EPSC Abstracts
Vol. 6, EPSC-DPS2011-1173, 2011
EPSC-DPS Joint Meeting 2011

SHOC: Sutherland High-speed Optical Cameras

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Abstract

We have constructed a new instrument for use on the 74-, 40-, and 30-inch telescopes at the South African Astronomical Observatory (SAAO) site in Sutherland. The Sutherland High-speed Optical Cameras (SHOC) were designed to provide, subsecond (or longer), accurately-timed, high-quality, visible-wavelength imaging. The instrument has the capability to run in conventional frame transfer mode or to increase signal via an electron-multiplying amplifier. We anticipate the application of SHOC for research projects ranging from stellar occultation observations to extrasolar planet transits to a variety of stellar phenomena.

1. Instrument overview

SHOC is based on MORIS, a similar instrument that is mounted on NASA's 3-m IRTF on Mauna Kea, Hawaii [1] and POETS, a portable suite of high-speed imaging cameras operated by MIT and Williams College [2, 3]. Some basic characteristics of SHOC are listed in Table 1. The primary component is an Andor iXon X3 888 UVB camera. The camera has high quantum efficiency (> 90% from roughly 480 nm to 700 nm), low read noise, and low dark current. The UVB designation indicates a back-illuminated CCD with UV phosphor, elevating the quantum efficiency to approximately 35% below 380 nm. The camera is thermoelectrically cooled, typically operating at -70º C.

SHOC's mounting plates allow attachment below the filter wheel at either the 30-, 40-, or 74-inch telescopes in Sutherland. The suite of available filters includes Bessell *U*, *B*, *V*, *R*, and *I*, H-alpha, and Strömgren *z* and *y*.

The camera has a range of available readout amplifiers: 1 MHz (16 bit) and 3 MHz (14 bit) in conventional mode or 1 MHz, 3 MHz, 5 MHz, and 10 MHz (all 14 bit) in electron multiplying (EM) mode. Each amplifier has multiple gain conversion settings. Full-frame readout rates range between 0.9 Hz (1 MHz) and 7.9 Hz (10 MHz). User-selectable binning and subframing can increase the cadence to a few hundred Hz.

In EM mode, transferred electrons undergo impact ionization, strengthening the observed signal without increasing read noise. This effectively reduces read noise to subelectron levels (at the expense of dynamic range), allowing a significant increase in data quality for photon-starved applications. Recent developments from Andor such as absolute EM gain selectability from a linear scale, self-recalibration of EM gain, baseline clamping, minimization of clock-induced charges, and a spurious noise filter allow flexibility in employing this unique technology.

GPS antennas and cables have been installed at the 30-, 40-, and 74- inch telescopes in Sutherland. Data

Table 1: SHOC characteristics

CCD….........	E2V CCD201; 1024 × 1024; 13μm^2
Full well capacity[a]…………………...	~144000 e-
Linearity…………………..........................	< 1%
Read noise[a]…….	5.84 e-/pixel (1MHz, 4.9×)
(select modes)	7.49 e-/pixel (1MHz, 2.4×)
	11.59 e-/pixel (3MHz, 2.4×)
	34.30 e-/pixel (3MHz EM, 2.4×)
	48.53 e-/pixel (5MHz EM, 2.4×)
	60.14 e-/pixel (10MHzEM,2.4×)
Dark current………………....	< 0.001 e-/pix/sec
Dead time…......................................	~6.7 msec
	(1024 rows at default shift speed)
GPS trigger accuracy………………….	< 1 μsec
Field of view…………...	3.8×3.8 arcmin (30 in)
	2.9×2.9 arcmin (40 in)
	1.3×1.3 arcmin (74 in)

[a]Camera specifications are for the Andor iXon 888 model that we currently have.

cubes, or individual frames, can thus be triggered to nanosecond accuracy using a Spectrum Instruments TM-4 GPS. Programmable GPS output pulses are used to set desired frame cadence. The control computer is custom-built, consisting of a small-form chassis, a 300 GB/10000 rpm hard drive, an Intel dual core 3.06 GHz processor, and the capability to host the camera PCIe card and GPS serial connection. Computer control is achieved via either internet protocol KVM (keyboard, video, mouse) or VNC (virtual network connection). Fiber optics were installed on each telescope to allow optimal communication with the instrument computer as well as efficient data transfer.

2. First light results

One complete system is currently in hand. In total, we are constructing two systems that contain all components and a third system will contain everything excluding a camera. Thus the third system acts as a swappable spare should problems arise, a particularly important consideration for time-critical observations. In addition, having two identical systems will allow simultaneous observations from two different telescopes.

We will present all measured instrument characteristics as well as results from the first light of SHOC on each of the three telescopes. Observations include open clusters (to check image quality and determine plate scale), standard stars (to check throughput and measure signal to noise ratios), and variable stars/star systems (to check timing). Investigations into the efficacy of the electron multiplying mode will be highlighted.

Acknowledgements

We gratefully acknowledge the support of the SAAO Telescope Operations, IT, electrical, and mechanical departments. Specific contributions have been made by Hamish Whittal, Geoff Evans, Ramotholo Sefako, David Buckley, Phil Charles, and Steve Potter. This work is supported by the SAAO, the South African Department of Science and Technology, and the National Research Foundation.

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