Comparison of low-light cameras - First results

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Outline

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- Experimental Set up
- LED Characterization
- Measurements
  - ICCD Measurements @ 500 nm
  - Average Photonflux per Pixel
  - First Look at the ROI
  - Comparison: 0.05 ms light pulse ICCD with 0.5 ms light pulse sCmos & emCCD (@ 500 nm)
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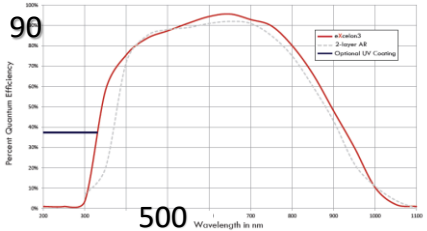
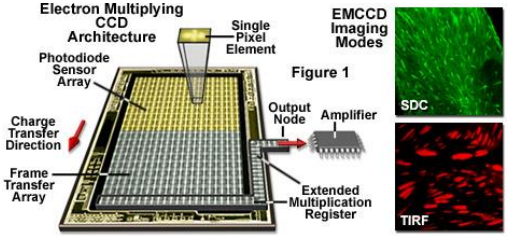
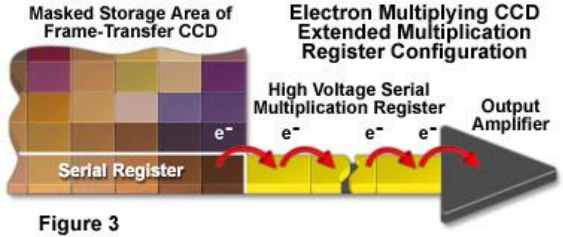
Overview: emCCD, sCMOS & ICCD

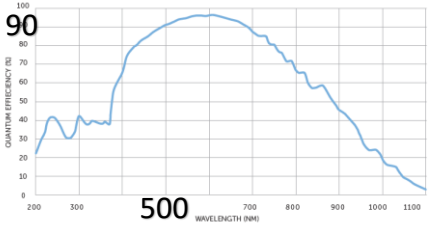
emCCD [1]

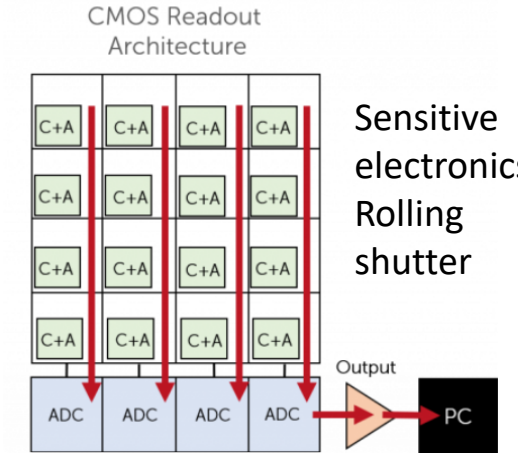






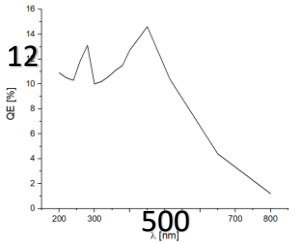
sCMOS [2]

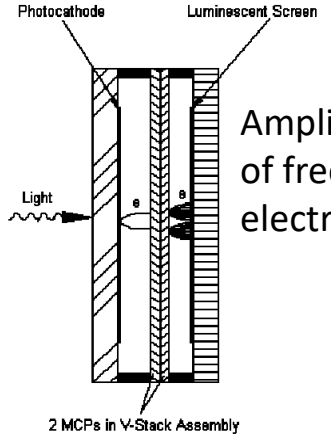




Sensitive electronics
Rolling shutter

ICCD [3]





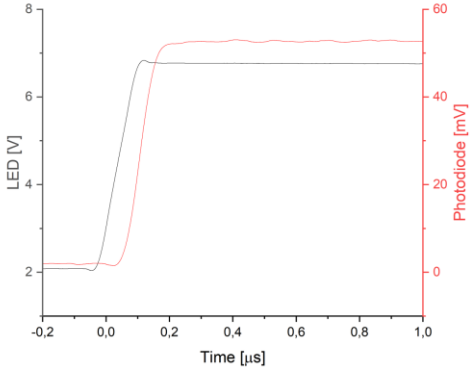
Amplification of free electrons

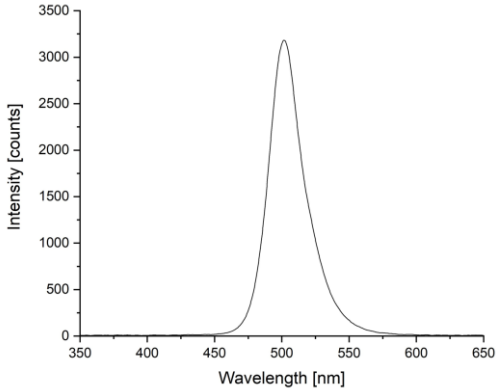
Experimental Set Up (1)

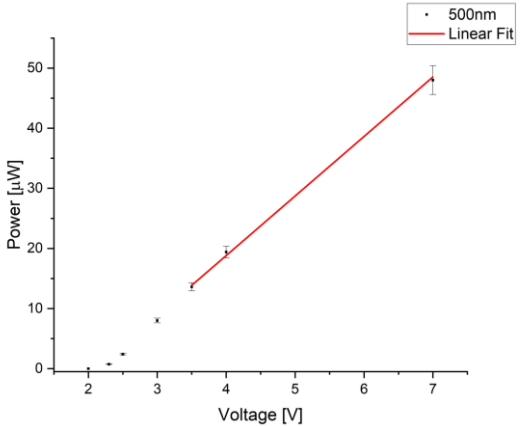
- Dark enclosure
- Blackend aluminium foil (reflectance < 5 %)
- PTFE pattern (reflectance ≈92 %)
- Neutral density filter (transmission: 27-31%)
- Distance between objective lens and screen: 87±0.5 cm
- Objective lens: f= 16 mm (FL-CC1614-2M (RICOH))

