The new CMOS Tracking Camera used at the Zimmerwald observatory

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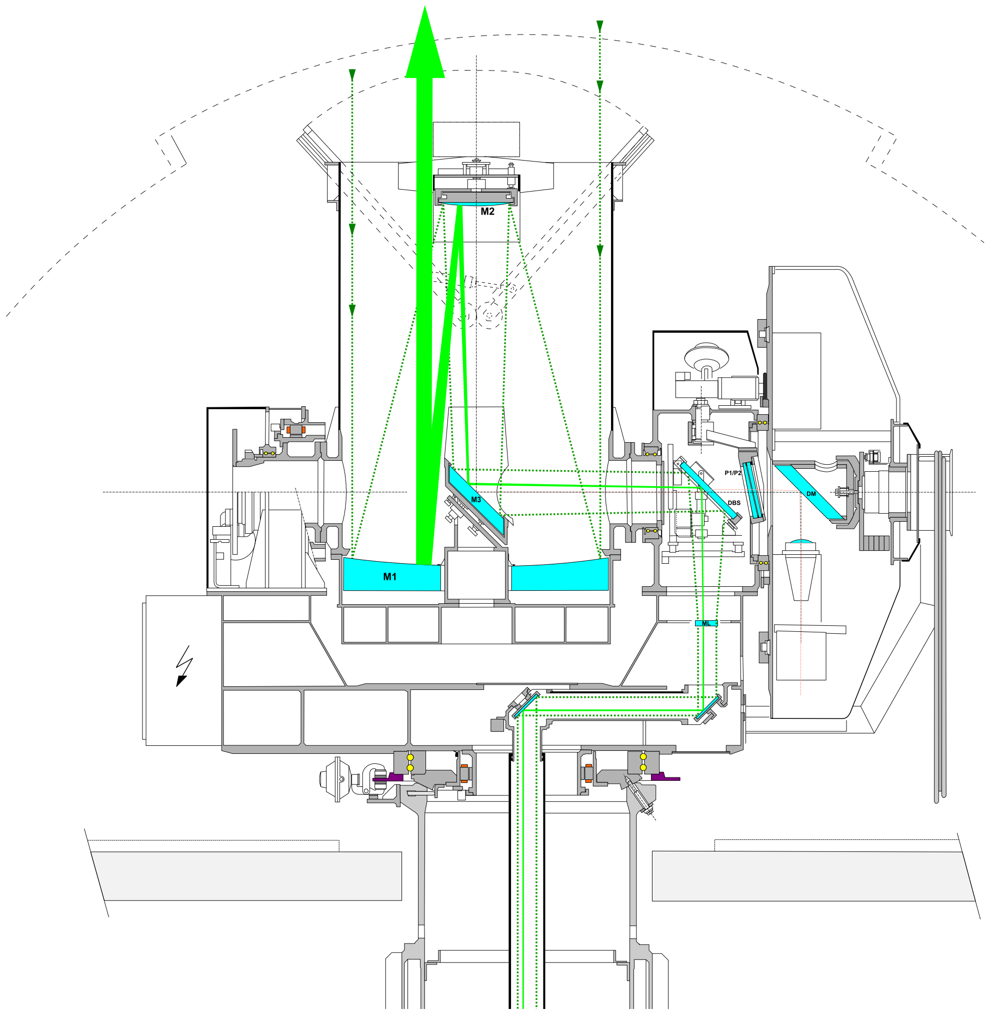
Tracking Cameras

- During the last years the use of tracking cameras for SLR observations became less important due to the high accuracy of the predicted orbits.
- Upcoming new targets like satellites in eccentric orbits and space debris objects, however, require tracking cameras again.
- Since a few months the interline CCD camera was replaced at the Zimmerwald Observatory with a so called scientific CMOS camera. This technology promises a better performance for this application than all kind of CCD cameras.
- After the comparison of the different technologies the focus will be on the integration in the Zimmerwald SLR system.

Zimmerwald Observatory

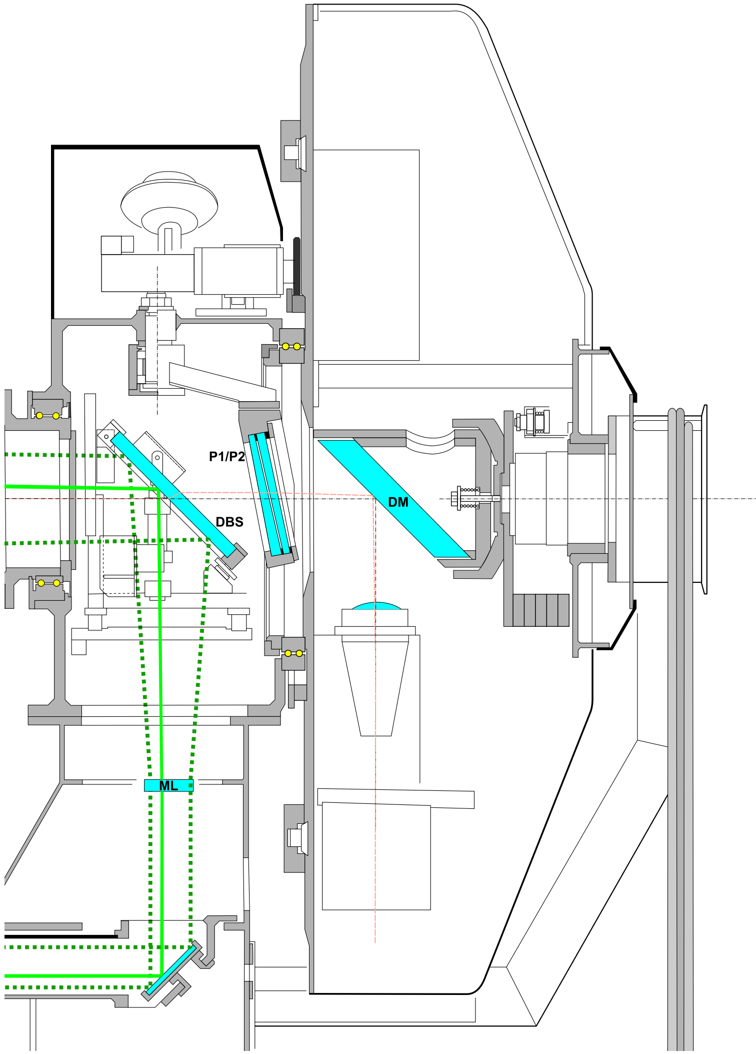
ZIMLAT – Zimmerwald Laser and Astronometry Telescope



- 1-m Ritchey Chrétien
- Altazimuth mount
- Derotator platform
- Dual use
  - SLR
  - Optical Obs.

