Universidad Autónoma de Madrid

INFIERI

6th Summer School on INtelligent signal processing for FrotIEr Research and Industry

LABORATOIRE D'ASTROPHYSIQUE DE MARSEILLE

Unité Mixte de Service PYTHEAS AMU - CNRS - IRD

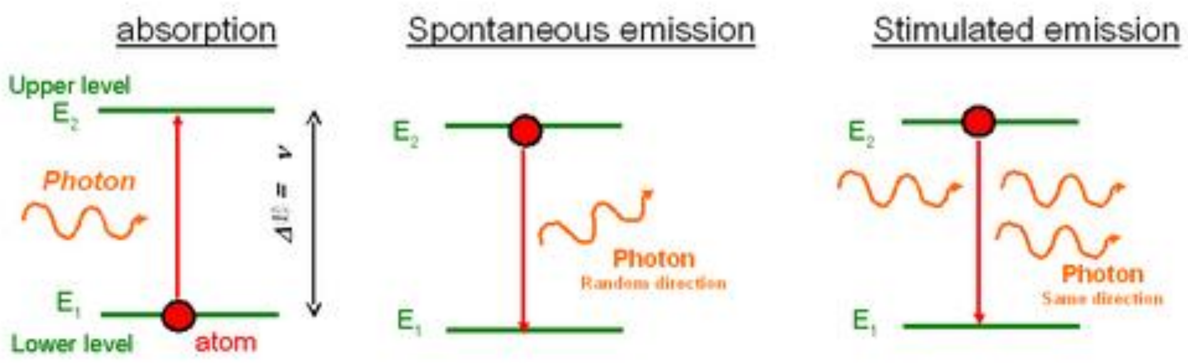
Detection lab

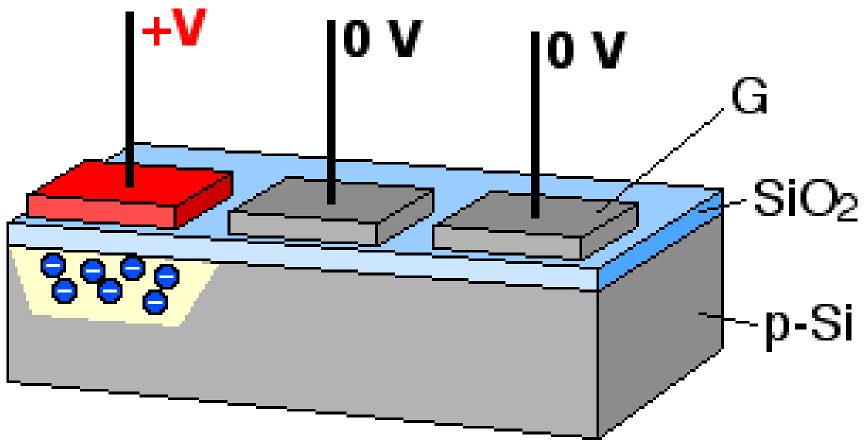
J.-G. Cuby

Speaker A. Le Van Suu

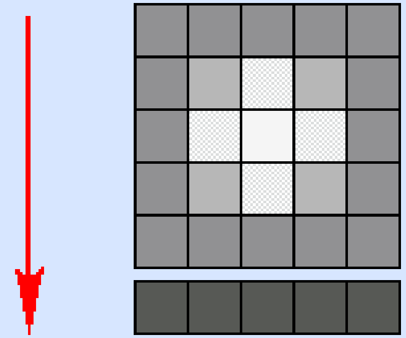
Credits: Hervé Le Coroller & Christophe Adami, LAM

