Replacement StanCam

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Introduction

An investigation into a replacement for the ageing StanCam has been made.

StanCam currently provides two principle functions, as a visible imager when none is available at Cassegrain and as an acquisition and fibre guider for Fies.

The present StanCam camera has a Tektronix's CCD, physical size of 1024 x 1024 with 24 μm pixels or (24.576 mm square) giving an unvigneted field of view (FOV) of 3 arc minutes square at a resolution of 0.176"/pixel. The read noise is given as 6.5 e^-/pixel. The 45 degree pick off mirror determines the available field.

It is expected the existing standby filter mechanism and shutter will be retained.

For maintenance, development and reliability using cameras similar to ones on the NTE seems reasonable. NTE will have an Andor EMCCD for the slit viewer, a customised Nüvü h-nü 1024 on the visible arm of the spectrograph, as well as the existing ALFOSC CCD controller and detector. The ALFOSC e2v CCD231-42 is a backside illuminated (BSI), deep depletion 2k square detector and will go on the visible imaging arm of NTE. It should not be necessary to duplicate this performance at standby position.

When NTE is mounted the visible imager will provide a FOV of at least 5' x 5' with the ALFOSC detector, also the instrument slit viewer with a Andor EMCCD 1Kx1K camera can provide imaging capability (and with suitable software lucky imaging) with a slightly vigneted FOV of 2' x 2', though after the NTE's atmospheric dispersion corrector (ADC).

Cameras

There are a large number of cameras available on the market that could replace StanCam and can be categorised by their detector technologies; conventional CCD, electron bombarded CCD (EMCDD) and CMOS.

For the existing functionality of StanCam a conventional CCD can suffice and to not duplicate the capabilities of NTE a basic Andor system could be considered. Such a camera is the Andor iKon 2048x2048 13.5 μm pixels backside illuminated with BV coating and 4 stage Peltier cooling. There are also versions that have deep depleted, fridge suppressed CCD's with different coatings at a higher price, see the table and quantum efficiency curves below. All Andor cameras come with either air or liquid cooling and 4 or 5 stage Peltier coolers. Such a camera would be able to use the full field of view of the standby focus.

It has been suggested that lucky imaging maybe a useful additional mode for the replacement StanCam and this would then require an EMCCD or possibly a CMOS detector. Teledyne e2v

(Te2v) are the only company that manufactures suitable EMCCD detectors, though Hamamatsu do produce an inferior device. Te2v produce several EMCCD devices ranging from 128 x 128 pixel square up to the 4096 x 4112, typically only the CCD97 512 pixel square and CCD201-20 1024 pixel square EMCCDs are readily available in commercial cameras. Staying with the chosen camera manufactures both Andor and Nüvü do cameras with the Te2v CCD201-20 1024 x 1024 13 μm pixels detector, namely Andor iXon Ultra 888 or the Nüvü h-nü 1024. Both these cameras can operate as either EM or in conventional CCD mode with a FOV at standby of 1.5' square. In conventional mode the readout noise is approximately 3.5 e^- at 100 Kpixels/sec (~10 second frame rate) for both. The Nüvü has a better EM specification (reduced clock induced charge – CIC, hence a lower noise floor resulting in a larger dynamic range) than the Andor iXon. There are other EMCCD cameras on the market with similar or inferior specifications.

For information Nüvü have manufactured a custom EMCCD camera using the Te2v 4K square split frame transfer device for a space application. Even if this camera was commercial available it would be very expensive and in its current form would not fit at the standby position.

Finally there is CMOS. These cameras typically have readout noises around 1.5e^- and can be read out at high frame rates, typically 10 to 100 frames/s, but often have relative high dark current. An example camera is the Andor CMOS Marana 2k x 2k 11 μm camera which has a maximum full frame rate at full dynamic range (16 bits) of ~12 frames/s and twice that at the lower dynamic range of 12 bits, can be cooled to -45 ºC giving a dark current of 0.3 e^-/p/s. This camera would have a FOV of about 2.7' square.

