Time-Delay Integration EMCCD

Olivier Daigle[1], Jérémy Turcotte[1], Yoann Gosselin[1], Alex Saint-Amant Lamy[1]
1. Nüvü Caméras, 355 Peel St, suite 603, Montreal, QC, H3C 2G9, Canada.

***Abstract*—Scientific EMCCD cameras are the detector of choice for extreme low-light conditions. With photon counting capabilities, sub-electron readout noise and low dark current, EMCCDs can detect very faint signals. Traditionally, EMCCD are operated in frame-transfer mode where the image is integrated in the light-sensitive region of the sensor and then quickly transferred to a storage array before being read out. Time-Delay Integration (TDI) is a specialized readout mode optimized to image fast moving objects while preserving light sensitivity. By shifting the photoelectrons simultaneously to the movement of the object, TDI effectively increases the integration time available to collect light. The newest version of Nüvü Caméras' CCD Controller for Counting Photons (CCCP) will allow operating EMCCD detectors using TDI readout mode with either internal or external trigger sources at more than 100k lines per second. The combination of TDI and EMCCD technologies represents a new leap for extreme low- light imaging in fast moving conditions opening EMCCD to a range of new applications.**

Keywords—EMCCD; Time-Delay Integration; Low Light Imaging

I. Electron Multiplying Charge Coupled Devices

Electron Multiplying Charge Coupled Devices (EMCCDs) are extremely sensitive devices capable of detecting a single photon in the visible spectrum. EMCCD cameras are based on a similar architecture to frame-transfer CCDs. An imaging area comprised of individual pixels are used to collect incoming light and trap resulting photoelectrons in the silicon substrate of the detector. One by one, each pixel line is shifted down and ultimately transferred to the horizontal register. A second high voltage serial multiplication register is then used to multiply the electrons from each pixel and propel the weak signals over the readout noise floor which allows for single photon sensitivity [1].

II. Time Delay Integration for EMCCDs

When trying to image fast moving objects, it is often a challenge to capture an image with a sufficient signal level while maintaining minimal motion blur or image smear. To alleviate this problem, Time Delay Integration (TDI) Charge Coupled Devices (CCD) were developed in the 1970's to allow continuous exposure of the object as it moves under the field of view of the camera [2].

Time-Delay Integration is a readout mode based on the concept of the accumulation of cumulative exposures of the same object as it is moving linearly under the detector. The goal is to synchronize the transfer of the charges from one line to the next with the same speed as the object moving under the camera. This allows to detect very-weak signals with a superior SNR compared to full-frame or frame-transfer cameras. An example of TDI readout is shown in figure 1.

TDI cameras produce a continuous stream of lines rather than 2D images. The number of TDI stages corresponds to the number of lines of the light-sensitive region of the detector and is also representative of the number of cumulative exposures each part of an object will accumulate. Compared to frame-transfer detectors, the operation of EMCCD in TDI mode doesn't add aditional noise to the image since the charge transfer is done similarly.

It is now possible for the first to use the TDI mode of operation on EMCCD cameras. This allows to benefit from the sensitivity of the EMCCD detector and the high-speed imaging capapiblities of TDI. It is now available on the three commercial EMCCD chips from e2v-Teledyne, the CCD60 (128x128), CCD97 (512x112) and CCD201-20 (1024x1024). The achievable line rate is dependant on the size of the detectors and can reach up to 140,000 lines per second on the smallest detector.

Multiple applications can benefit from the TDI readout mode. These applications range from industrial visual inspection, space or ground based earth observations, flow cytometry imaging, histology slide imaging and much more.

Fig. 1. Example of imaging the word NÜVÜ using Time-Delay Integration readout mode. The intensitiy of the signal is increased as the word moves across the detector.

References

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