CCDs

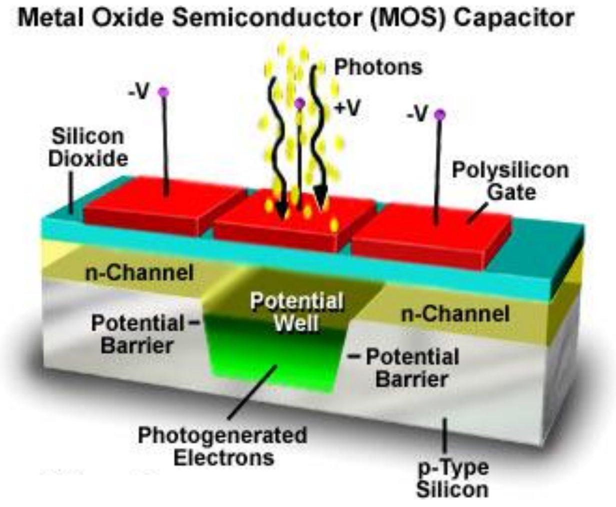


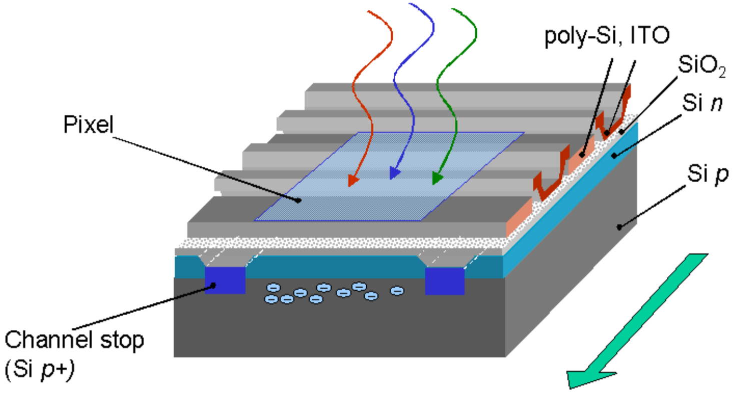


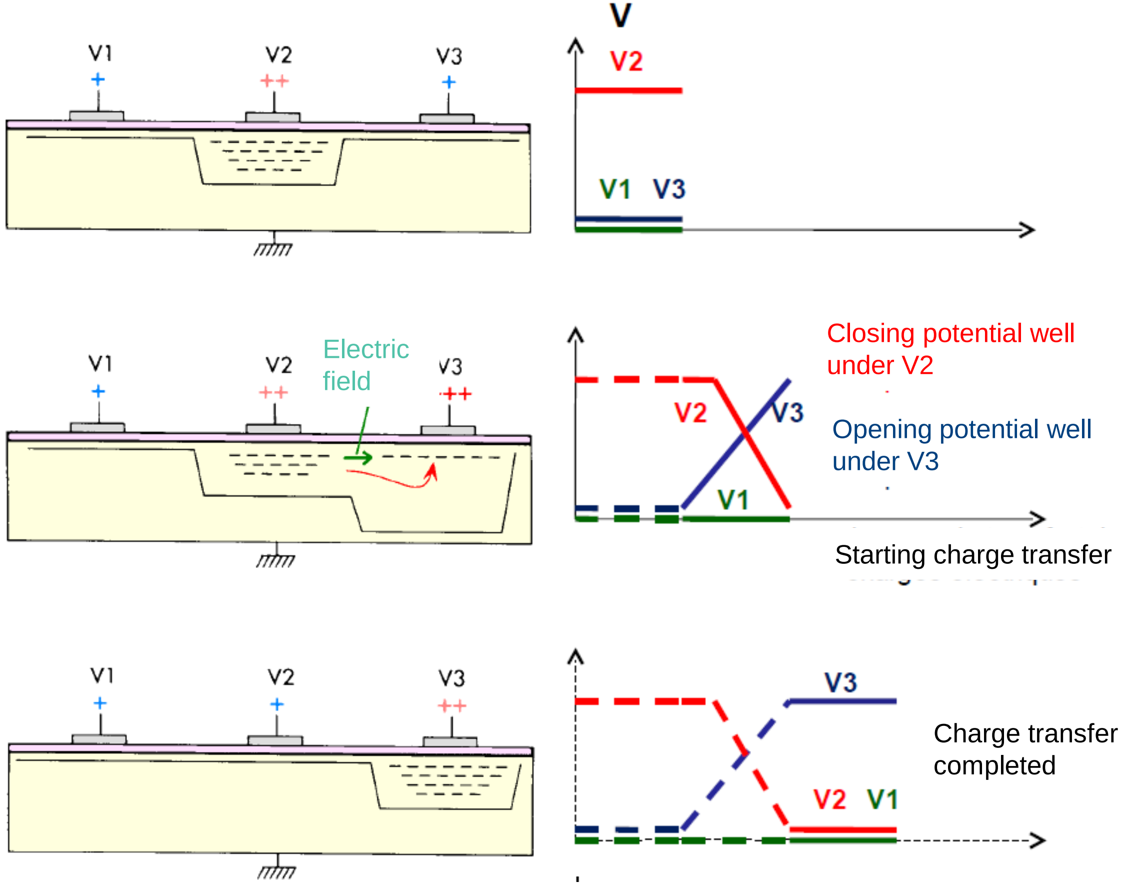
Clocking Parallel Register



CCDs



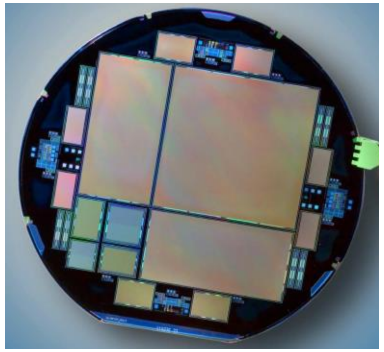




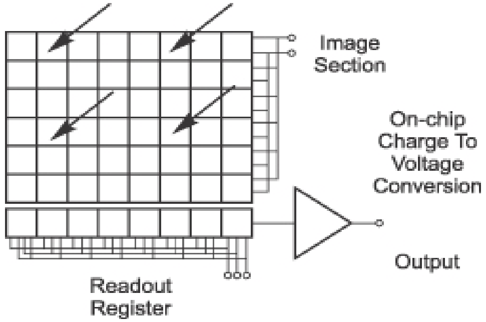
- Charges are collected under electrodes (as long as the voltage is applied)
- Charges are then transferred pixel to pixel by adequate clocking of the electrodes