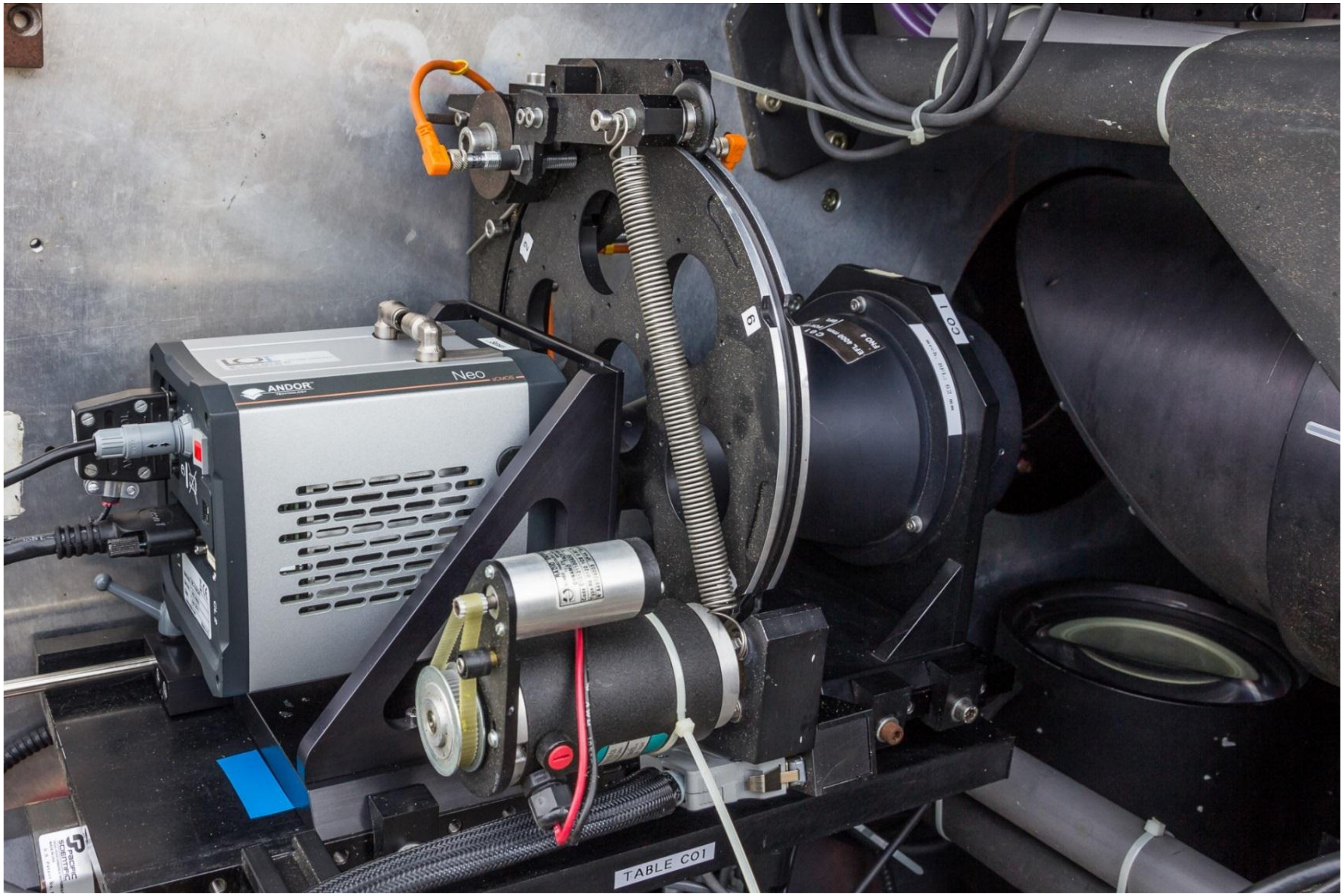
- Nd:YAG Laser
- 1064 nm / 532 nm
- 90 – 110 Hz
- 58 ps Pulselength
- 9 mJ @ 532 nm

