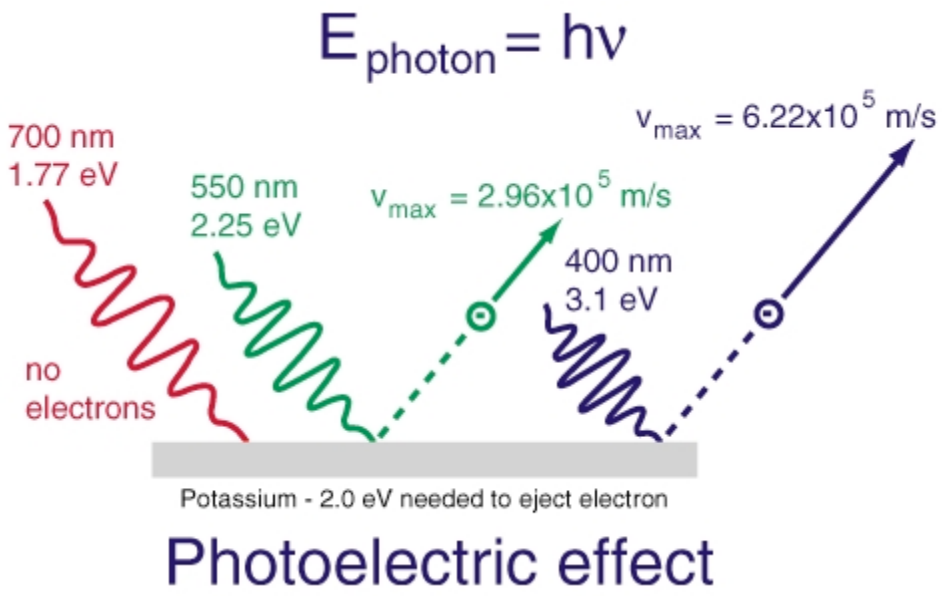
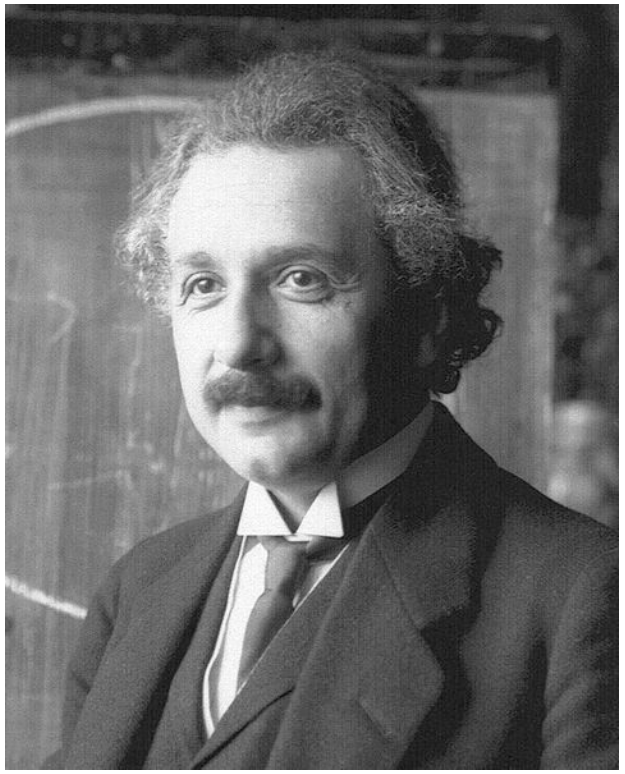
The Photoelectric Effect (1905)