A large variety of CCDs

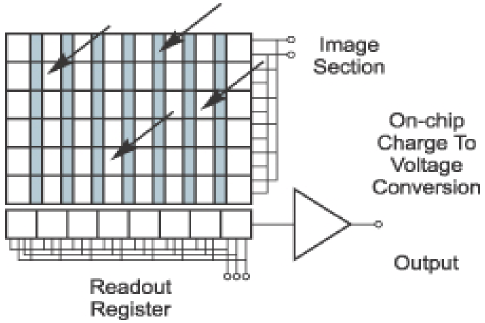
Formats



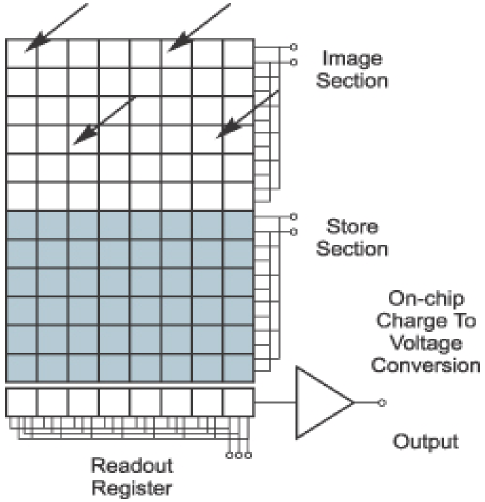
Readout architecture



Full frame CCD

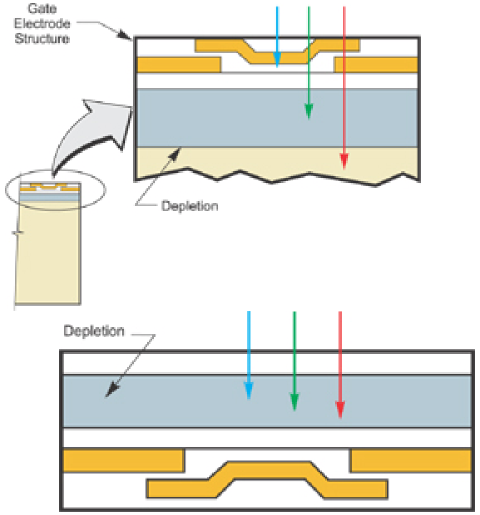


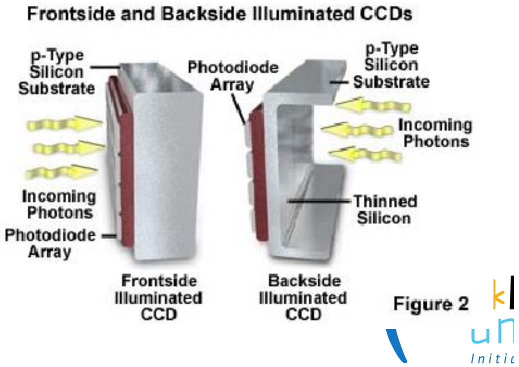
Interline transfer CCD

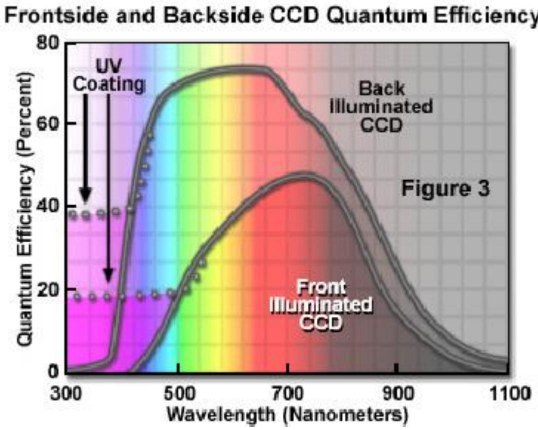


Frame transfer CCD

