Astronomical Techniques I

Lecture 6

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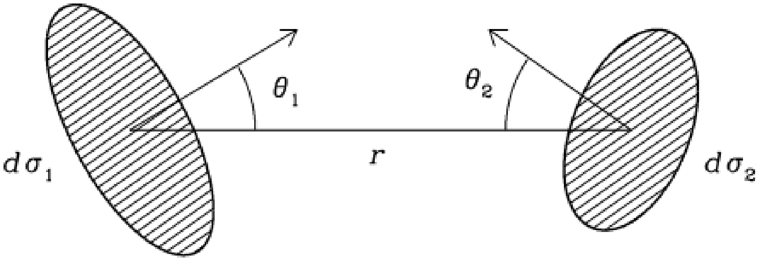
Surface brightness of an extended source



Let $d\Omega_1$ be the solid angle subtended by $d\sigma_2$ as seen from the center of the surface $d\sigma_1$ and $d\Omega_2$ the solid angle subtended by $d\sigma_1$ as seen from the center of the surface $d\sigma_2$. Then $d\Omega_1 = (cos\theta_2 d\sigma_2)/r^2$ and $d\Omega_2 = (cos\theta_1 d\sigma_1)/r^2$ and

$$dW_1 = (I_\nu)_1 cos\theta_1 \frac{cos\theta_2 d\sigma_2}{r^2} d\sigma_1 d\nu, dW_2 = (I_\nu)_2 cos\theta_2 \frac{cos\theta_1 d\sigma_1}{r^2} d\sigma_2 d\nu$$

Surface brightness of an extended source

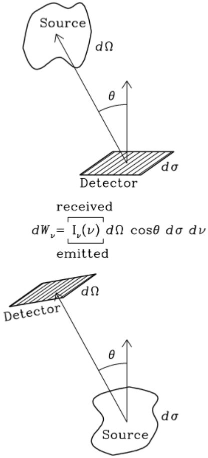
If there is no absorption or emission, then

$$dW_1 = dW_2 \Rightarrow (I_\nu)_1 = (I_\nu)_2$$

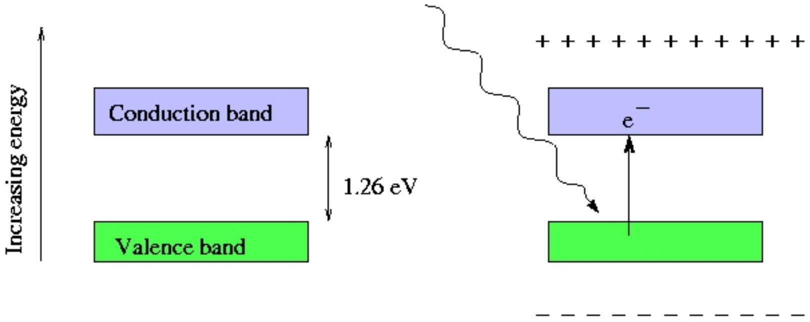
Implications:

- Brightness is independent of distance. Thus the camera setting for a good exposure of the Sun would be the same, regardless of whether the photograph was taken close to the Sun (from near Venus, for example) or far away from the Sun (from near Mars, for example), so long as the Sun is resolved in the photograph.
- Brightness is the same at the source and at the detector. Thus you can think of brightness in terms of energy flowing out of the source or as energy flowing into the detector.

2 ways to think of surface brightness

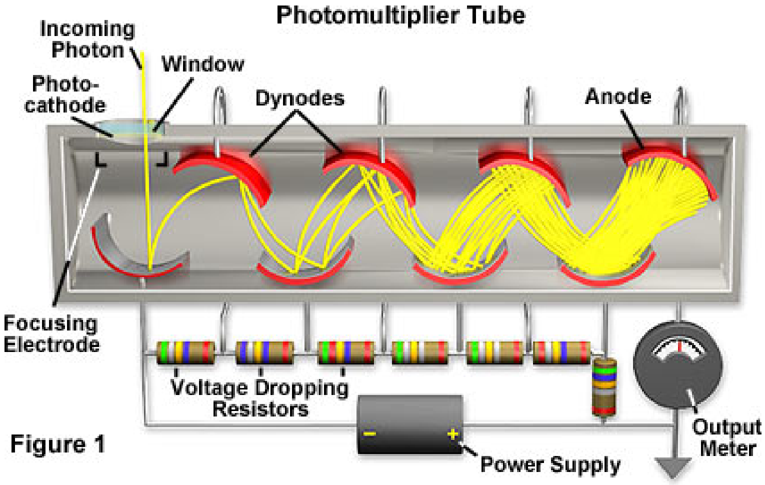


Principle: Photoelectric effect



Thermally generated electrons are indistinguishable from photo-generated electrons. They constitute a noise source known as "Dark Current" and so PMTs and CCDs have to be kept cold to reduce the number of thermal electrons.