$$h\nu = E_{kinetic} + \phi_{metal}$$

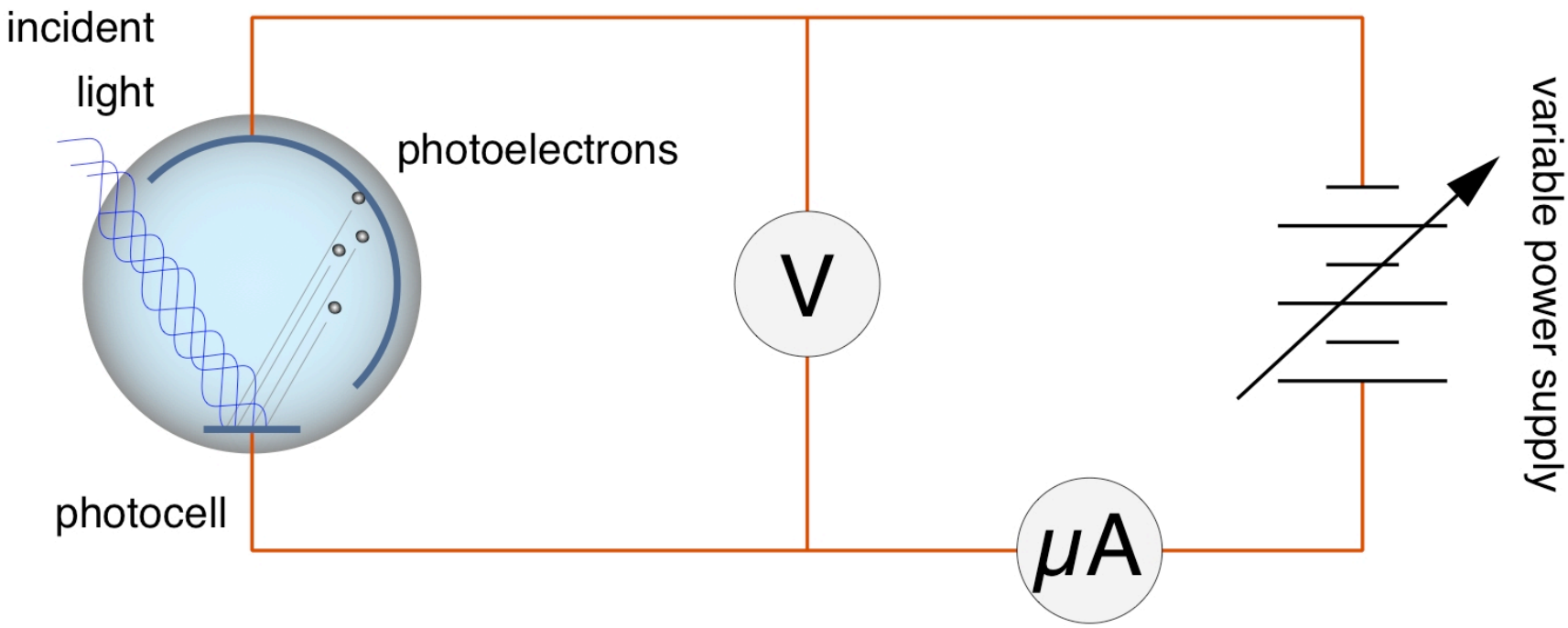


Albert Einstein
1879-1955

A Photomultiplier Tube (PMT) is a very sensitive instrument for detecting photons via the photoelectric effect.

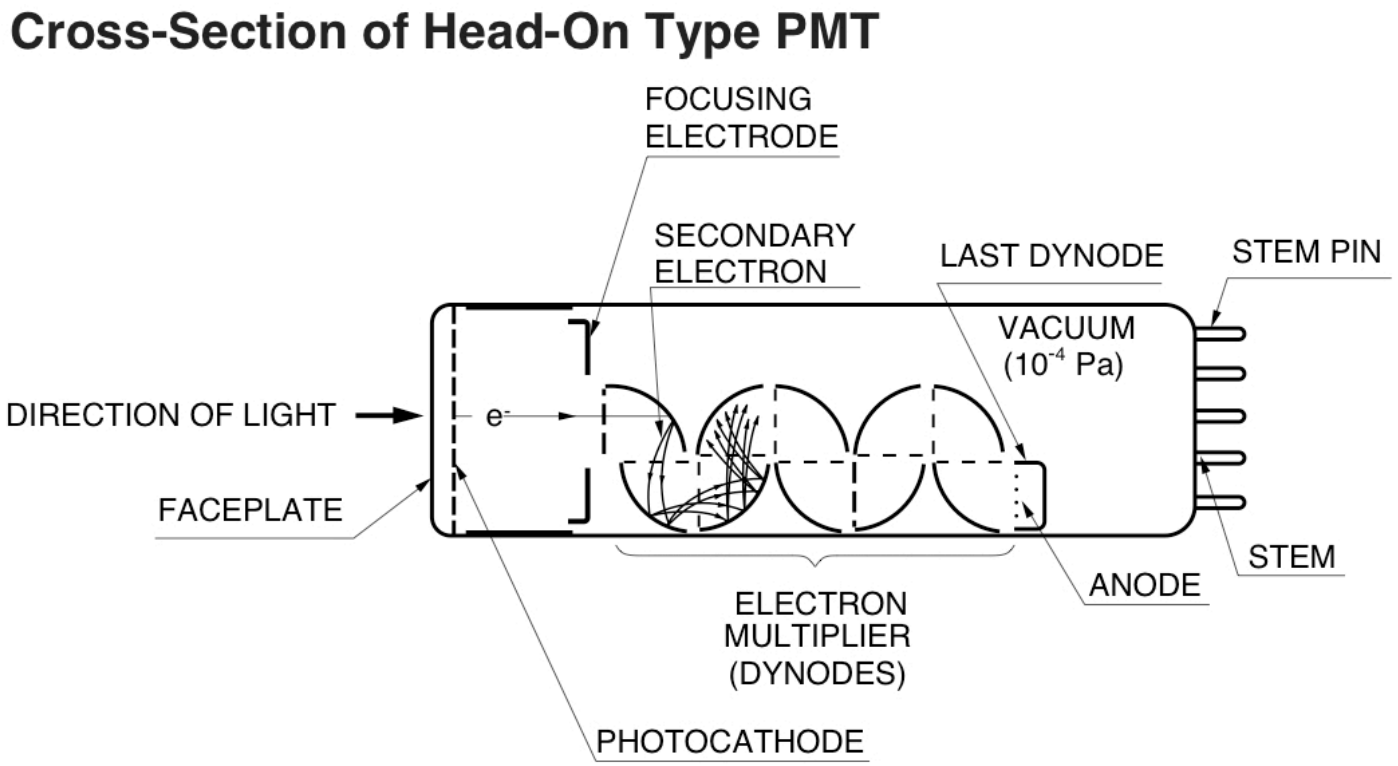
Nobel Prize (his only one) awarded in 1921.