Teledyne Princeton Instruments propose to manufacture a camera called COSMOS-10 which would be 3.3 K square with 10 μm pixels and have a dark current of 0.05 e^-/p/s @ -25 ºC and a full frame rate of 61 frames/s. Unfortunately this camera will not be available for a couple of years, but can be order know!

Other CMOS cameras are made by QHYCCD who produce a range of cameras mainly for the amature market, they use open source software and are quite cheap. This is one of the few manufactures that use the Gpixel CMOS sensors that have reasonable sized pixels 9 – 12 μm, otherwise you will typically get pixels less than 5 μm, but a lot of them! Anton Norup Sørensen at NBI did an evaluation of the QHYCCD QHY600M Pro CMOS camera and though when the camera worked it gave some impressive performance figures it was also unreliable with issues with the camera hanging, cooling problems when reading full frame images and poor documentation. A table at the end of this document summaries several QHYCCD cameras.

Software and Interfaces

For the Andor cameras you can purchase a separate Software Development Kit (SDK) for 615 € and Nüvü also provide a SDK for US$3 K, both can operate under Linux and since they will both be used with the NTE joint code development can occur. Actually for the (older version of the) Andor EMCCD used for the NTE slit viewer sequencer commands already exist and it would be assumed that also for the conventional Andor CCD iKon camera the commands will be of identical form.

The Andor cameras use USB interfaces and the company can supply an extender that operates up to 100m at 1026 €. The Nüvü EMCCD camera uses GigE Vision (Gigabit Ethernet) so again can operate up to 100m from the PC.

The idea of a EMCCD is to provide the option to do lucky imaging, though to do this in real time significant effort will be required to develop the analysis software to implement a lucky imaging mode ,e.g. strehl determination, frame selection, centroiding, shift and add etc, or a third party compatible program will need to be acquired! Even simpler post-processing software will take some time and effort to develop.

In addition to the communication interface a mechanical flange will need to be made to mount the camera on the adapter and an electronic connection made to operate the existing shutter.

It has been stated that the optical window for StanCam is flat i.e. not a field flattener, which means no customised dewars and related cost and effort.

Recommendation

From the cameras considered it is proposed that either a conventional Andor iKon CCD camera or an Andor EMCCD iXon camera replaces StanCam. An iKon 2k x 2k camera will provide the full field of view with an improved performance over the existing system where as an Andor iXon with a field of view of about 1.5’ square and has the capability to do lucky imaging but still with better detector performance than the existing StanCam CCD. As mentioned above sequencer commands have already been written for an Andor camera used on the NTE so simplifying the development, but no lucky imaging software exists.

Without the need to duplicate the NTE imaging functionality a basic Andor iKon-L 936 with a BV coated CCD at 53,776 € should suffice. Alternatively the Andor iXon Ultra 888 at 38,366 €. For both of these systems a SDK at 615 € and a USB extender at 1026 € would be required. In both cases liquid cooling could be provided through the telescope cooling system at minimal expense. The only additional work is then the mechanical interface to the adapter and control of the shutter.