Derotator Platform

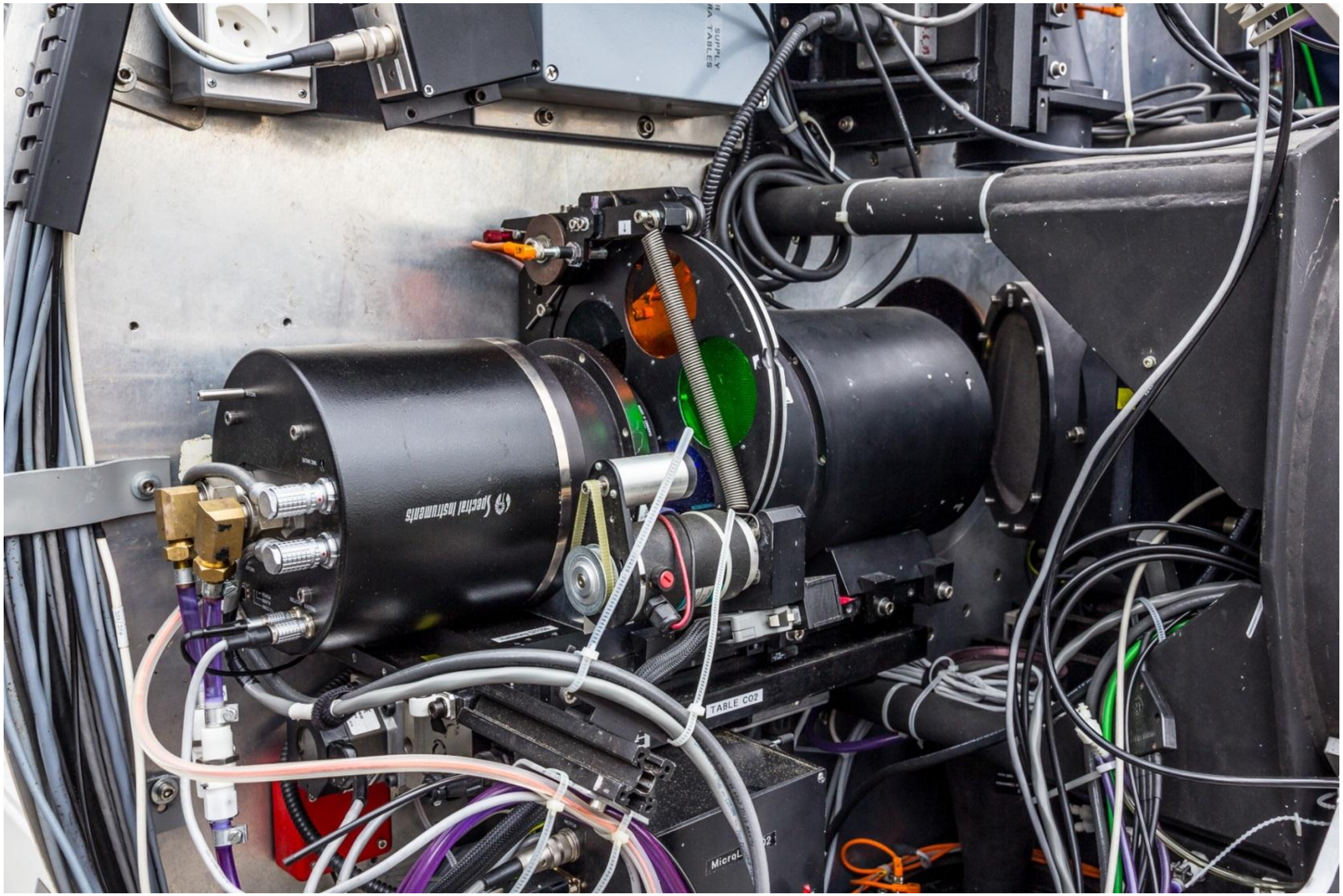


- Dichroic Mirror (DBS) allows for the use of tracking cameras simultaneously with SLR observations
- Derotator Mirror (DM) allows for the use of 4 Corrector Lenses and cameras.
- Focal length varies between 1 m, 4m and 8 m.
- 2 Trackingcameras
    - sCMOS: ≈10′ FOV
    - CCD: ≈30′ FOV

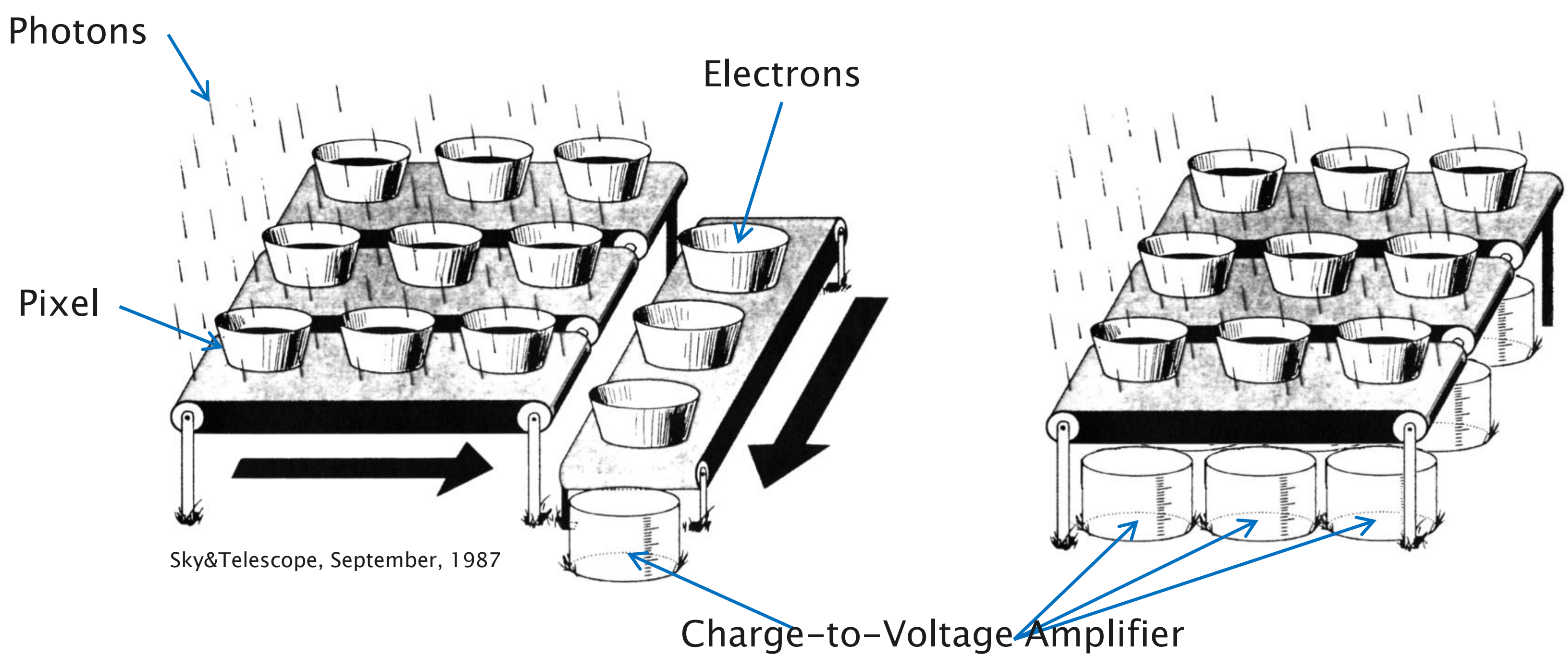
ANDOR NEO sCMOS Camera



SPECTRAL INSTRUMENTS CCD Camera



Full-frame CCD vs. CMOS

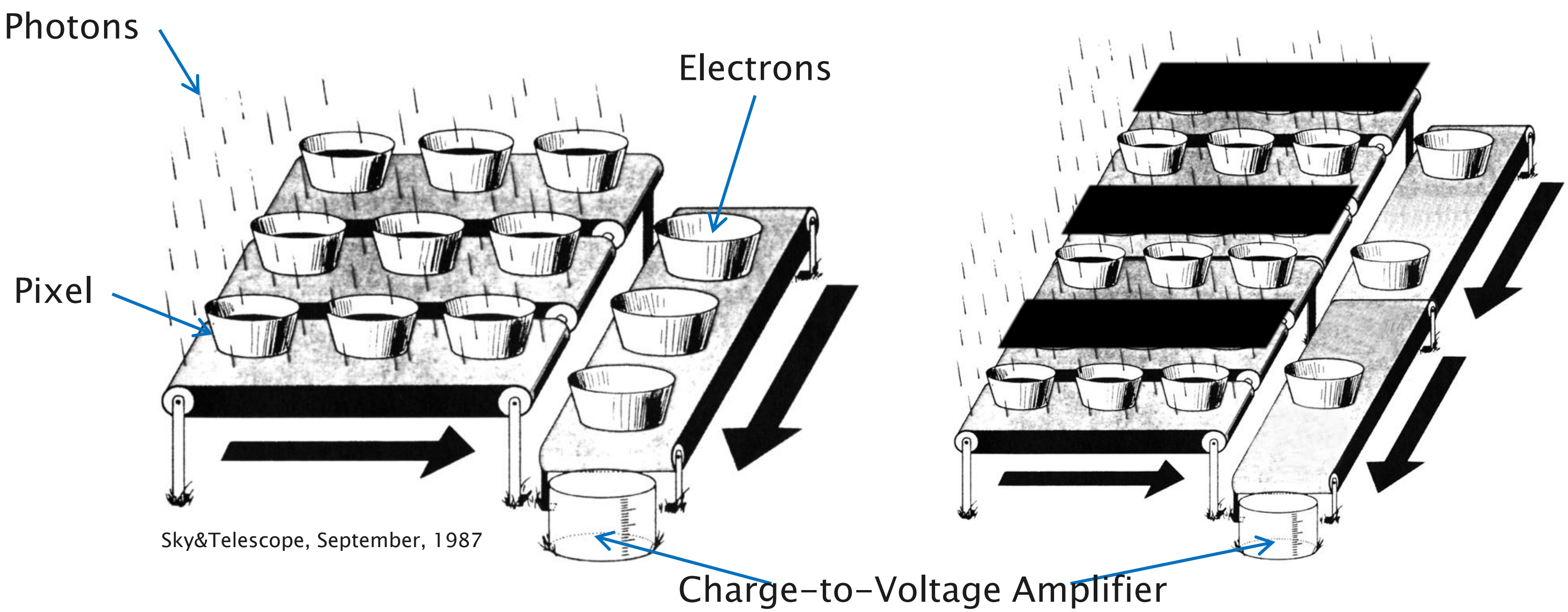


Sky&Telescope, September, 1987

At the output amplifier(s) the photoelectrons are counted.