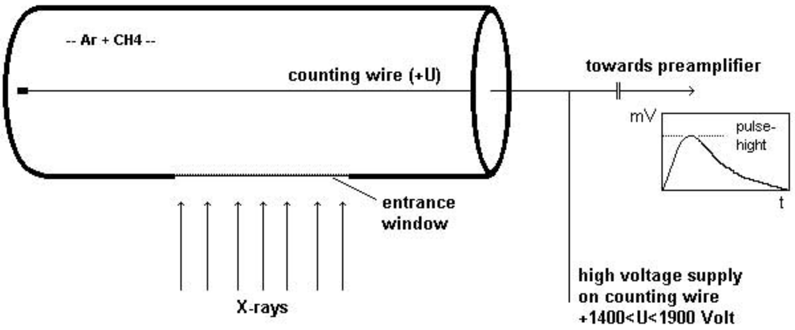
Photomultiplier tubes



today used mostly for accurate photometry of relatively bright stars.

Real PMT

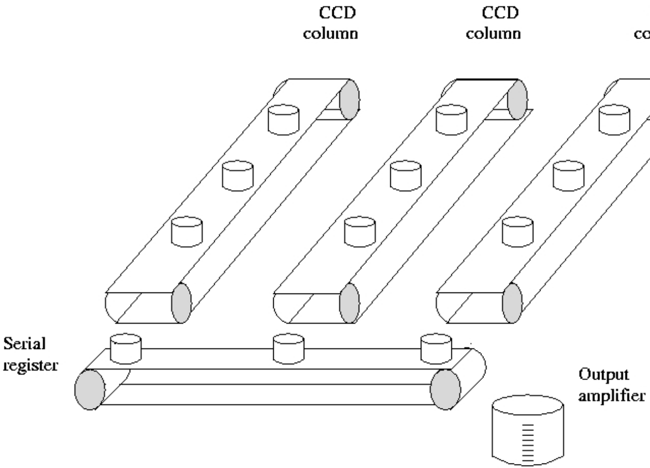
Same principle used in Proportional counters for X-rays



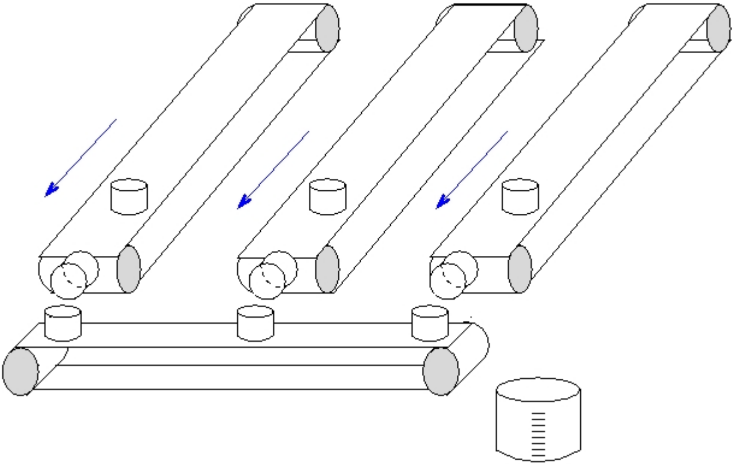
Questions

Why are silicon CCDs not usuable at wavelengths longer than a micron?