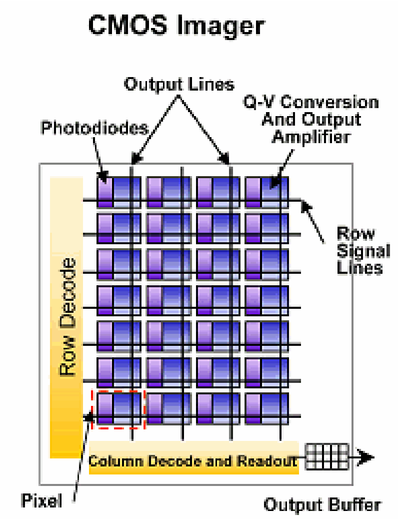
Frontside vs backside illumination

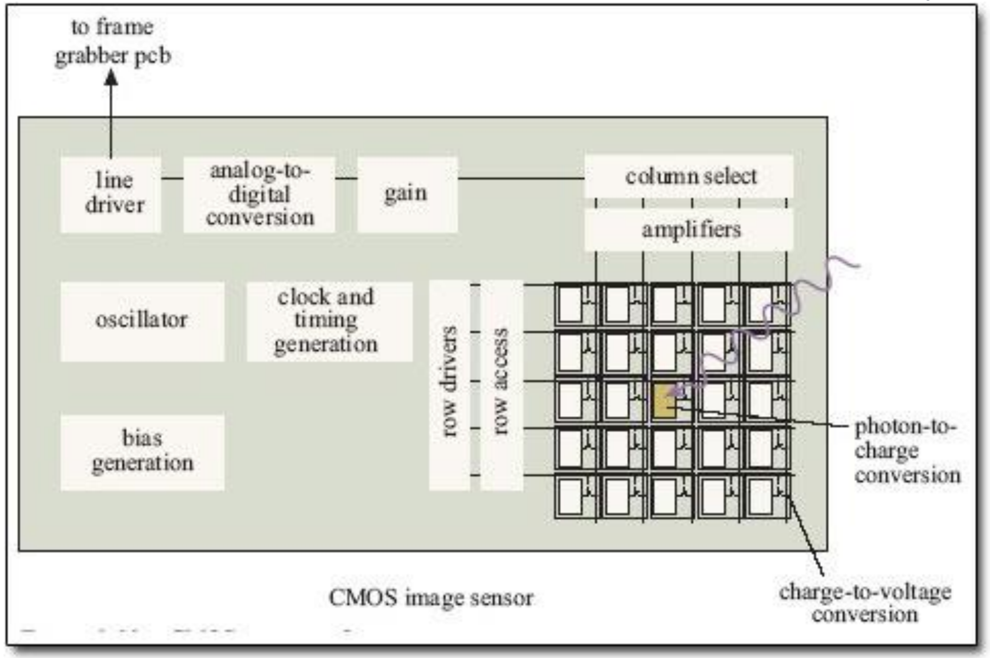






CMOS, infrared detectors





CMOS

CMOS vs. CCDs

Lower fill factor (hence QE). Higher readout noise. Higher readout speed. No blooming. Integration of processing functions. Lower electrical consumption. Less expensive