- CCD: photoelectrons of all pixels are counted in the same amplifier
- CMOS: number of amplifiers ≙ number of pixels
  - On-chip binning and on-chip stacking for increasing the sensitivity is not possible
  - Individual readnoise for each pixel

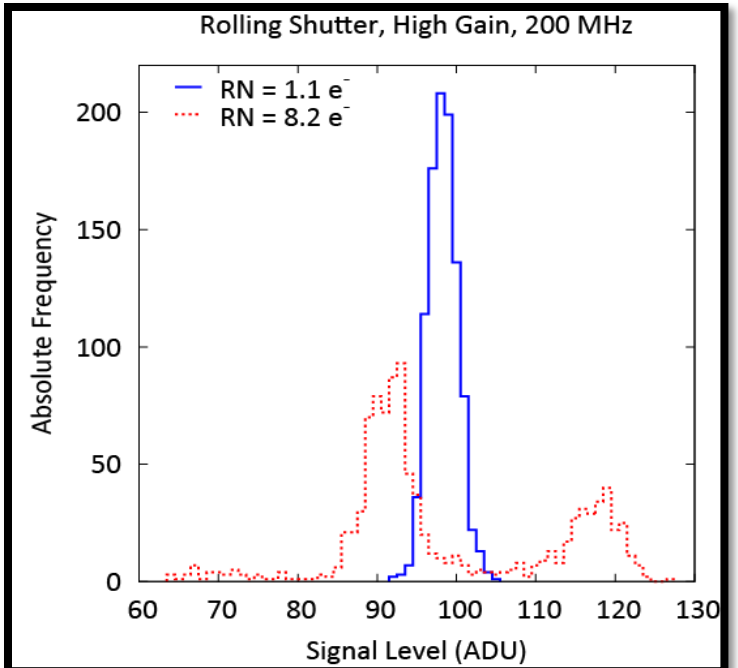
Full-frame CCD vs. Interline CCD

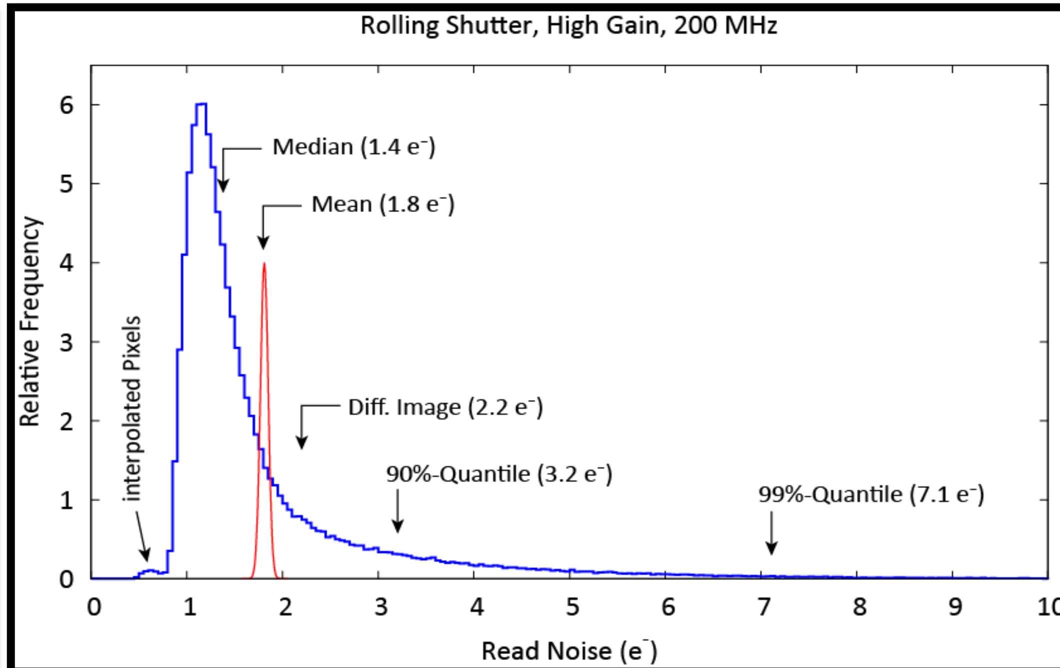


All photoelectrons are counted in the same output amplifier

- Interline CCD: every second column of the sensor is masked for storage
  - ⇒ fill factor of the image area is dropped by a factor of 2
  - ⇒ quantum efficiency is dropped by an equivalent amount
  - ⇒ microlenses on the surface direct light away from the opaque region
  - ⇒ no mechanical shutter necessary
  - ⇒ shutter times less than a microsecond are possible

Read Noise Andor NEO





Distribution of the signal levels of two individual pixels / entire sensor

- The read noise varies considerably from pixel to pixel
- Some pixels show a double peaked distribution
- No Gaussian distribution of the read noise
- Read noise specification between CCD (mean value) and CMOS (median value) not comparable!

