Electron Multiplying CCD Camera Performance Tests

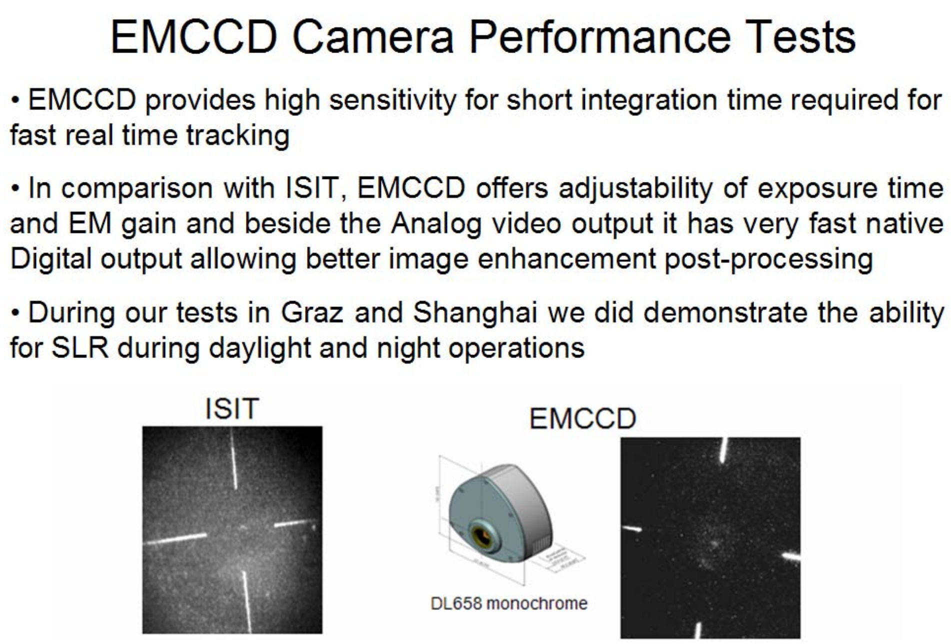
D. Lewová[1], M. Němec[1], I. Procházka[1], K. Hamal[1],G. Kirchner[2], F. Koidl[2], D. Kucharski[3], Yang Fumin[4]

1. Czech Technical University in Prague, Brehova 7, 115 19 Prague 1, Czech Republic,
2. Graz Observatory, Austrian Academy of Sciences, Austria
3. Space Research Centre, Polish Academy of Sciences, Poland
4. Shanghai Observatory, Chinese Academy of Science, China

Contact: lew.dana@gmail.com , nemecm1@troja.fjfi.cvut.cz

Abstract

For satellite laser ranging, TV guiding is widely used to point the laser beam on the satellite. The ISIT (Intensified Silicon-Intensifier Target) camera has been applied in last years for its high sensitivity, which enabled to track all satellites of interest. However, there is a strict limitation to use it for daylight observation. The new type of CCD camera Electron Multiplying CCD (EMCCD) provides high sensitivity for short integration time required for fast real time tracking while maintaining the high ruggedness for daylight tracking. An additional internal gain reaches a factor up to 200 in comparison with regular CCD. During our tests in Graz and Shanghai, we did demonstrate the ability for satellite laser ranging during the daylight and during the night time exploiting the higher sensitivity, as well. The test results and a comparison with ISIT technology will be presented.

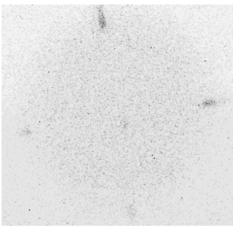


EMCCD Camera Performance Tests

EMCCD Images of GPS, Etalon 2, Glonass and Lageos 2 illuminated by Sun only

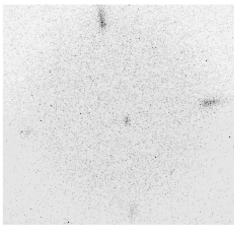
Digital output – no enhancement

(Images are captured with the same EMCCD settings and inverted)



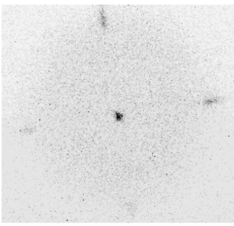
Gps BIIA-24, 0.2s, Gain 250
2006-08-25T20:07:39 UTC
Sun only, Altitude ~ 20,100 km

10x10pixels	**Object**	**Backgr.**
Standard Deviation	350,37	243,86
Mean	939,13	818,49
Maximum	2603	2263
Total Counts	375652	327396