Infrared detectors

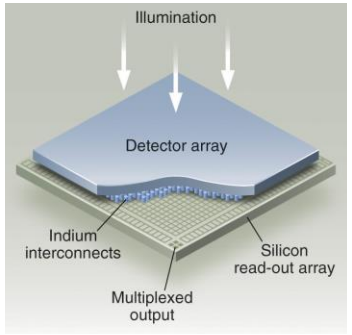
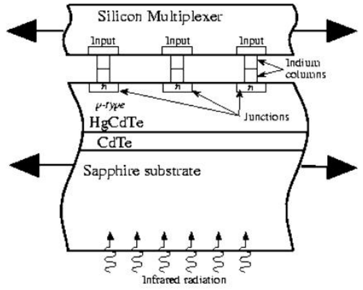
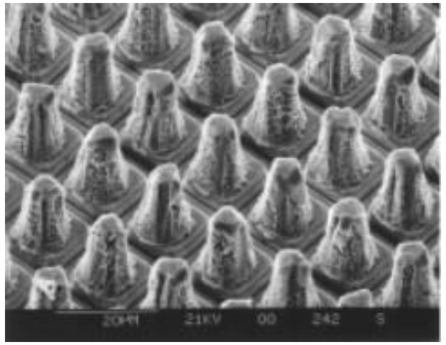


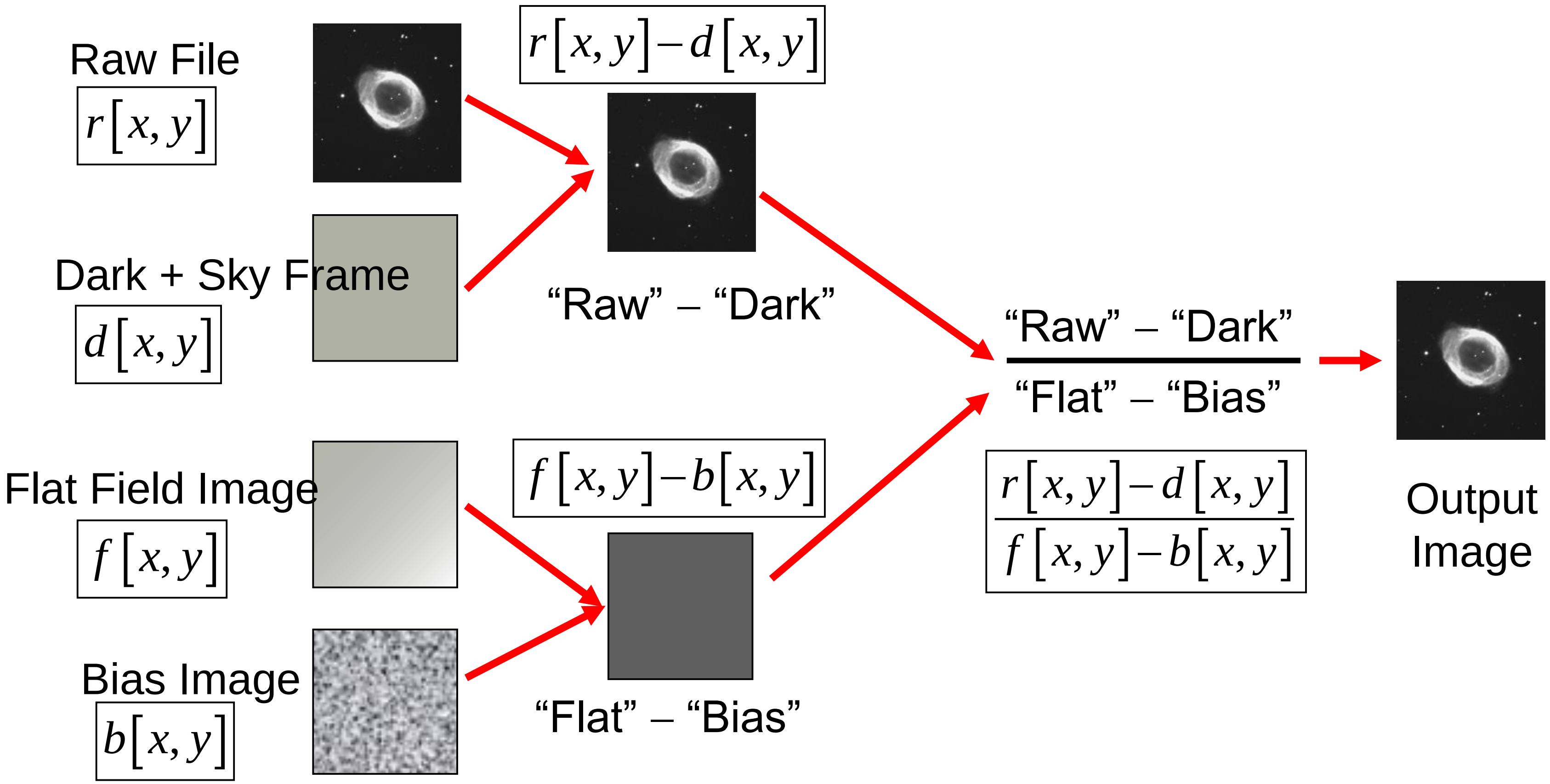
Figure 7.1: Cross–section of a NICMOS3–type detector (not to scale)