LED Characterization

- Pulsed light source (Leading edge: 100 ns; Trailing edge: 1 µs; Width: 0.5 ms- 8 ms)
- Photodiode & spectrometer measurements
- Power meter measurements: decreasing LED driving voltage







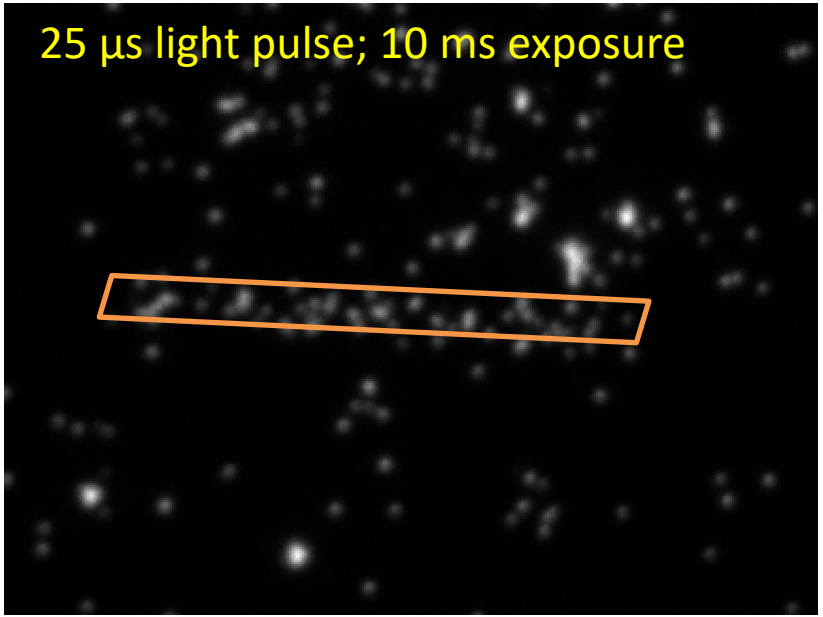
Measurements

Camera	Wavelength [nm]	Lightpulse duration [ms]	Mode	Set Exposure time [ms]
ProEM+:512B emCCD	500; 470; 430; 400; 390; 385	0.5,…,8	Full Frame in em Mode; em Gain: 1; 10; 100; 1000	0.7; 1; 10; 25; 50; 100; 1000; 5000
Kinetix 22 sCMOS			Sub-Electron; Sensitivity; Dynamic Range	10; 20; 20.3
Pco.edge 4.2bi sCMOS				34; 5000
ICCD	500	0.002,…,0.5		10; 5000

Comment: The actual exposure time is not necessarily equal to the set one for ProEM B+512 and Kinetix 22

ICCD Measurements @ 500 nm

- Same camera as at CERN BGS-test bench
- Parameters: MCP Gain Voltage: 3.7 V
- Light pulse: 25 µs
- Counted Photons: 46 $\pm$ 5
- QE photocathode $\approx$ (11.3 $\pm$ 1)%
- MCP efficiency $\approx$ (80 $\pm$ 10) %
- ROI: 10176 $\pm$1120 Photons in 0.5 ms



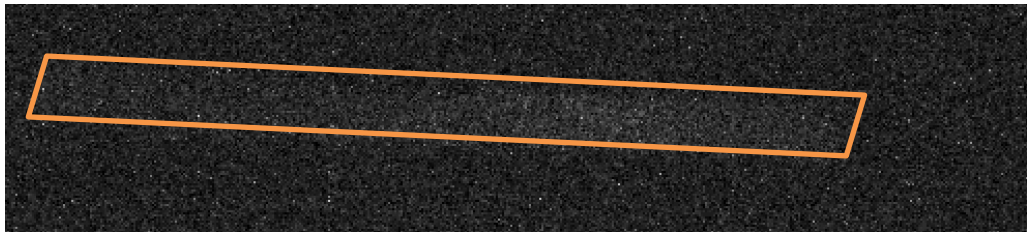
Average Photon Flux per Pixel

Camera	Quantum Efficiency @ 500 nm [%]	Pixel in ROI	Estimated Average Photons per pixel on Sensor in ROI, 0.5 ms light pulse	Electrons/ADU	Average Photons per pixel on Sensor in ROI detected
Pco.edge 4.2 bi	89	11949	0.758± 0.033	0.7	0.637
Kinetix 22	92	11949	0.783±0.033	Sub-Electron: 0.015 Sensitivity: 0.282 Dynamic Range: 0.228	0.795 0.856 0.759
ProEM+:512B	88	1305	6.86±0.98	5.12 (electron multiplication= 1)*	30 (not expected, to be investigated)