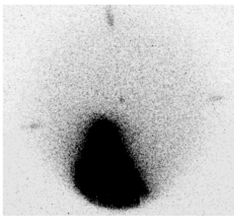
Etalon2, 0.2s, Gain 250
2006-08-25T20:39:42 UTC
Sun only, Altitude ~ 19,100 km

10x10pixels	**Object**	**Backgr.**
Standard Deviation	471,25	274,1
Mean	1024,35	820,27
Maximum	4129	2119
Total Counts	375652	328106



G87- Glonass, 0.2s, Gain 250
2006-08-25T22:53:02 UTC
Sun only, Altitude ~ 19,100 km

10x10pixels	**Object**	**Backgr.**
Standard Deviation	1508,39	310,89
Mean	1870,07	869,8
Maximum	10835	2235
Total Counts	748028	347920



Lageos2, 0.2s, Gain 250
2006-08-25T19:27:57 UTC
Sun only (Laser outside the object)
Altitude ~ 5625 km

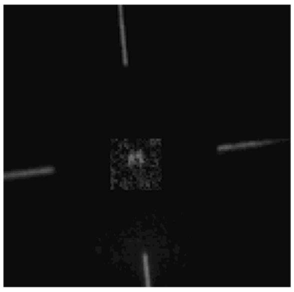
10x10pixels	**Object**	**Backgr.**
St. Deviation	629,62	503,65
Mean	1713,28	1495,48
Maximum	4375	3389
Total Counts	685310	598194

EMCCD Camera Performance Tests

Analog video output enhancement

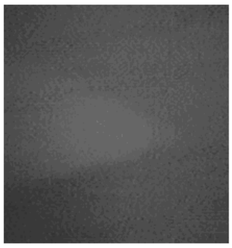
On-line video filter - Contrast enhancement
GPS 36

before

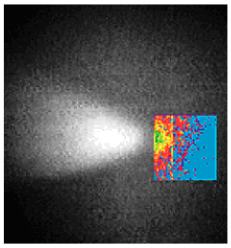


after

On-line video filter - Pseudocolor mapping



before



after

For more details see the following Poster.

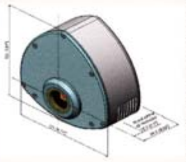
Electron Multiplying CCD Camera Performance Tests

D. Lewova, M. Němec, I. Procházka, K. Hamal (1)
G. Kirchner, F.Koidl (2)
Yang Fumin(3), D. Kucharski (4)

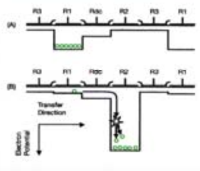
(1) Czech Technical University in Prague, Czech Republic, (2) Satellite Laser Station Graz, Austrian Academy of Sciences, Austria
(3) Chinese Academy of Sciences, Shanghai, China, (4) Space Research Centre, Polish Academy of Sciences,Poland

For satellite laser ranging, TV guiding is widely used to point the laser beam on the satellite. The ISIT (Intensified Silicon-Intensifier Target) camera has been applied in last years for its high sensitivity, which enabled to track all satellites of interest. However, there is a strict limitation to use it for daylight observation. The new type of CCD camera Electron Multiplying CCD (EMCCD) provides high sensitivity for short integration time required for fast real time tracking while maintaining the high ruggedness for daylight tracking. An additional internal gain reaches a factor up to 200 in comparison with regular CCD. During our tests in Graz and Shanghai we did demonstrate the ability for satellite laser ranging during the daylight and during the night time while exploiting the higher sensitivity , as well. The test results and a comparison with ISIT technology will be presented.

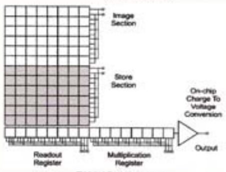
Andor Luca DL658 (monochrome)



Technology	Electron Multiplying CCD ("gain off" operable)
Active Pixels (horiz x vert)	658 x 496
Pixel Size (horiz x vert; μm)	10 x 10
Image Area (mm)	6.58 x 4.96
Sensor	TIL
Peak Q.E.	52%
Minimum Oper. Temp (°C)	-20
Active Area Pixel Well Depth(e- typical)	25,000
Conventional Register Pixel Well Depth (e- typical)	100,000
Pixel Readout Rate	12.5
Read Noise (e-)	25
Min Operating Temp (°C)	-20
Digitization	14-bit
Max. Frame rate	30 full frames/sec
PC Interface	USB 2.0 only
Price	$8850 / €7500
Software	Solis (Not Recommended) $1500 / €1400