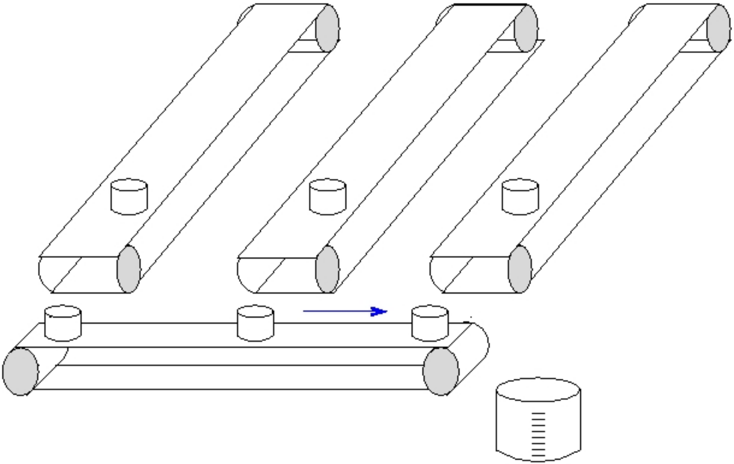
CCD Exposure



Transfer to serial register



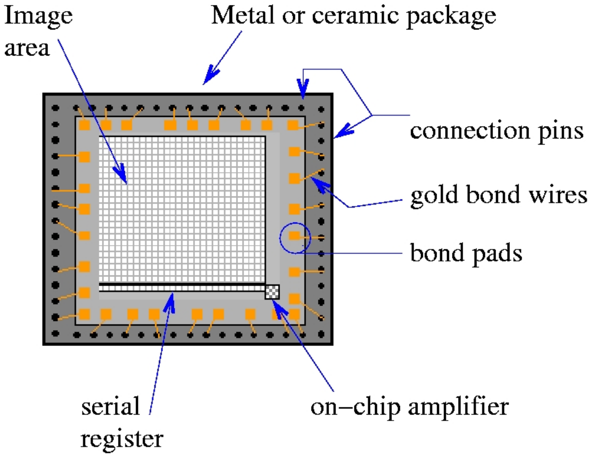
Measurement of output



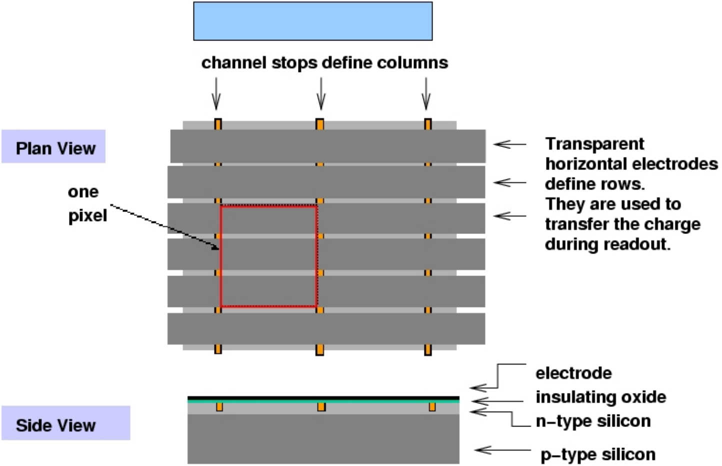
Question

With a 1 MHz clock what is the minimum time needed to read out a 1000×1000 pixel CCD?

CCD Structure

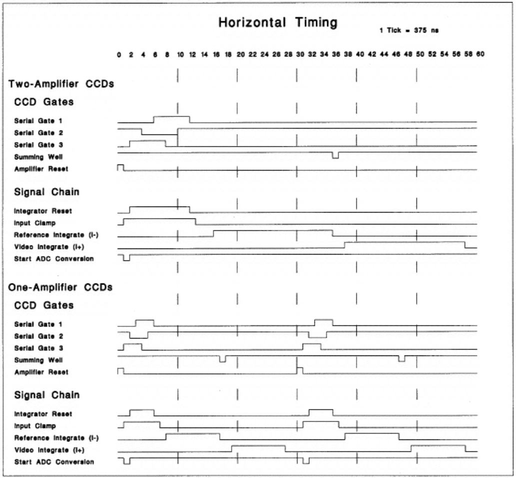


Three phase CCD

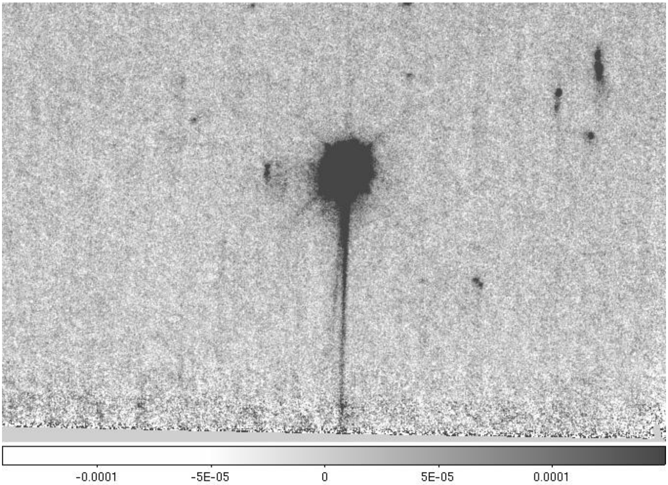


Transfer animation

Sloan timing diagram



Charge transfer efficiency



Full well capacity

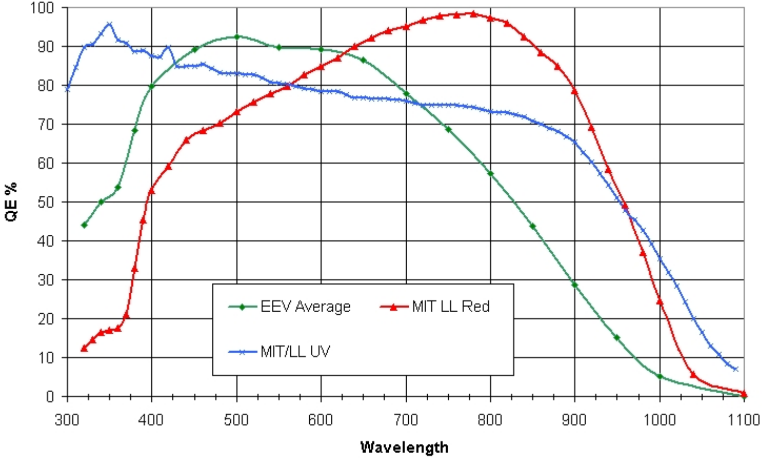
- As a general rule, finer pixel scale $\Rightarrow$ shallower full well capacity.
- typical full well capacity is 50000 e^- in astronomical CCD's
- e2V Kepler mission CCDs have 27 μm pixels with capacity of $\sim$1 million electrons.

Dynamic range

Dynamic range = full well capacity / read noise

High dynamic range very important in the search for *extrasolar planets*

CCD Quantum Efficiency



This is why we need 30m class telescopes!