Full-Frame CCD vs. Interline CCD vs. CMOS

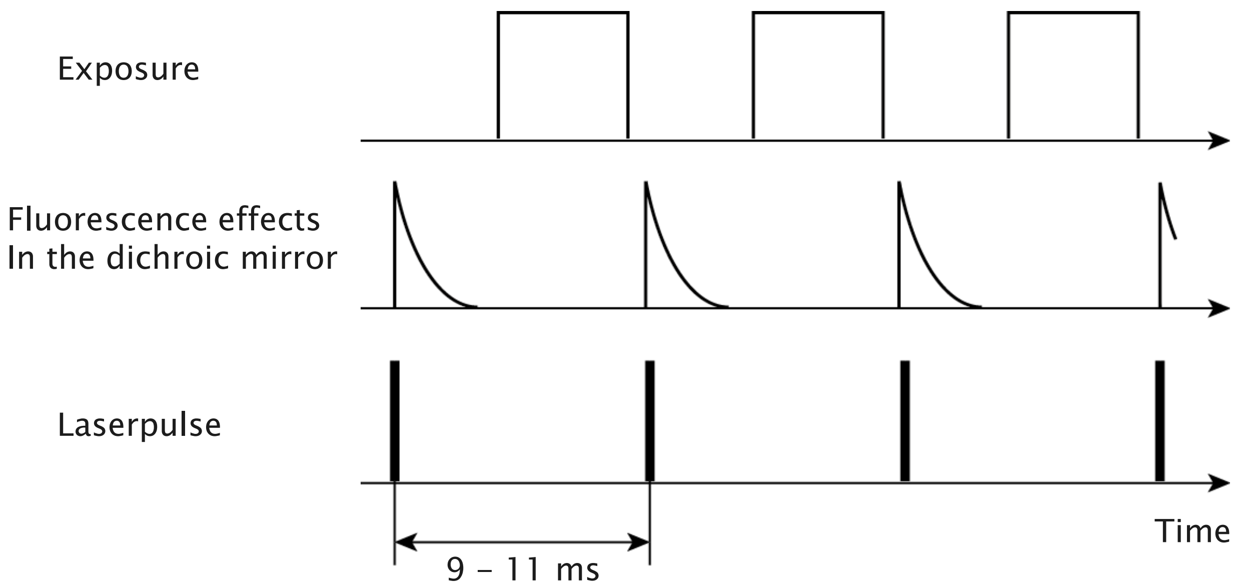
	FF-CCD	IL-CCD	CMOS
Array Size	+	–	–
QE	+	+/–	+/–
Pixel Size	+	–	–
Fast Exp.	–	+	+
Readout Time	–	+/–	+
Binning	+	+	–
Stacking	+	+	–
Readnoise	+/–	+/–	+/–
PRNU	+	+	+/–

Camera specifications

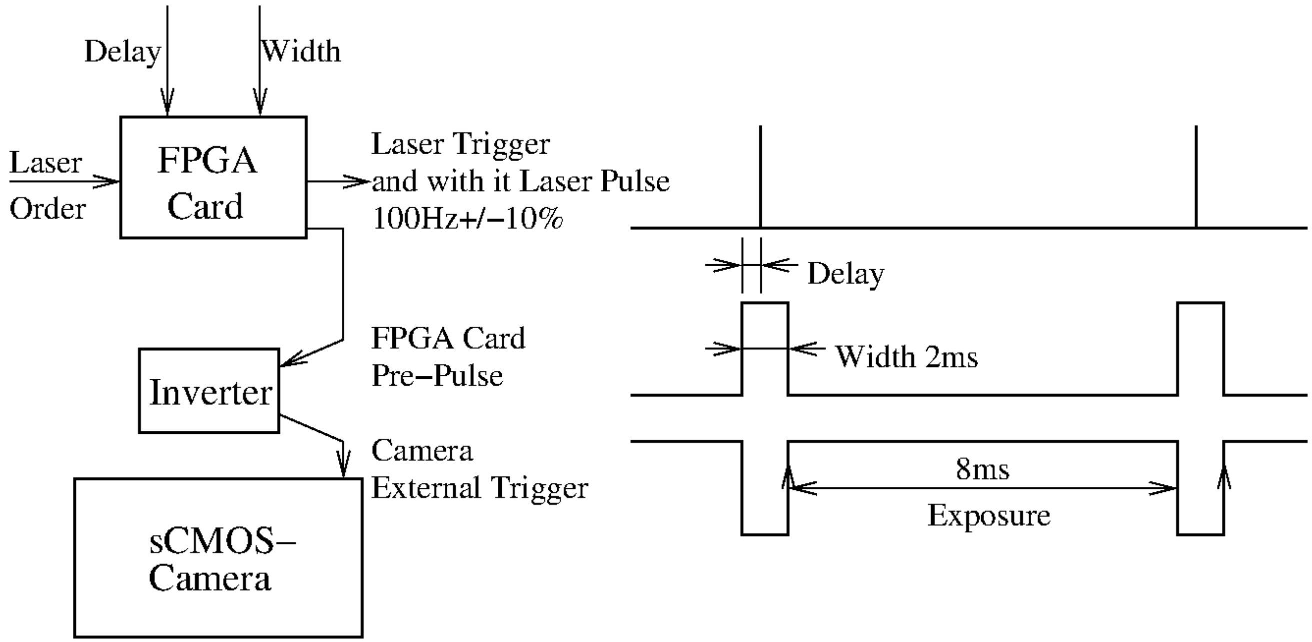
	Full-frame CCD	Interline CCD	CMOS
Factory	Spectral Instr.	PCO	Andor
Model	SI1100	Sensicam SVGA	NEO
Array Size (mm)	31 x 31	9 x 7	17 x 14
Number of Pixels	2048 x 2064	1280 x 1024	2560 x 2160
Pixel Size (µm)	15	6.7	5.5
Quantum Eff.	95 %	40 %	60 %
Full Well Cap.	150 000 e^-	25 000 e^-	30 000 e^-
Scan Rate	4 x 1 MHz	1 x 12.5 MHz	2 x 280 MHz
Readout Frequ.	1 fps	8 fps	100 fps
Readout Noise	8 e^-	8 e^-	2 e^-
Cooling	Peltier / water	Peltier / air	Peltier / water,air

Concept of the CMOS Camera Integration

- Nd:YAG Laser with a pulse rate between 90 – 110 Hz
- The sensor will be exposed between the transmitted laser pulses.
- It is not possible to make use of the full time span of about 10 ms for chip exposure due to fluorescence effects in the dichroic mirror after transmitting a laser pulse.