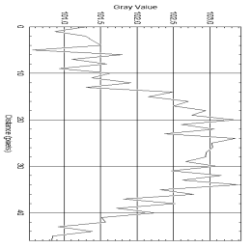
ADU= Analog to Digital Unit
*other values possible

sCMOS: estimated photons per pixel ≈ dected photons per pixel

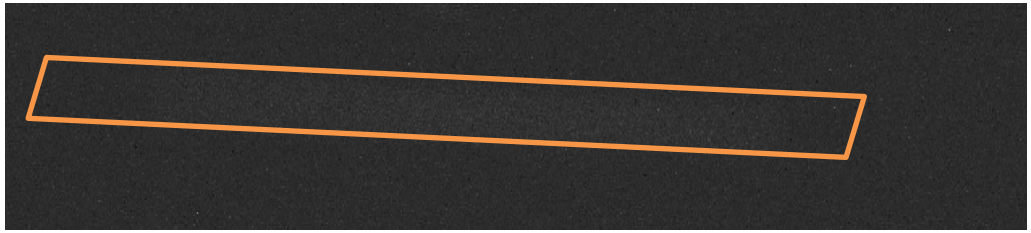
First look at the ROI (1)



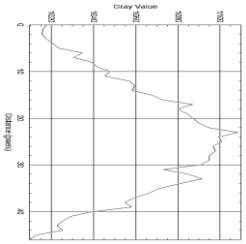
Gray values: 90-120



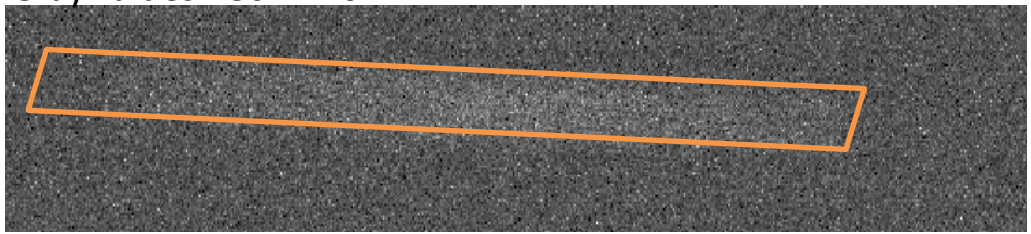
Pco.edge 4.2 bi
9 ms full image exposure time;
0.5 ms light pulse



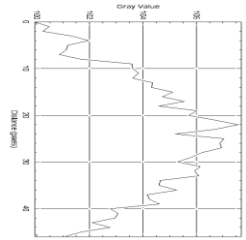
Gray values:780-1440



Kinetix 22 Sub-Electron Mode
10 ms full image exposure time;
0.5 ms light pulse

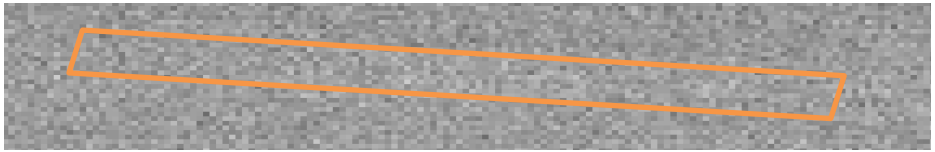


Gray values: 80-140

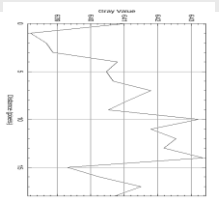


Kinetix 22 Sensitivity Mode
9 ms full image exposure time
0.5 ms light pulse

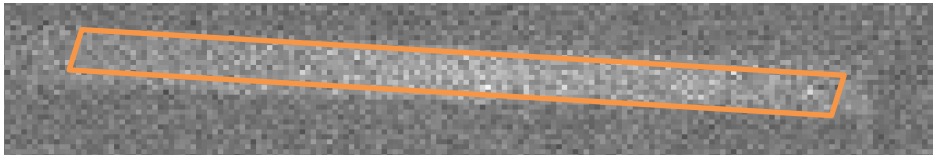
First Look at the ROI (2)