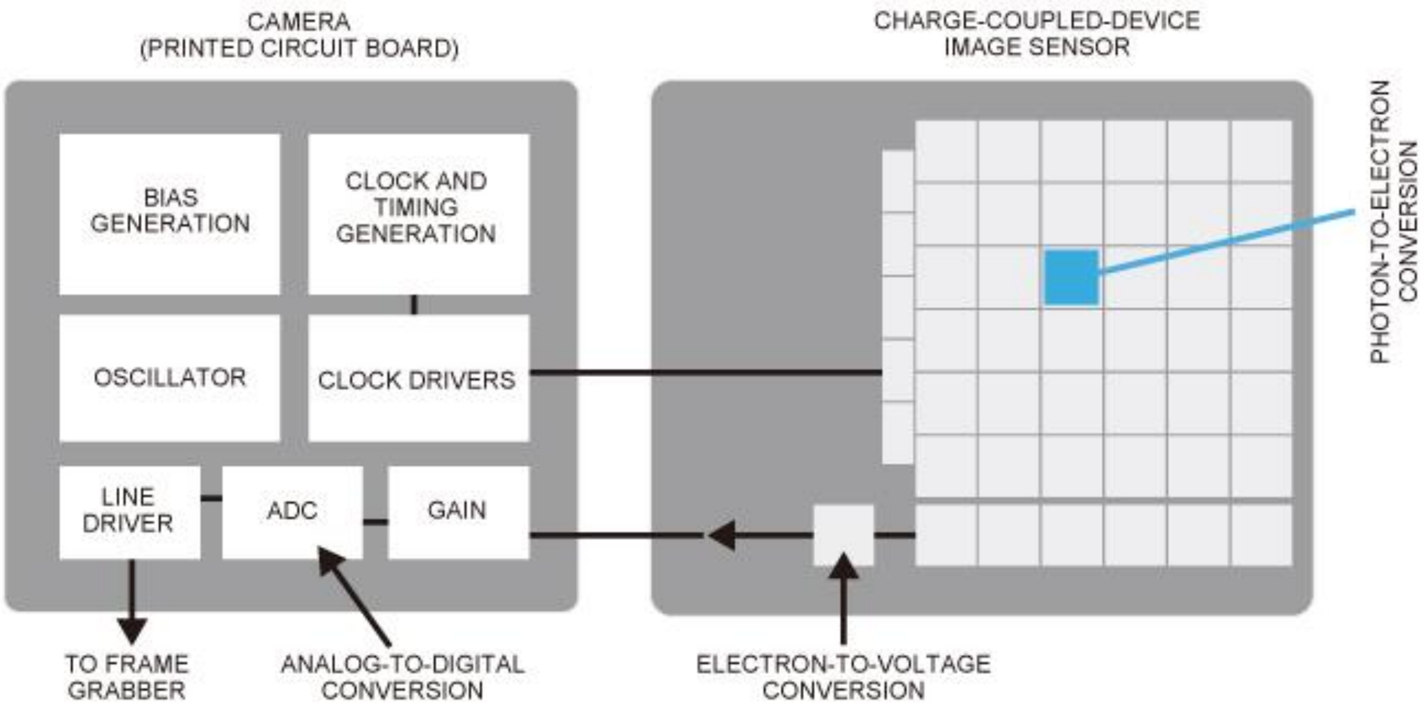


Hybridization of the detector layer to a CMOS readout circuit

Correction of Raw Image with Bias, Dark, Flat Images



CCD gain



Pixel intensities end up as digital numbers (‘counts’) – in Analog to Digital Units (ADU). If you want to relate these numbers to the original number of electrons stored in the pixels, you need to know the conversion factor that is called the CCD gain g (in e^{-} ADU^{-1}).