Realization of the CMOS Camera Integration

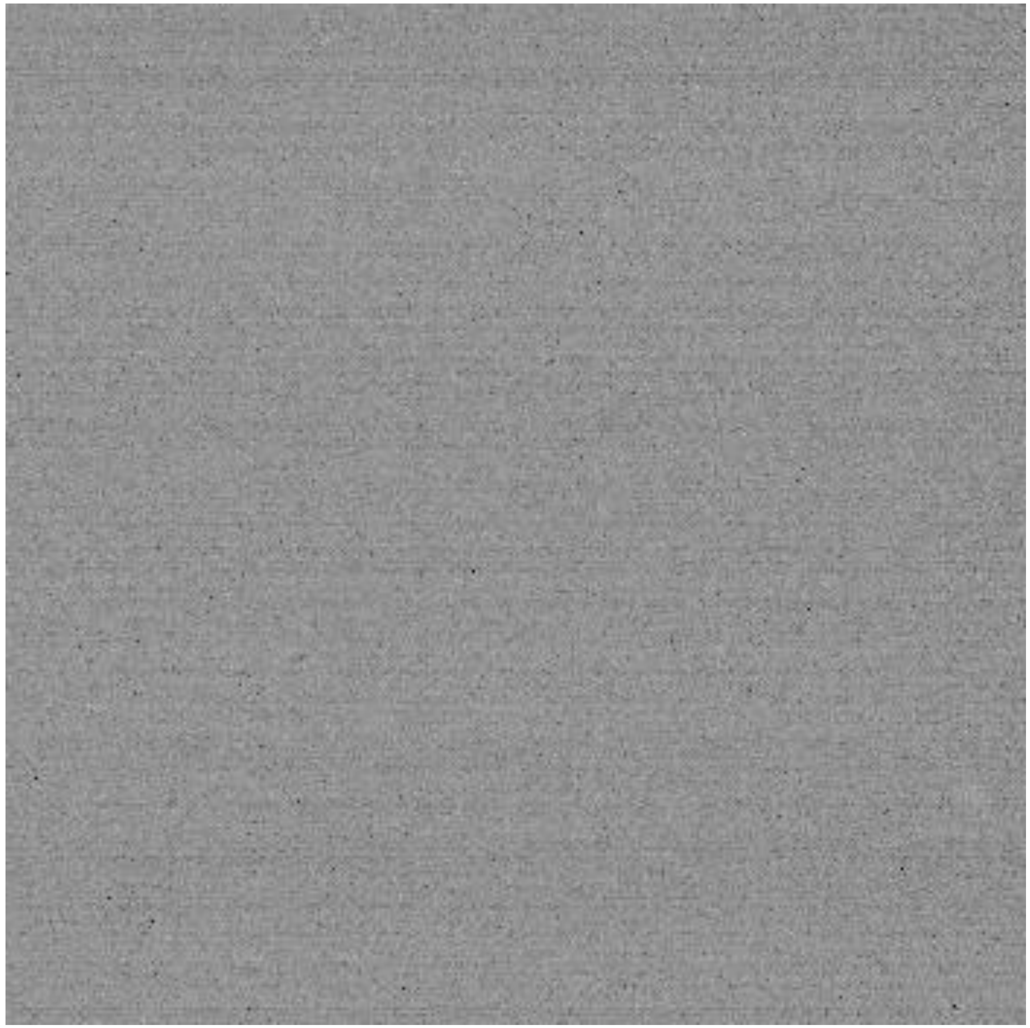


- The FPGA card, responsible for the timing of the laser, transmits a pre-pulse with variable delay and pulse width.
- This pulse can be used for triggering the exposure of the camera and for controlling the exposure time.

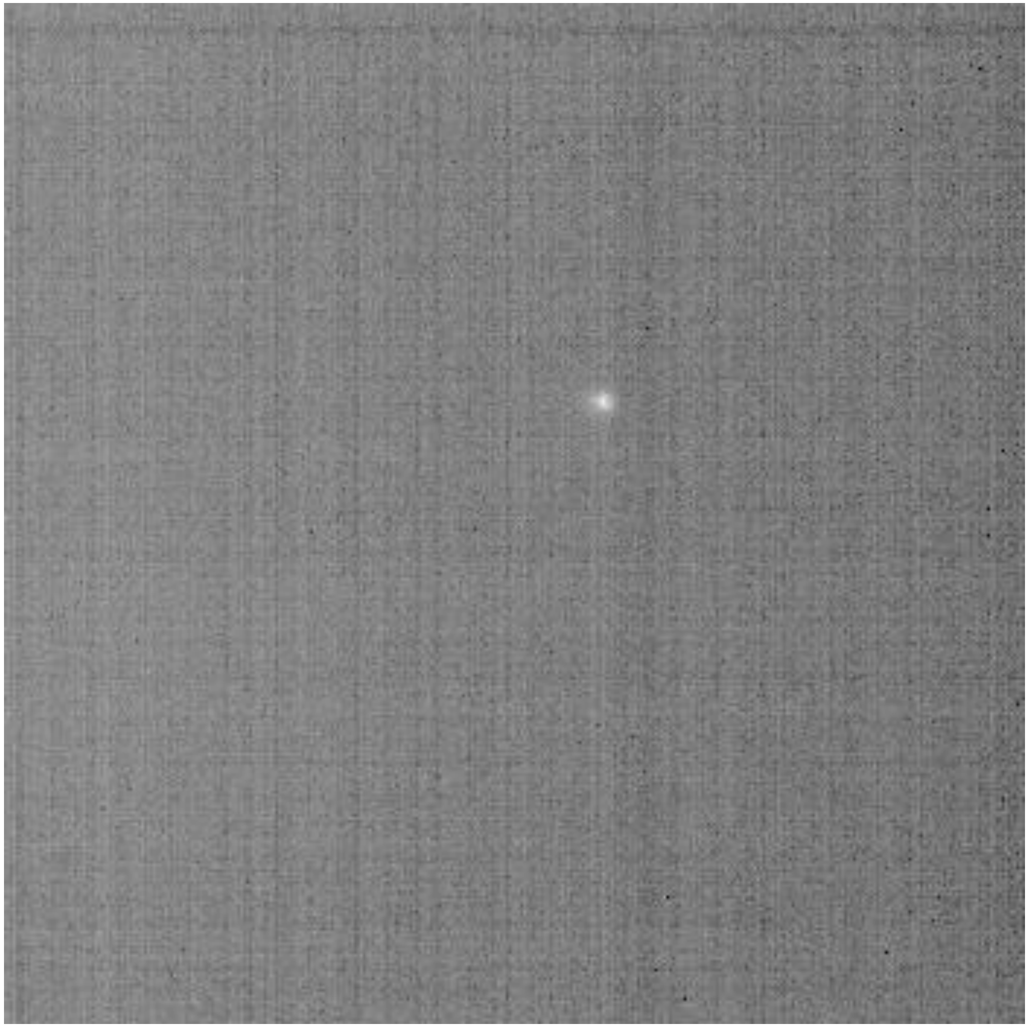
Current Status of Work

- Mechanical and electrical integration of the tracking camera in our laser system has been completed
- First tests during some satellite passes have been carried out successfully
- The CMOS camera was used already during the 'bistatic' experiment in video mode (no triggering of the individual exposures) for the pointing correction of the telescope
- During above tests some problems have been identified that prevent to use the camera on a routine basis:
  - GUI is not user friendly
    - Default settings cannot be stored (more than 40 modes of operation available)
    - No continuous acquisition mode available
    - Contrast and brightness of the displayed images not flexible enough
    - No cross hairs available
    - Unknown rotation of the image w.r.t. zenith resp. moving direction of the satellite
  - No Autofocus function available
  - Point of highest echo rate is not stable on the image