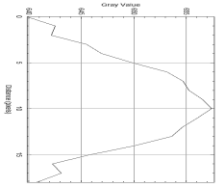
Gain 1



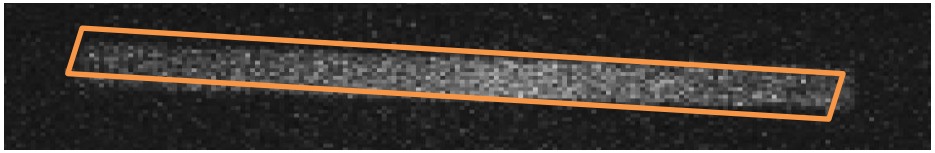
Gray values: 570-670



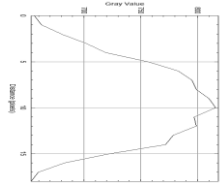
Gain 10



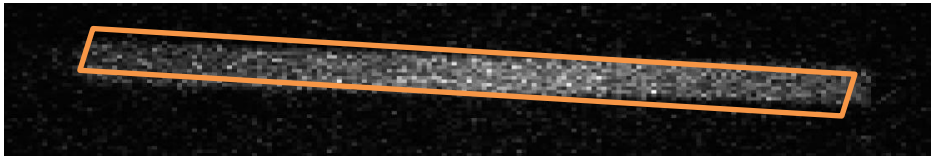
Gray values: 570-710



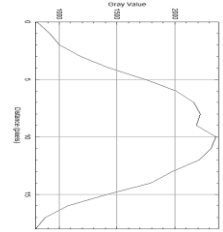
Gain 100



Gray values: 570-1250



Gain 1000

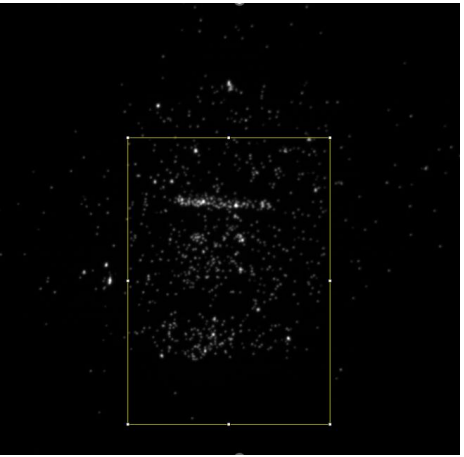


Gray values: 570-5600

emCCD ProEM+:512B
Set exposure time: 10 ms
Light pulse: 0.5 ms

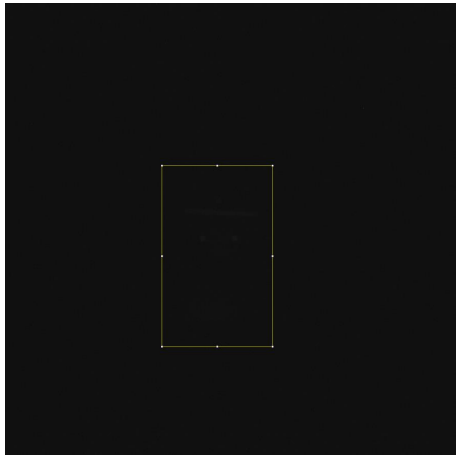
Comparison: 0.05 ms light pulse ICCD with 0.5 ms light pulse sCmos & emCCD (@ 500 nm)

