HORIBA
Scientific

AToR
HDR IMAGING AND FAST, EVEN TRACKING FOR ASTRONOMY

ELEMENTAL ANALYSIS
FLUORESCENCE
GRATINGS & OEM SPECTROMETERS
OPTICAL COMPONENTS
FORENSICS
PARTICLE CHARACTERIZATION
RAMAN
SPECTROSCOPIC ELLIPSOMETRY
SPR IMAGING

Ultra-high dynamic range
Detects falling meteors

Introduction

Traditionally, astronomers have used a CCD camera with a combination of cooling and low readout-speed to achieve the long integration times necessary to detect faint objects. This approach, however, has two limitations: the dynamic range is limited by the electron well depth of the pixel, and long exposure times are not suitable for tracking fast-occurring events such as falling asteroids or space debris.

In addition, because where or when asteroids or debris will fall cannot be known, tracking these kinds of objects requires a unique combination of wide field of view, very high sensitivity, and speed.

Electron Multiplication

Driving a CCD camera at 20 frames per second greatly reduces its sensitivity and the amount of collected photons. Only EMCCDs are capable of achieving fast

frame-rates required for this application while maintaining good sensitivity levels, thanks to the embedded on-chip Electron Multiplication (EM gain), which eliminates the readout noise. Electron Multiplication allows a gain of sensitivity of up to 4 stellar magnitudes compared to a traditional CCD (compare Figures 1 and 2).

Readout-noise removal

The removal of readout noise and resulting added sensitivity can be used in two ways:
• Lifting the limitation of the pixel well depth and obtaining ultra-high-dynamic-range images. This is achieved through a combination of negligible readout noise and accumulation of short exposure images.
• Increasing the acquisition frame rate in order to capture faint and fast transient events.

Ultra-high dynamic range with AToR

Figure 3 shows how a single 100 ms exposure allows the

Figure 1: 50 ms exposure time with no EM gain. 20 mm, f/1 lens.

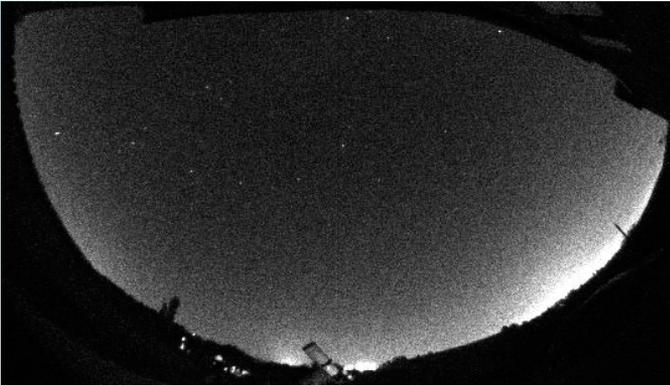Figure 1: 50 ms exposure time with EM gain enabled. 20 mm, f/1 lens.

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Figure 3: Single 100 ms exposure time, EM gain enabled, fisheye lens ($F = 1.8$ mm) with AToR. Magnitude 3 stars can be detected.

detection of stars down to stellar magnitude 3 with 16-bit dynamic range. Figure 4 shows a stack of 1500 images, equivalent to 2 minutes 30 seconds cumulative exposure. The resulting image exhibits Ultra-High Dynamic Range (UHDR) from the window's house light and light-pollution near the horizon up to the faint Milky Way and many constellations.

Summing images without EM gain does not result in the same increase in dynamic range or sensitivity because of the higher readout noise (see comparison of Figure 5 and Figure 6).

Detection of falling meteors

With a little luck, a wide-angle lens, high sensitivity, and a detector with a fast frame-rate, image-capture of falling meteors into the Earth's atmosphere is possible (see Figure 7).

Figure 4: 1500 × 100 ms exposure time fisheye lens with AToR. Ultra HDR in only 2 minutes 30 seconds!

The camera's high sensitivity allows it to detect quick changes of the meteor's shape and the way it degrades throughout its entry into the Earth's atmosphere. Moreover, this kind of sequence can tell if remains of the meteor can be retrieved from the ground.