Basics of noise

- The variance of the sum of independent random variables is the sum of the variances
- The sum of N random independent variables (with finite means and variances) tends to a normal (gaussian) distribution
- A series of random events occurring continuously and independently of one another is described by a Poisson distribution:

$$\mathrm{Prob}(N, \bar{N}) = \frac{(\bar{N})^N e^{-\bar{N}}}{N!}$$

$$\text{Variance: } \mathrm{Var}(N) = N$$

$$\text{Standard deviation: } \sigma = \sqrt{\bar{N}}$$

where N is the measured number of events (counts), $\bar{N}$ the mean of N, Var is the variance and σ the standard deviation

Sources of signal and noise

Let's assume that the CCD is illuminated by a uniform and stable source of light generating M_{e^-} electrons per second (e$^-$ s^{-1}) (per pixel)

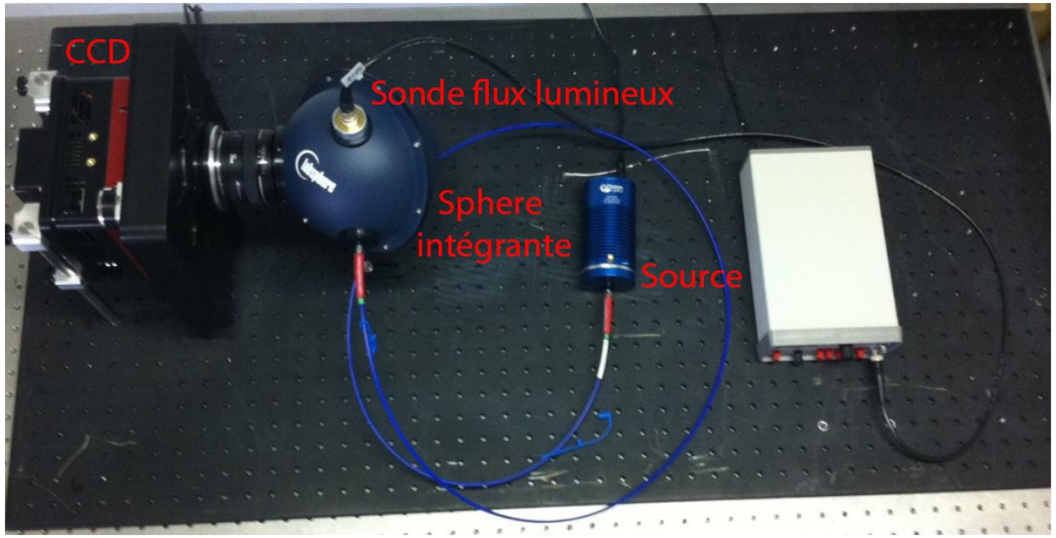
CCD gain in e$^-$ ADU^{-1}	g
Readout noise (e$^-$ rms) (per pixel)	R (random variable added to the signal, $\bar{R} = 0$ and variance R^2)

Measurement	$M_{ADU} = g^{-1} \times (M_{e^-} + R)$
Average	$\overline{M_{\text{ADU}}} = g^{-1} \times \overline{M_{e^-}}$
Variance	$\text{Var}(M_{\text{ADU}})$

Using the noise properties of the signal, expected to follow a Poisson distribution, it is possible to derive the CCD gain and noise.