ICCD
0.05 ms light pulse



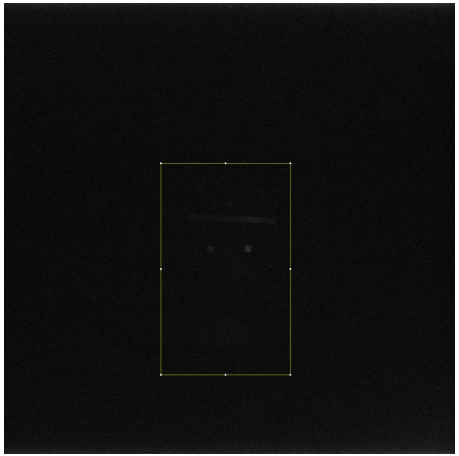
Contrast≈ 0.64

Kinetix 22 Sensitivity
Mode 0.5 ms light pulse



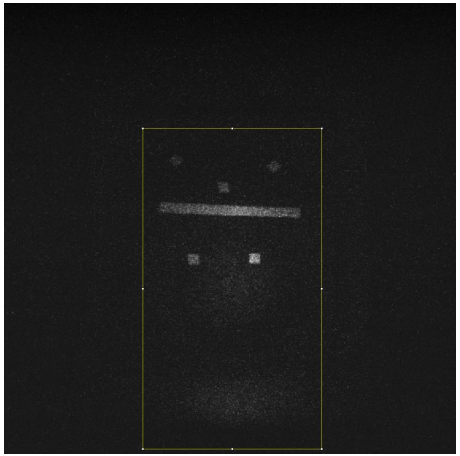
Contrast≈ 0.02

Pco.edge 4.2bi
0.5 ms light pulse



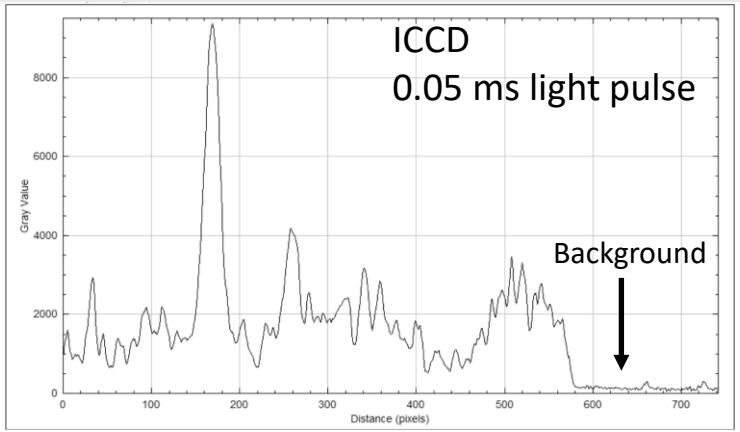
Contrast≈ 0.009

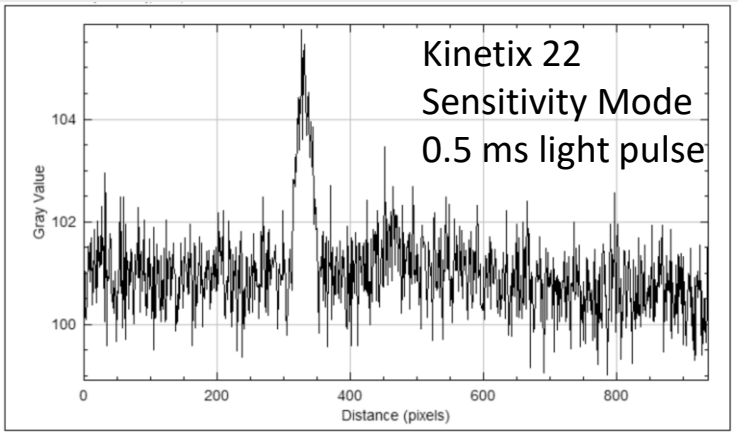
emCCD gain 100
0.5 ms light pulse

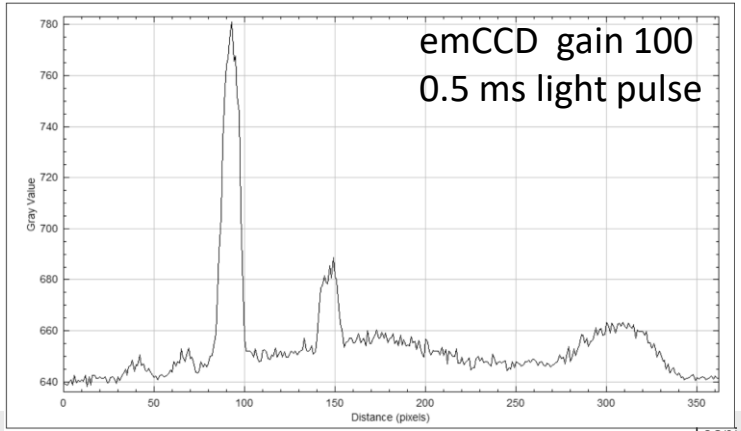


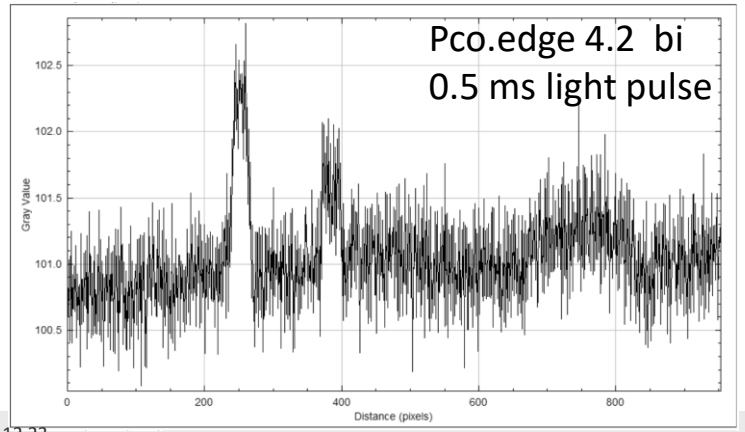
Contrast≈ 0.1

Projections @500 nm









Summary and Outlook

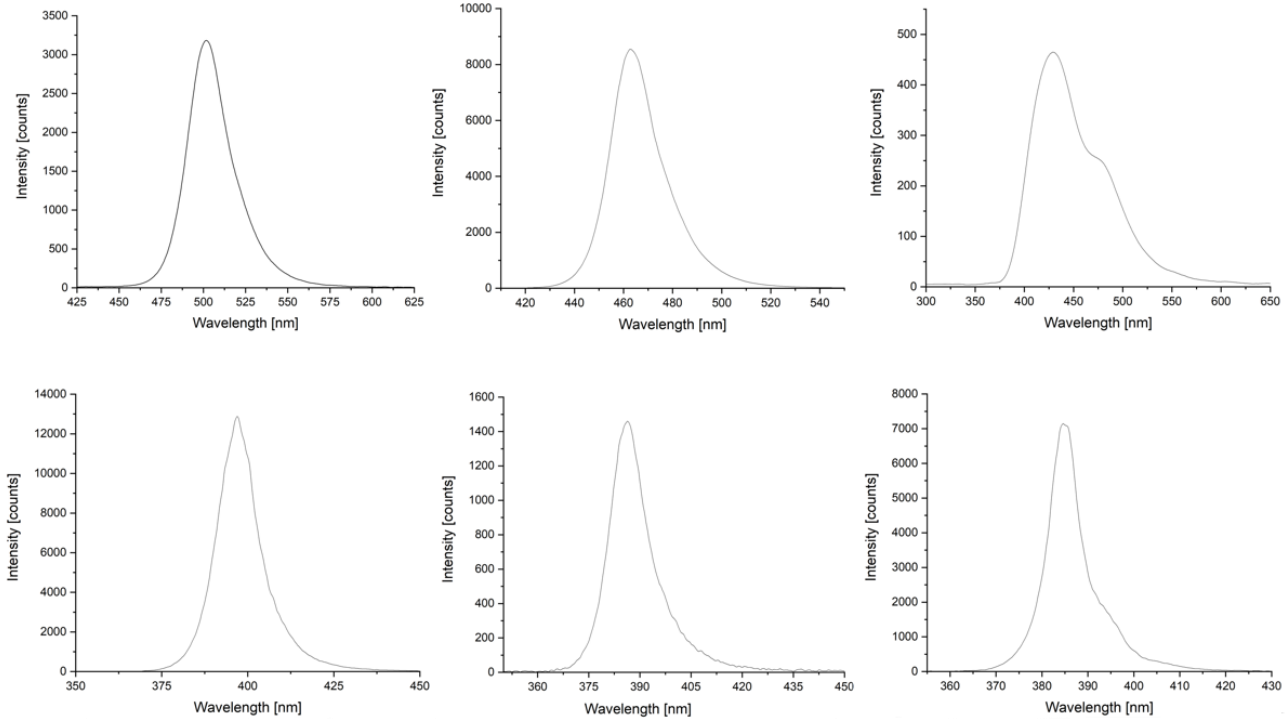
- Experimental set up was build and LEDs were characterized
- emCCD and sCMOS Measurements are finished
- ICCD: Estimation of the average photons per pixel in a ROI for 0.5 ms light pulse at 500 nm
- Determination of the detected average photons in the ROI on the sensor for 0.5 ms light pulse and 500 nm for the sCMOS cameras in different modes and the emCCD camera
- ICCD: 0.05 ms light pulse: projection visible
- sCMOS & emCCD: projection from 0.5 ms light pulse duration on visible
- Next steps: complete the measurements for the ICCD; analyse the data for all measurements and compare the cameras.