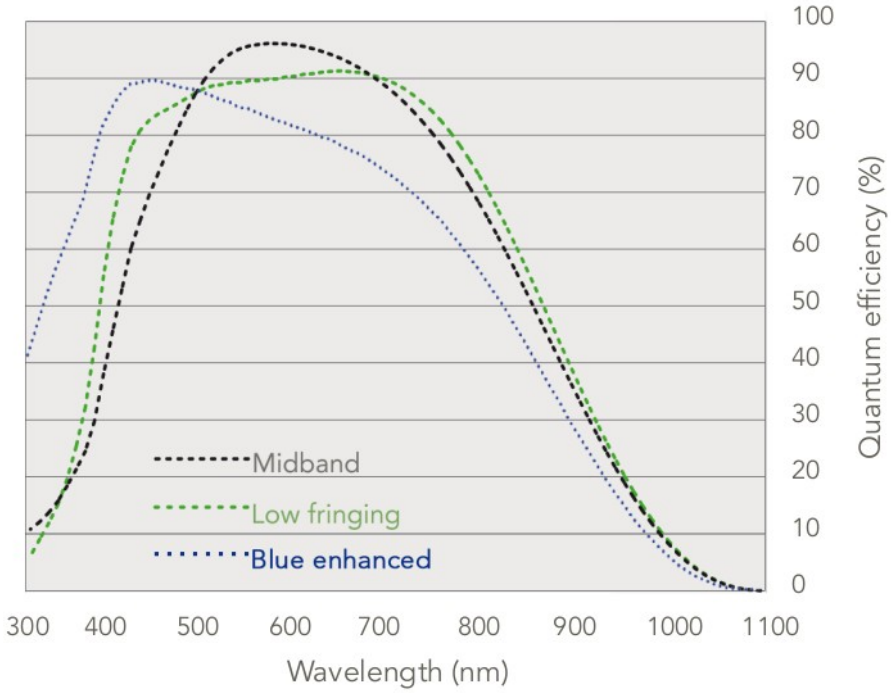
Specifications

The following are the figures for the Andor iKon and iXon cameras and the Nüvü h-nü 1024 camera.

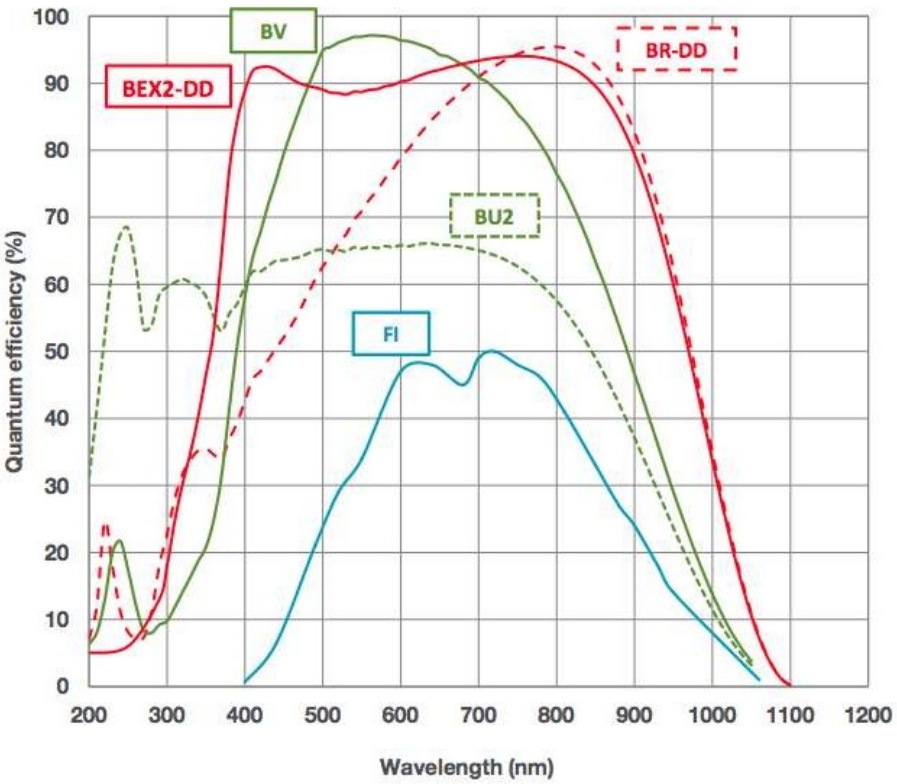
Cameras	***Andor iKon-L 936***	***Andor iXon Ultra 888***	***Nüvü h-nü 1024***
Active Area	2048 x 2048	1024 x 1024	1024 x 1024
Sensor Size	27.6 x 27.6 mm	13.3 x 13.3	13.3 x 13.3
Pixel Size	13.5 µm	13 µm	13 µm
FOV	3.3’ x 3.3’ [1]	1.6’ x 1.6’	1.6’ x 1.6’
Well Depth	100000 e^-	80000 e^-	
Read Noise	2.9 e^- @ 50 KHz	3.5 e^- @ 100KHz	3 e^- @ 100KHz
	7 e^- @ 1 MHz	<1 e^- with EM	< 0.1 e^- @ 20 MHz
CIC	-	0.005 @ gain = 1000	0.0015 α and ɣ models
Cooling Air	-70 ºC	-60 to -80 ºC [2]	-80 ºC
Cooling Liquid	-80 ºC	-75 to -95 ºC [2]	-90 ºC
Dark current (e^-/p/s)	0.0004 @ -70 ºC	0.00025 @ -80 ºC	0.00007 @ -85 ºC
	0.00013 @ -80 ºC	0.00011 @ -95 ºC	