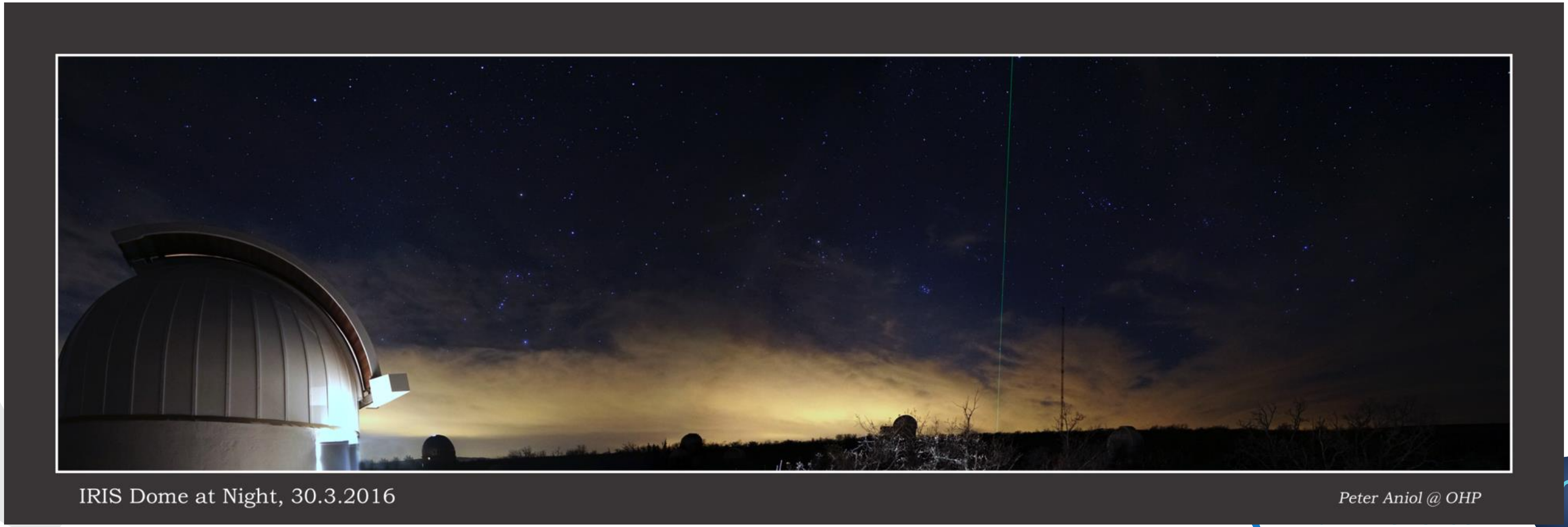
Lab summary

- Get familiarized with a CCD, take images, change parameters (integration time, temperature, etc.)
- Do basic image processing (bias and dark frame subtraction, flat-fielding)
- Do basic statistical analysis (histograms, average, standard deviation)
- Study the statistical properties of the dark current at different temperatures
- Study the CCD linearity range
- Determine the gain and readout noise of the CCD from the statistical properties of the measured signal



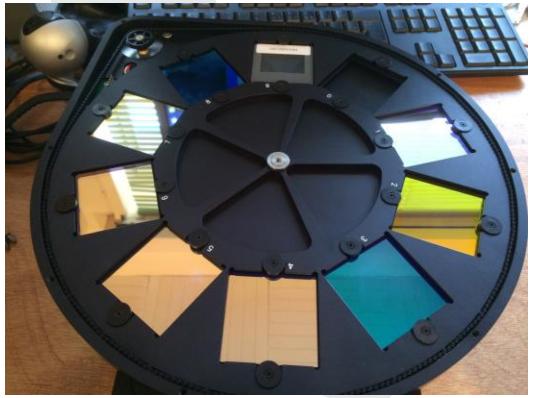
Optional

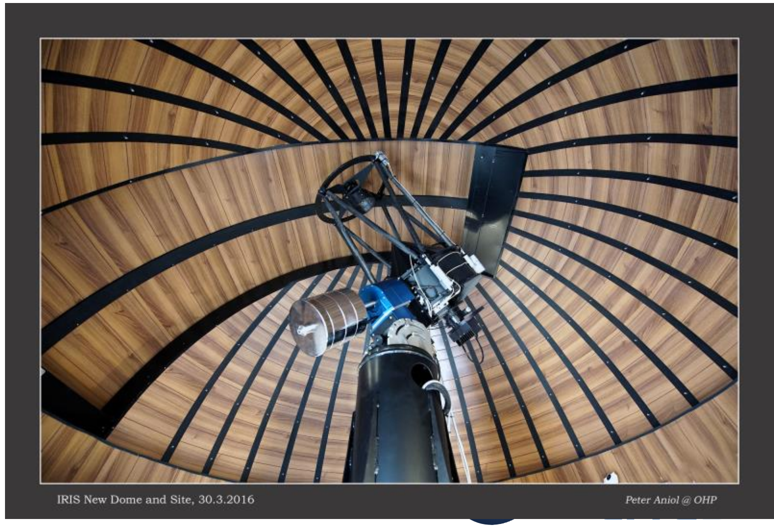
Astronomical observations with a 50-cm telescope at Observatoire de Haute Provence (IRiS)



Equipment

Characteristics	Value
Telescope diameter	50 cm
Beam speed / numerical aperture	f/8
Pixel size (on sky)	0.7 arcsec pixel^{-1}
Field of view	24 arcmin
Camera	E2V 42-40
Size	2048 x 2048 pixels
Minimum integration time	5 s (for shutter safety)
Filters	g, r, i et z, H-alpha, OII





Astronomical observations

- Some remote Night Observation session will be organized depending on weather conditions and practical aspects in UAM
- If you are interested, please contact us
- Prepare your targets !
- More at http://iris.lam.fr/ (mostly in French)
- Simulators http://iris.lam.fr/observer-sur-iris/controle-du-telescope