References

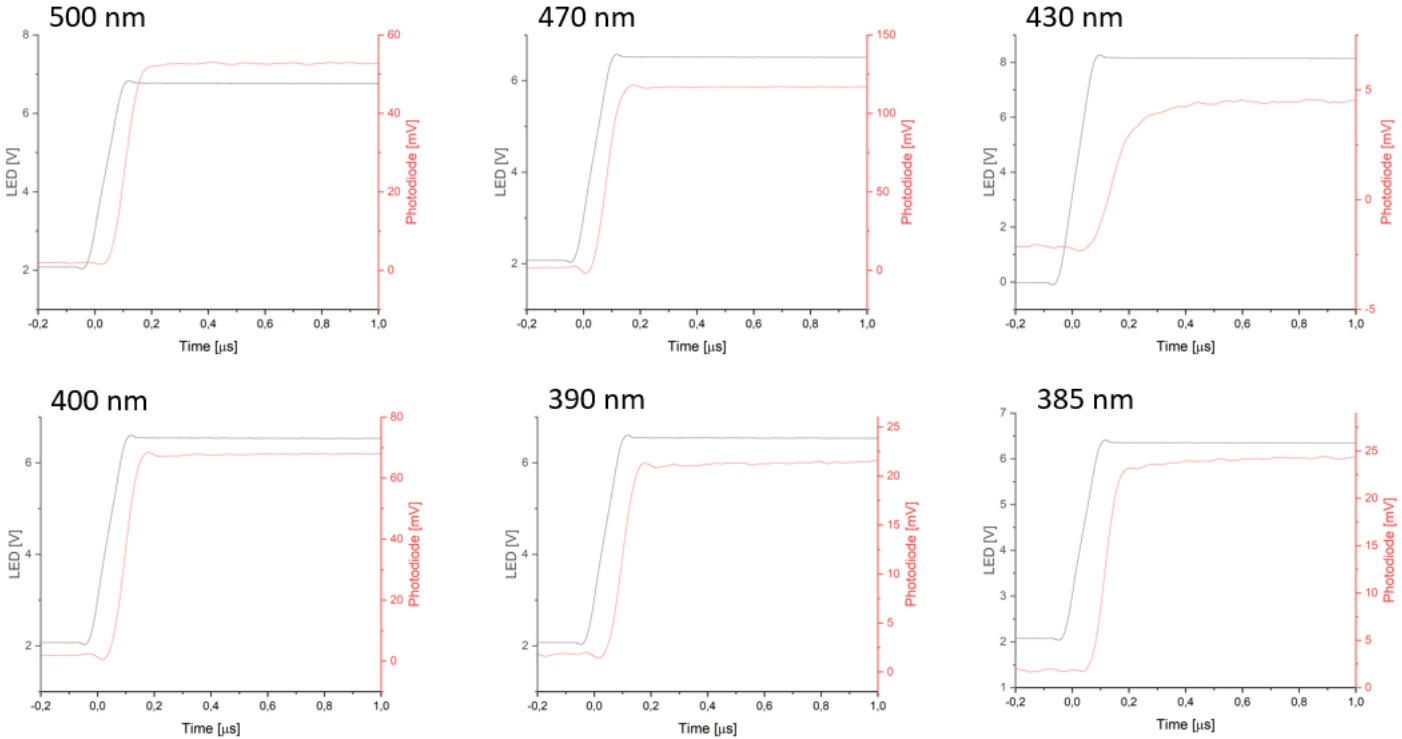
- [1] https://hamamatsu.magnet.fsu.edu/articles/emccds.html (10.12.23)
- [2] https://www.princetoninstruments.com/learn/camera-fundamentals/scmos-the-basics (30.11.23)
- [3] High Performance Image Intensifiers; booklet; PROXITRONIC Detector Systems GmbH; 27.07.2011
- [4] Pco.edge 4.2 bi Data sheet; Excelitas PCO GmbH; v1.08
- [5] Kinetix 22 Data sheet; Teledyne Photometrics; Rev A3-05112021
- [6] ProEM+ System Manual; Princeton Instruments; Version 1B; 07.01.2012

Thank you!