Ajisai – No accumulation

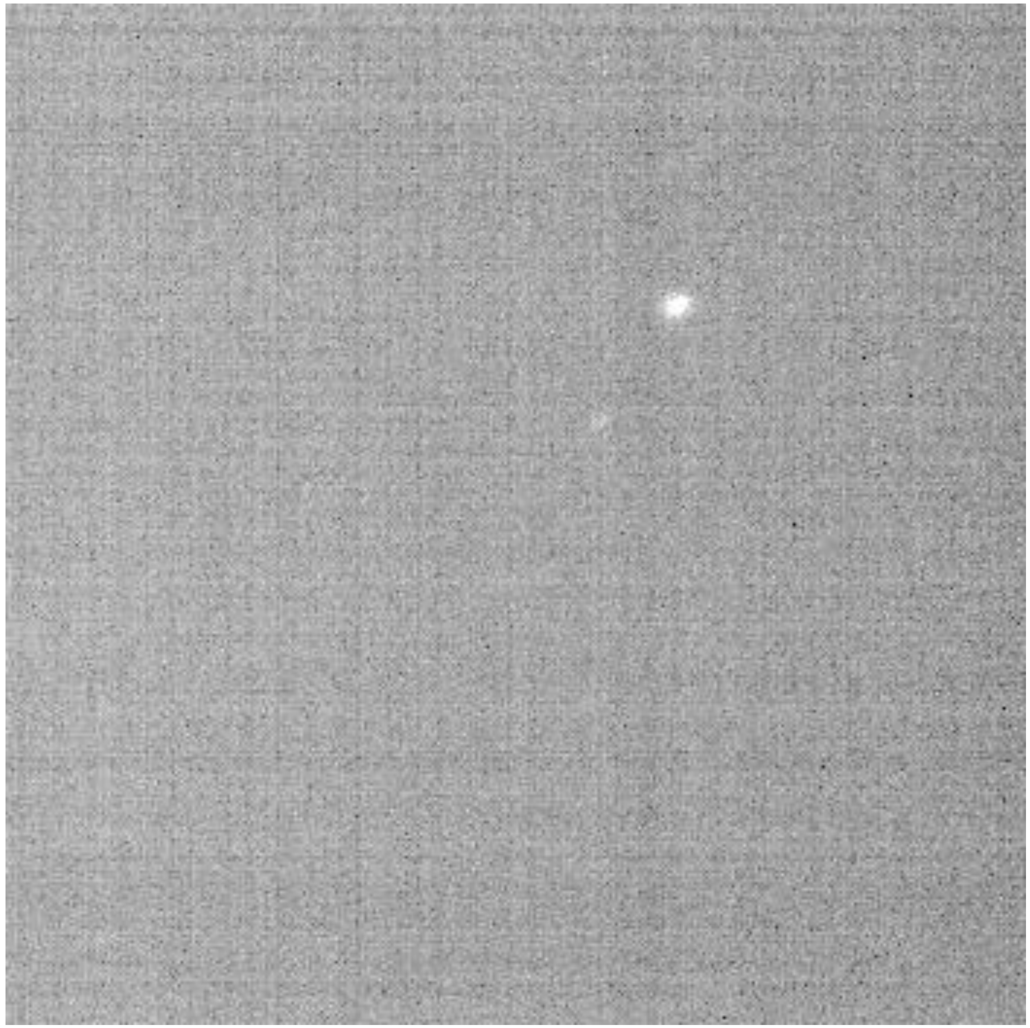


Ajisai – accumulation of 10 images

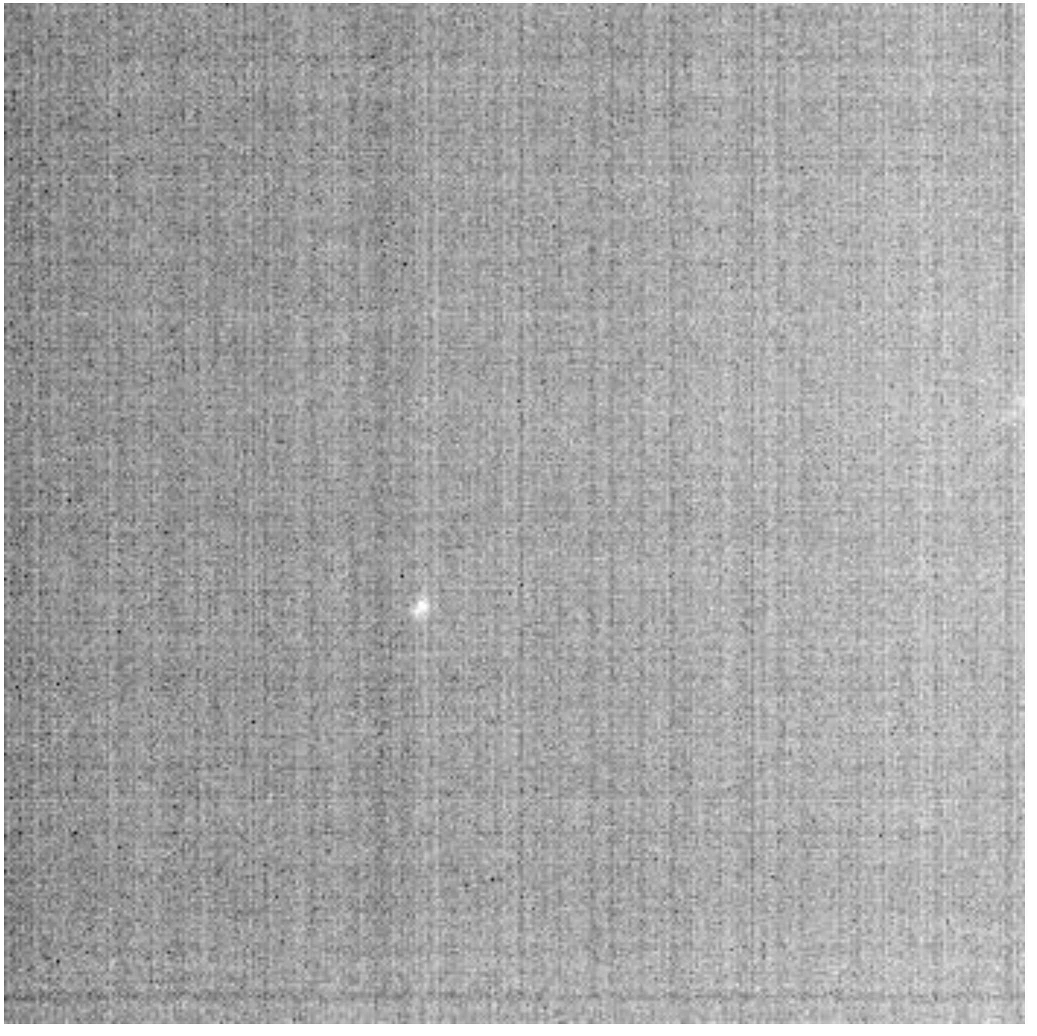


Fixed-pattern noise

Glonass 107 – No accumulation

