must be adjusted as part of the recalibration routine, will eventually reach a maximum threshold value, after which further rescaling is not possible and EM gain will then fall off irreparably upon further extensive use of the camera. The question is, when is this likely to happen under typical use?

Andor ran extensive testing on the iXon 897 camera in order to project the operational lifetime of the 'gain register' (where signal amplification occurs on-chip) in back-illuminated EMCCDs, the conditions of testing are described below:

- Overall duration of test: ~14 months
- Camera usage during this period: Continuous 24 hours per day, 7 days per week
- Frame rate: 30 frames / sec
- EM gain setting: x1000
- Photons / pixel / frame: 90
- Number of pixels illuminated: ~ 200,000 (~ 75% of array)
- EMCAL: Applied once per day.

Results

The clock voltage required to maintain the EM gain calibration was measured once daily using Andor's EMCAL™ routine and the plot shown was generated by extrapolating from the equation derived from the gain ageing trend. This shows that under the test conditions employed, the EMCCD calibration would only be expected to reach

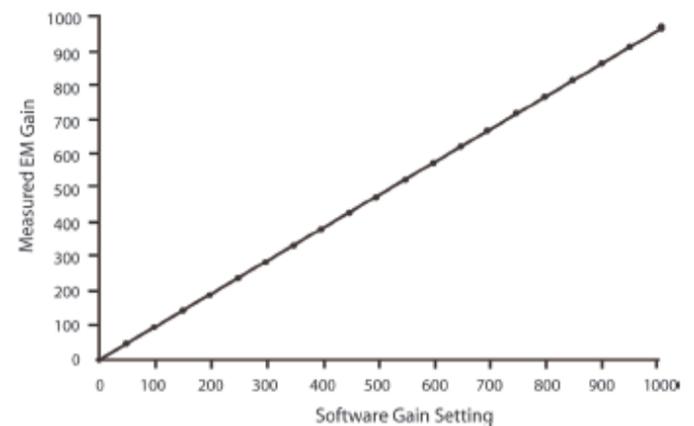


Figure 1 - RealGain™ calibration in the iXon - the same linear relationship holds across all cooling temperatures.

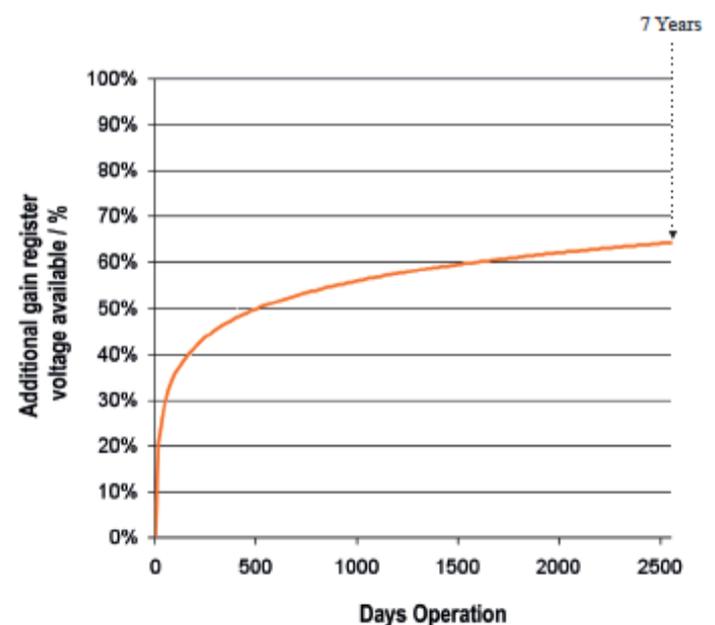


Figure 2 - Ageing profile of an Andor backlit EMCCD. Test conditions: 24/7 operation; 30 fps; x90,000 electrons per pixel through gain register; ~ 200,000 pixels illuminated

~ 65% of the available clock voltage scale after 7 years of continuous operation.

Demanding test conditions

The combination of parameters employed in this test represents quite aggressive acquisition conditions. ~1.1 billion images were recorded during this period, with ~ 200,000 illuminated pixels per image, corresponding to ~ 220,000 billion pixels being amplified through the gain register with x1000 EM amplification per pixel.

Most users would not subject the camera to 24/7 continuous acquisition at 30 fps. We also strongly recommend that, except for photon counting, the EM gain setting is limited to no more than x300 for the vast majority of applications, but x1000 was chosen here as a more rigorous test condition. Finally, it is quite rare that 75% of all pixels in the array will be subjected to uniform signal of this magnitude, as was imposed on the sensor here. In reality the light emitting species of typical user samples will project onto a much smaller fraction of pixels from frame to frame.

EMCAL™ does NOT accelerate EM gain ageing

It is important to recognize that the rate of ageing is not accelerated by routine application of Andor's EMCAL™ routine. The rate of ageing is determined by the illumination and EM gain conditions that the sensor is subject to through operation, irrespective of routine recalibration using EMCAL™. If the 'previous' mechanism of EM gain recalibration were to be used, whereby the camera is shipped back to factory less frequently for manual readjustment of the clock voltage, the progress along the ageing curve would not be any different from that shown here (adjusting for the additional time that the camera would be out of action).

Conclusion For the vast majority of low-light applications and taking due care and attention to stay within recommended operating conditions, applying EMCAL™ as required, the gain ageing phenomenon is not considered to ever impose a restriction on the quantitative reliability of your Andor iXon camera.