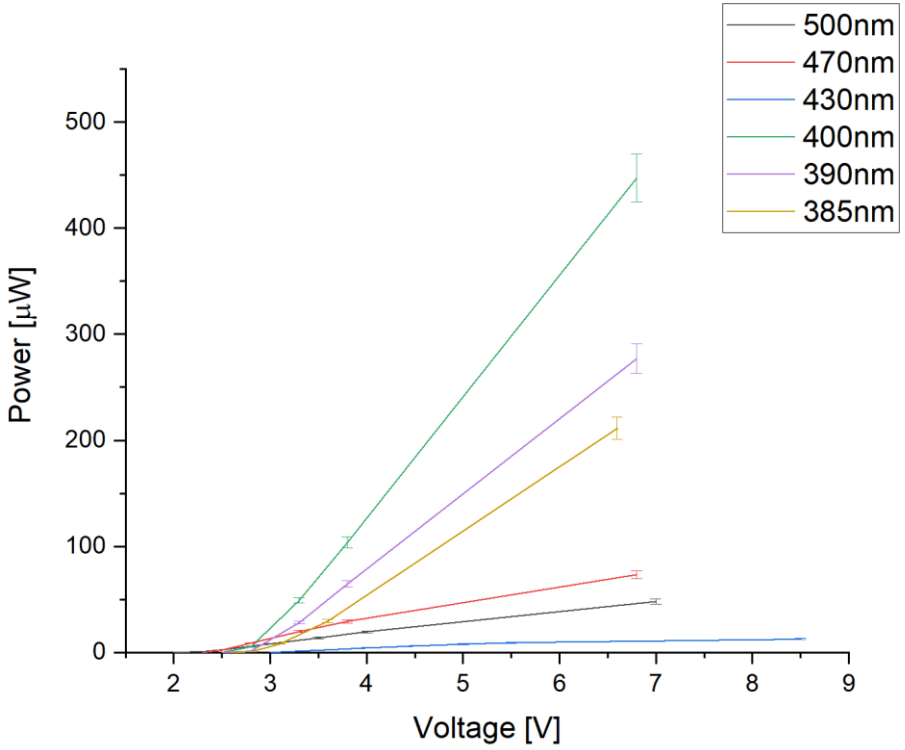
Backup: Spectrometer Measurements



Backup: Photodiode Measurements



Backup: Power meter Measurements



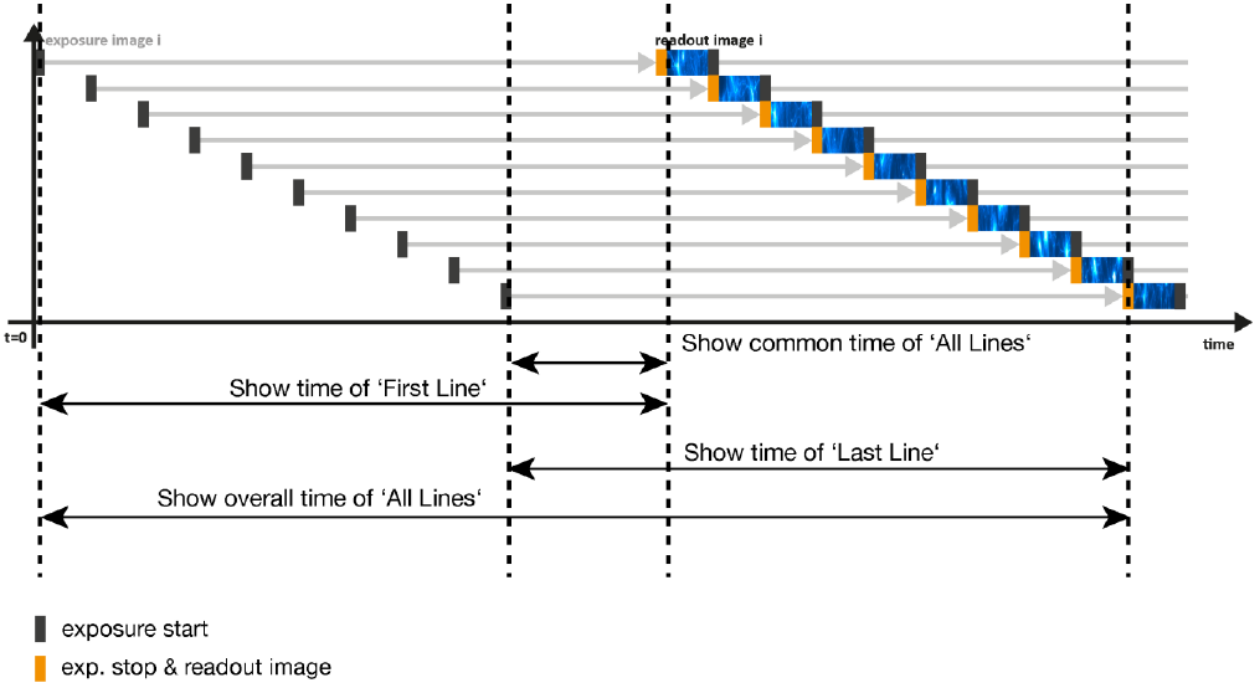
Backup: Used Devices and Materials

Device	Producer	Model/ Part number
Function generator	Tektronix	AFG 3102
LED (385 nm)	Lumex	VAOL-5GUV8T4
LED (390 nm)	Bivar	UV5T2-390-30
LED (400 nm)	Bivar	UV5T2-400-30
LED (430 nm)	Lumex	SSL-LX5093SBC/A
LED (470 nm)	Liteon	LTL1CHTBK4
LED (500 nm)	Bivar	3UTC-F
Oscilloscope	Tektronix	DPO 3034
Photodiode	Osram	BPX 65
Power meter	Gentec-EO Inc.	MAESTRO
Spectrometer	Ocean Optics	HR4000
Transimpedance Amplifier	Femto	DHPCA 100

Camera	Model	Producer
emCCD	ProEM+:512B	Teledyne Princeton Instruments
sCMOS	Kinetix 22	Teledyne Photometrics
sCMOS	pco.egde 4.2 bi	Excelitas
CMOS (for Image Intensifier)	acA1920-40gm	Basler
Image Intensifier	BV 2581 TX-V 100 N	ProxiVision