[1] Possibly vignetted slightly,
[2] Depends on read speed

Quantum Efficiency Curves



Typical spectral response as specified by Teledyne e2v for the EMCCD detectors.



Quantum efficiency curves for the Andor iKon-L 936 conventional CCD cameras.

Camera prices, August 2022

Description	Part Number	Price
ikon 2Kx2K BSI, BR-DD, fringe Suppressed. 4 stage Peltier cooling	DW936N-BR-DD	85,912 €
iKon 2Kx2K BSI, BV, 4 stage Peltier cooling	DW936N-#BV	53,776 €
iKon 2Kx2K BSI, BR-DD fringe Suppressed, 5 stage Peltier cooling	DZ936N-BR-DD	89,876 €
iKon 2Kx2K BSI, BV, 5 stage Peltier cooling	DZ936N-#BV	57,860 €
iKon 2Kx2K BSI, BEX2-DD, fringe suppression, 4 stage Peltier cooling	DW936N-BEX2-DD	77,625 €
iKon 2Kx2K BSI, BEX2-DD, fringe suppression, 5 stage Peltier cooling	DZ936N-BEX2-DD	81,450 €
Ixon Ultra 888 1Kx1K BSI EMCCD	DU888U3-CSO-#BV	38,366 €
Nüvü h-nü 1024, 1Kx1K BSI EMCCD	-	US$ 59,500
Teledyne / Princeton Instrument COSMOS-10	-	US$ 80,000

Sample of QHY cameras

Model	**QHY600**	**QHY294M PRo**	**QHY268PRO**	**QHY4040PRO**	**QHY2020**	**QHY1920**	**QHY42PRO**
Price	$4600 - $5k	$1295	-	-	-	-	-
Detector CMOS	Sony IMX455	Sony IMX492	Sony IMX571	Gpixel Gense4040	Gpixel Gense2020	-	Gpixel GSENSE400
Pixel Size	3.76 x 3.76um	4.63um x 4.63um	3.76um x 3.76um	9.0um x 9.0um	6.5um x 6.5um	12um x 12um	11um x 11um
Pixel Area	9576 x 6388	4164 x 2796	6280 x 4210	4096 x 4096	2048 x 2048	1920 x 1200	2048 x 2048
FOV	36mm x 24mm	19mm x 13mm	23.6mm x 16mm	37mm x 37mm	13.3mm x 13.3mm	23mm x 14.4mm	22.5mm x 22.5mm
RON[1]	1.0e- to 3.7e-	1.6 to 1.2e- (6.9e- to 5.2e-)	1.1e- to 3.5e- (5.3e- to 7.4e-)	Typical 2.3e-	1.6e-	1.1e-	1.7e-
Dark Current	0.0022e/p/s -20C, 0.0046e/p/s -10C	0.002 e/p/s -20C, 0.005 e/p/s -10C	0.0005 e/p/s -20C, 0.001 e/p/s -10C	0.05e/pixel/sec @ -15C	TBD	-	TBD
Exp. Time Range	40us – 3600sec	60us - 3600sec	30us - 3600sec	20us – 600sec	20us – 300sec	15us – 300sec	20us - 300sec
Interface	USB3.0	USB3.0	USB3.0	USB3.0 + 2*10Gbps Fiber	USB3.0	USB3.0	USB3.0
A/D							Dual 12-bit A/D

[1] RON depends on gain