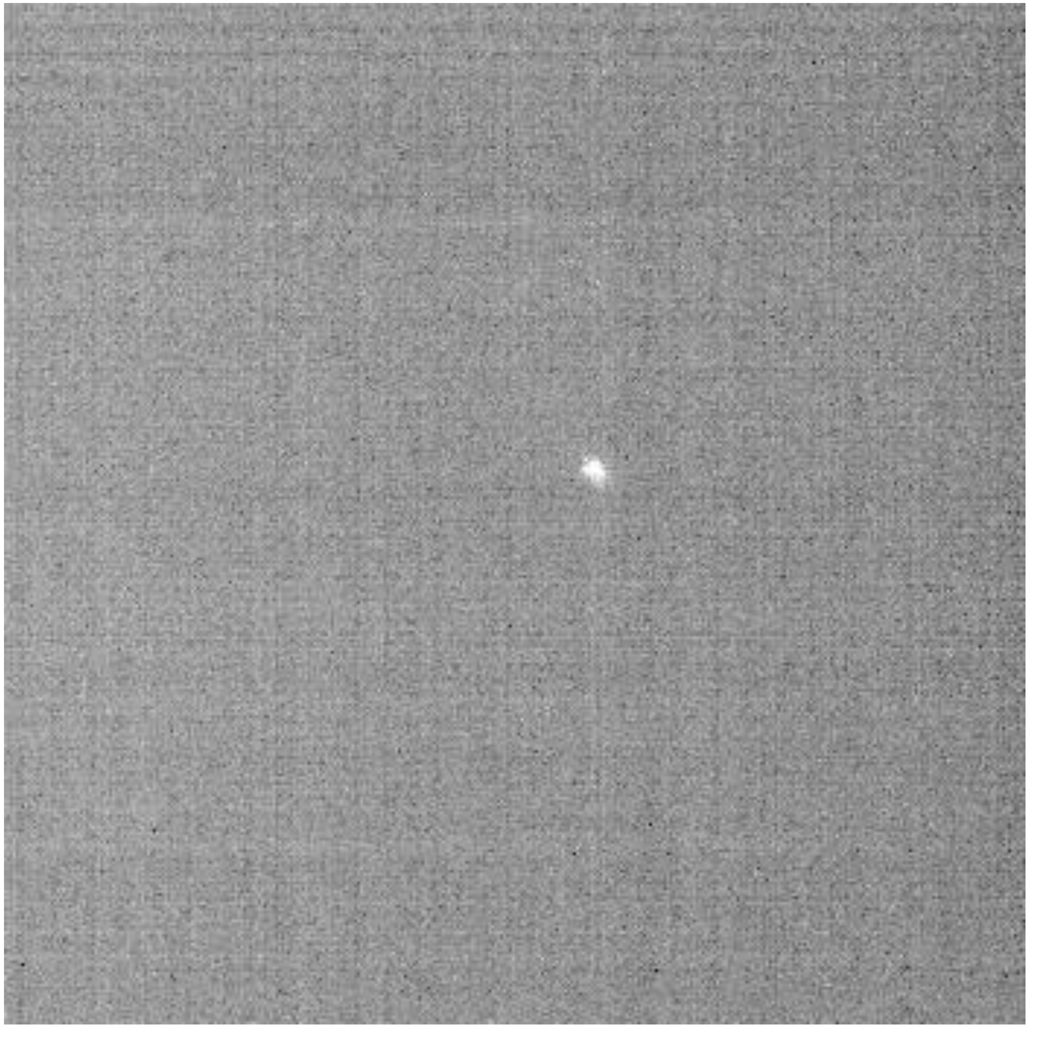


Glonass 107 – accumulation of 10 images

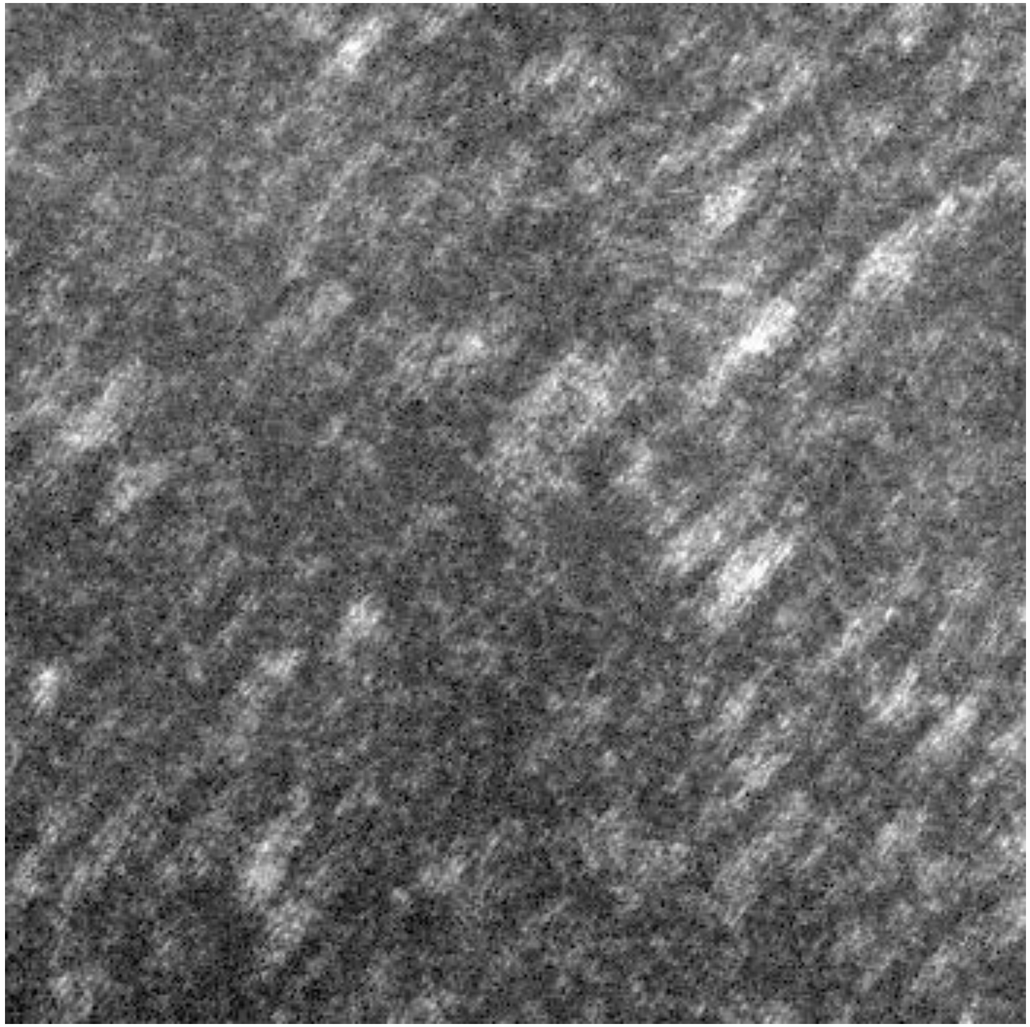


Fixed-pattern noise

Hy2A – No accumulation



Hy2A – Laser pulses



Saral – accumulation of 10 images