EM camera performance can also provide, with this kind of time-capture sequence, information on satellites' re-entry into the Earth's atmosphere, and what and where can be recovered on the ground.
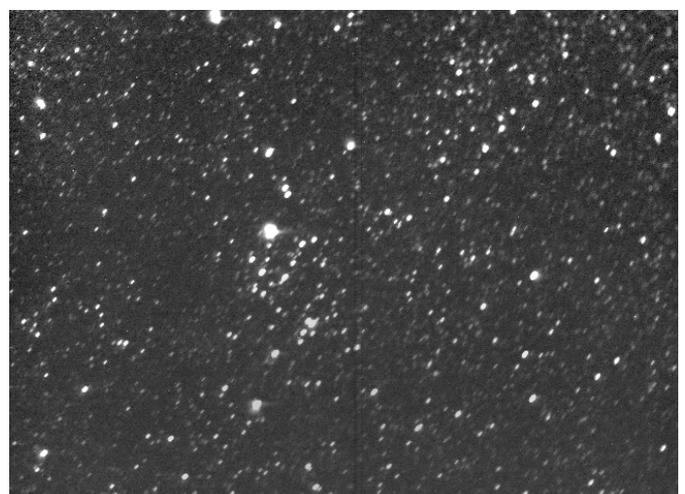

Figure 5: 500 × 50 ms exposure time with no EM gain, 20 mm, f/1 lens with AToR.

Figure 6: 500 x 50 ms exposure time with EM gain, 20 mm, f/1 lens with AToR.

Conclusions

HORIBA Scientific's AToR offers the possibility of studying random and fast-occurring events in the Earth's atmosphere as well as obtaining ultra-high dynamic range images within a very short accumulated exposure, all within a proven compact and rugged package.
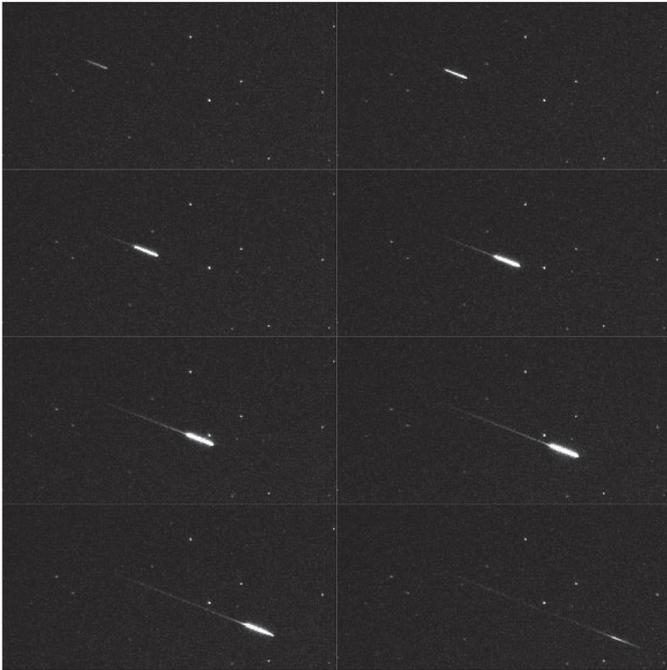

Figure 7: Meteor, 100 ms exposure time, 10 mm, *f*/1.8 lens with AToR.

Summing images without EM gain does not result in the same increase in dynamic range or sensitivity because of the higher readout noise (see comparison of Figure 5 and Figure 6).

AToR Features

- 658 × 596, 10 µm × 10 µm EMCCD sensor. Enables optimum image resolution in low-light imaging applications.
- B/W EMCCD technology. Enables high-sensitivity imaging with up to 1000× on-chip gain.
- 16-bit CameraLink output provides wide dynamic range.
- 53% QE from Virtual Phase sensor. Optimum photon collection.
- No image intensifier. Optimum B/W image sharpness in ALL light conditions.
- Interlined. No mechanical shutter required; vibrationless CCD readout.
- Real-time imaging. Optimum image sharpness in ALL light conditions.
- Compatible with XCAP software. Ready-to-run powerful image-analysis software.

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