The Photoelectric Effect and Photocurrents



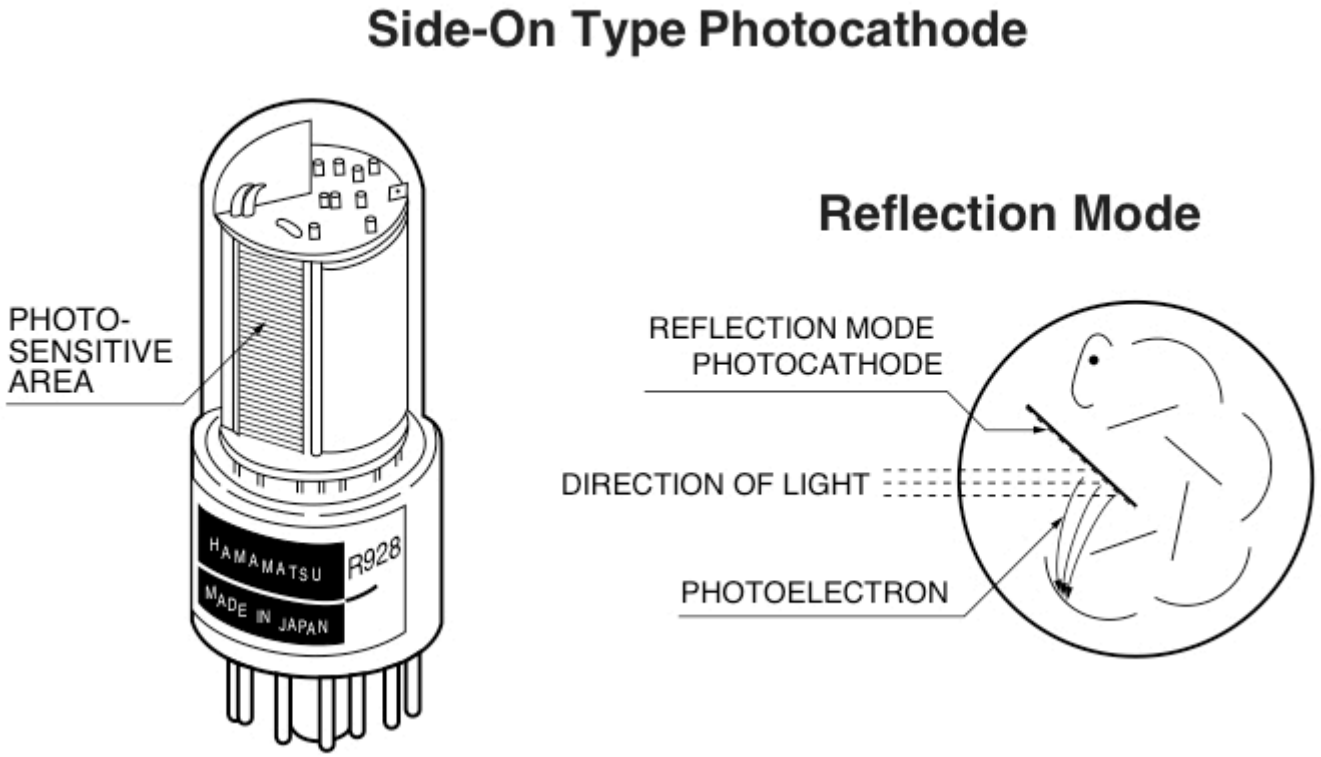
The photoelectric effect converts light into electrons. These electrons can be measured as a photocurrent.