Gain register operation



EMCCD structure

EMCCD Camera Tests

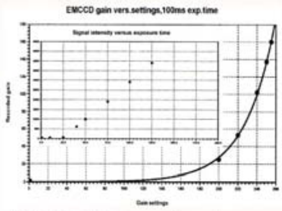
Shanghai Observatory

Graz Observatory

Test conditions:

optics	Canon lens TV-16, 1:1.4, f=50 mm, C-mount
optics settings	f/D = 22, additional ND filters 12 x each, 3 pieces
signal source	red LED, 7m distance, dark room
software	ANDOR Solis for imaging, ver. 4.3.0.0
PC notebook	UMAX Vision Book 632LX, Celeron D, 2.5GHz, 512 MB,USB2.0

EMCCD and ISIT, Graz, 2006



EMCCD Gain experiment :

- green LED
- additional 2 ND filters inserted into optical path
- exposure time set to 100 ms
- the "EMDAC setting" set to values in the range of 1 to 255

Exposure time linearity:

- the gain setting =1 (no EM additional gain)
- one ND filter inserted into optical path
- the image intensity evaluated as a function of image exposure time (linear dependence expected)
- the gain increases with exposure time starting at 1 ms exposures
- the gain increase is linear only for exposure times >= 25 ms !

ISIT vs. EMCCD Comparison

GPS-36 25.8.2006 22:08 Local time

Satellite object max/background level : 1,3

ISIT
only night observation
high FPS (30)

Satellite object max/background level : 3

EMCCD
Negs.:
night + day observing
up to 30 FPS
only 5 FPS
(for the same results)
EM ageing / anti-ageing
Pros.:
lower sensitivity
lower noise (EM gain on)
adjustability of exposure time and EM gain

Gps BIIA-24, 0.2s, Gain 250
2006-08-25T20:07:39 UTC
Sun only, Altitude ~ 20,100 km

10x10pixels	Object	Backgr.
Standard Deviation	350,37	243,86
Mean	939,13	818,49
Maximum	2603	2263
Total Counts	375652	327396

Etalon2 0.2s, Gain 250
2006-08-25T20:39:42 UTC
Sun only, Altitude ~ 19,100 km

10x10pixels	Object	Backgr.
Standard Deviation	471,25	274,1
Mean	1024,35	820,27
Maximum	4129	2119
Total Counts	409740	328106

G87- Glonass, 0.2s, Gain 250
2006-08-25T22:53:02 UTC
Sun only, Altitude ~ 19,100 km

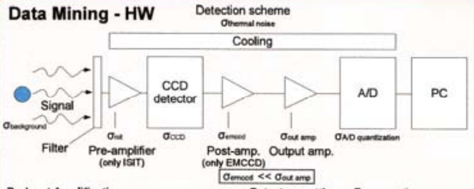
10x10pixels	Object	Backgr.
Standard Deviation	1508,39	310,89
Mean	1870,07	869,8
Maximum	10835	2235
Total Counts	748028	347920

Lageos2, 0.2s, Gain 250
2006-08-25T19:27:57 UTC
Sun only (Laser outside),
Altitude ~ 5625 km

10x10pixels	Object	Backgr.
St. Deviation	629,62	503,65
Mean	1713,28	1495,48
Maximum	4375	3389
Total Counts	685310	598194

Data Mining - HW

Detection scheme

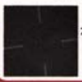


Pre/post Amplification
- decreasing readout noises levels (Low-noise internal amplification of signal before high-noise external output amplification)
- Increasing influence of S/N

Detectors settings - Exposure time
- Internal binning
- Post/pre amplifications

Filtration - interested wave-lengths pass only
- background influence(level) elimination

Cooling - Decreasing thermal noises



GPS BIIA-24 on-line filter
2006-08-25T22:09:39 UTC
Averaging - 25 frames
Selected area – contrast enhanced

Adjusted Contrast and brightness in the selected area

PC – Software methods

Methods for S/N increasing :
SW binning – 3D (integration in time + 2D in space)
SW Exposure - summation of frames
Averaging (mean; time)
Flatfield – Intensity levels calibration
Background Reduction
- Bcg. Frame subtraction(frame without object)
- AVG Filter } Artificial Background estimation and subtraction
- Median Filter

Original image

Estimated background by median filter

Estimated Background Image subtraction

Visualization

Methods for better visibility of objects in real time :

Levels selection - Image histogram
Adjusting of contrast and brightness
Gama correction
Color inverting
Pseudo-color mapping

Pseudo color mapping

40W, 2J laser Moon shooting

Shanghai observatory

Replacing dichroic mirror

During tests in Graz and Shanghai we did demonstrate the ability for satellite laser ranging during the daylight and during the night time while exploiting the higher sensitivity

15th International Workshop on Laser Ranging, Canberra, Australia,15-20 October, 2006