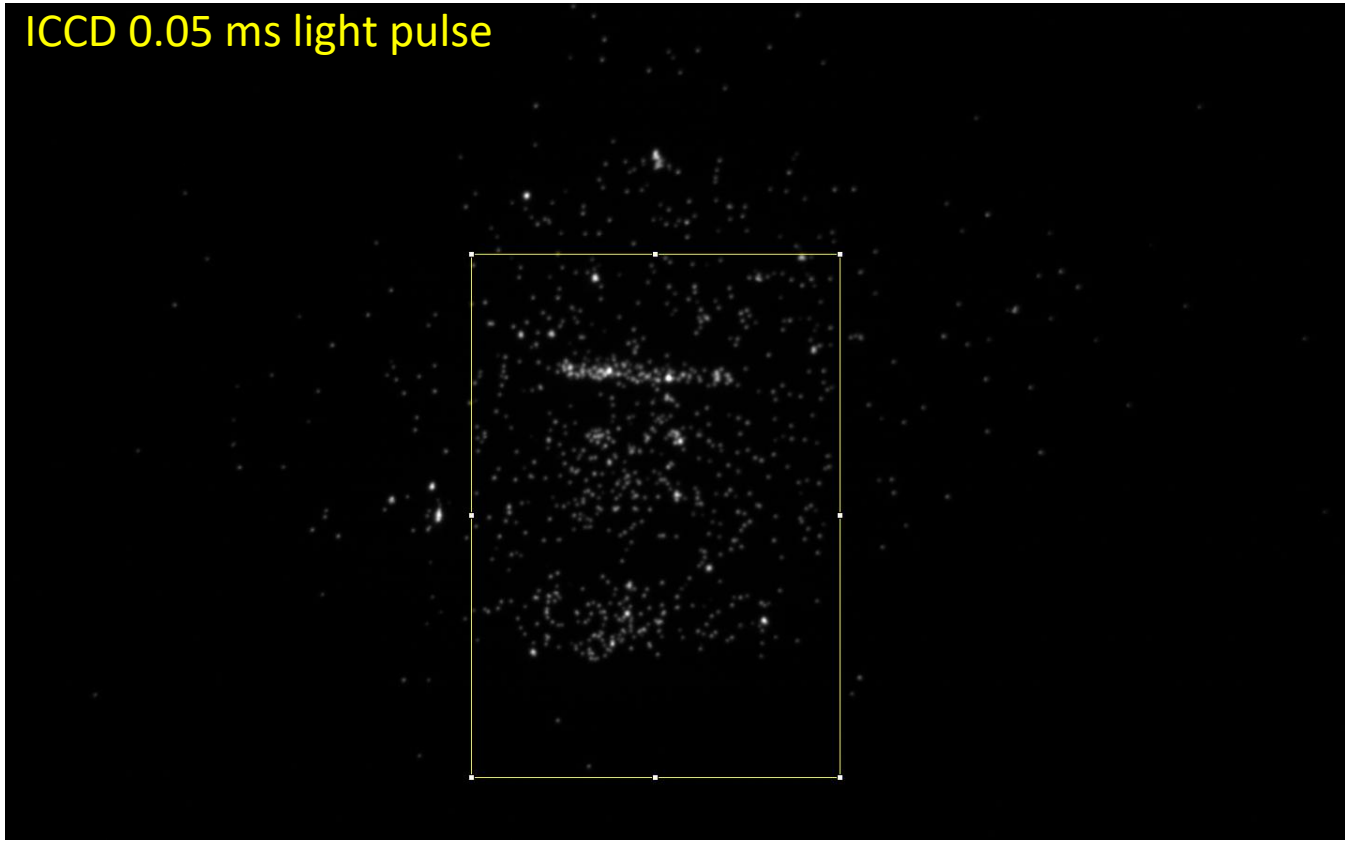
Item	Producer	Description
Black aluminium foil	Thorlabs	BKF12
Black aluminium foil tape	Thorlabs	T205-1.0
Neutral density filter	Thorlabs	UVFS Refelctive ND Filter; OD=0,6
PTFE sheet	Thorlabs	PMR10P1

Backup: Rolling Shutter



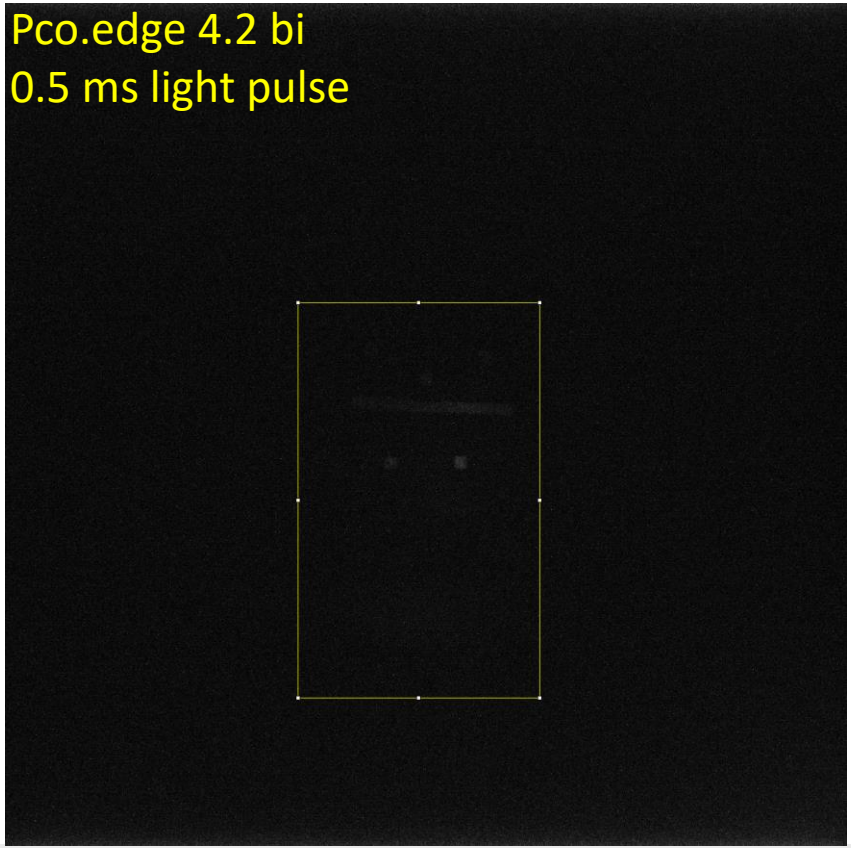
Taken from [4]

Back up: ICCD @ 500 nm



Backup: Kinetix 22 @ 500 nm

Backup: Pco.edge 4.2 bi @ 500 nm



Backup: ProEM+:512B @ 500 nm