The Photoelectric Effect and Photocurrents



Photomultiplier tubes (PMTs) amplify the photocurrent from a alkali metal photocathode, creating pulses of a million electrons that can be detected.

The Photoelectric Effect and Photocurrents



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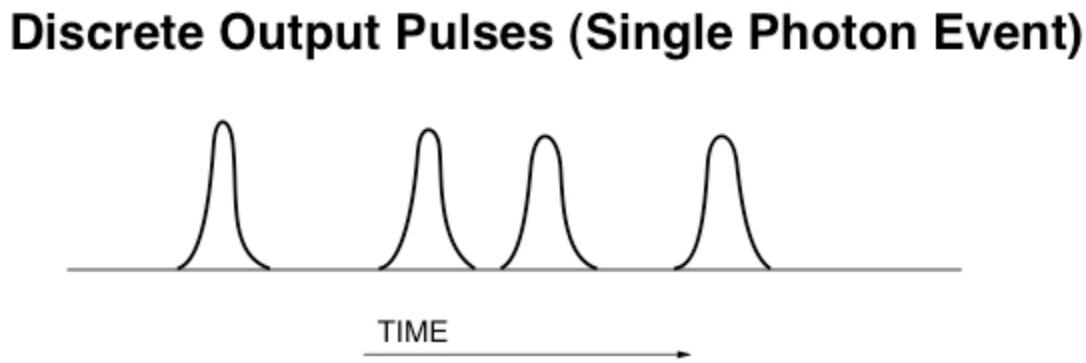
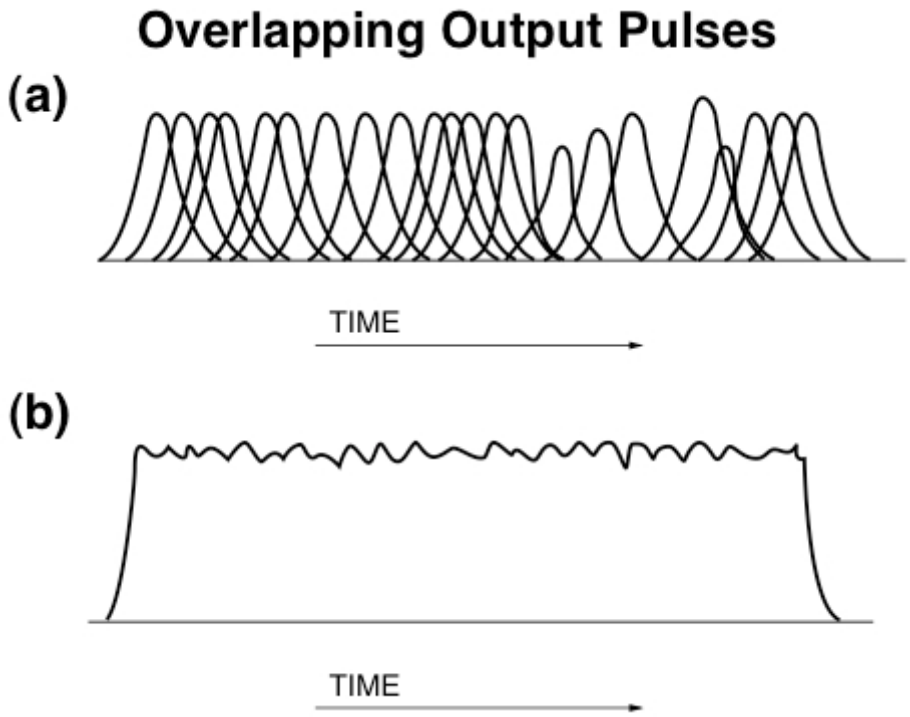
The Photoelectric Effect and Photocurrents



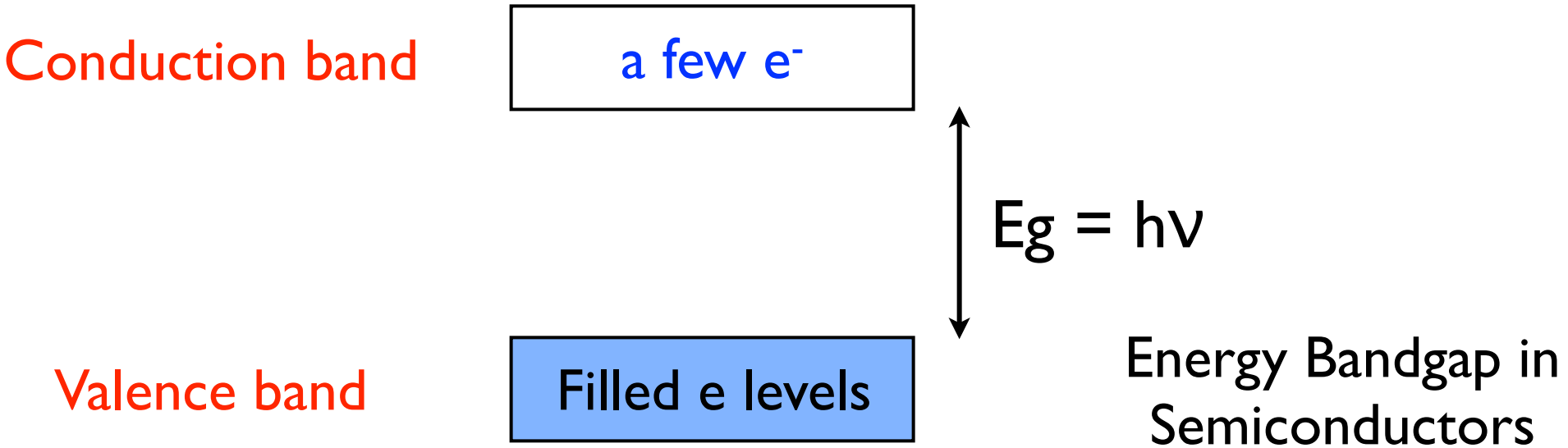
The photoelectron pulses from the PMT can be counted, yielding a measurement of photons per second. This detection method is called "photon counting".

The Photoelectric Effect and Photocurrents



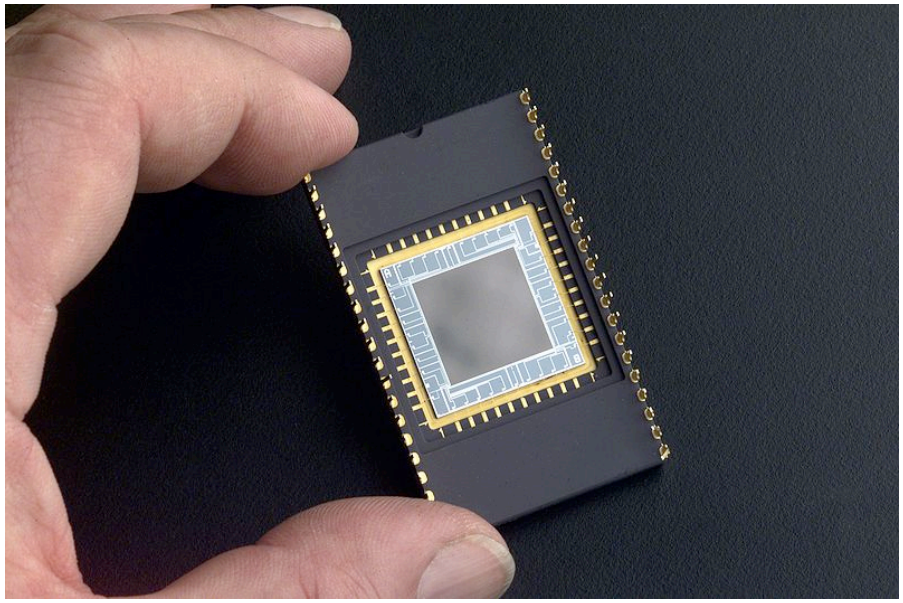
If the number of photoelectron pulses from the PMT becomes too large to detect individually, an average photocurrent can be measured. Photon flux can be calculated from the Radiant Sensitivity (A/W) of the PMT.

Electrons in the conduction band of semiconductors like Si can move about freely.



We can detect photons by measuring the conduction electrons created when we shine light on a semiconductor with energy greater than the bandgap energy Eg.

2009 Nobel Prize in Physics



the CCD sensor

Willard S. Boyle

George E. Smith

One half of the 2009 Nobel Prize in Physics went to Willard S. Boyle and George E. Smith "for the invention of an imaging semiconductor circuit – the CCD sensor" at Bell Laboratories in Murray Hill, NJ.

A CCD element collects the photoelectrons created by incoming light in a small potential well.

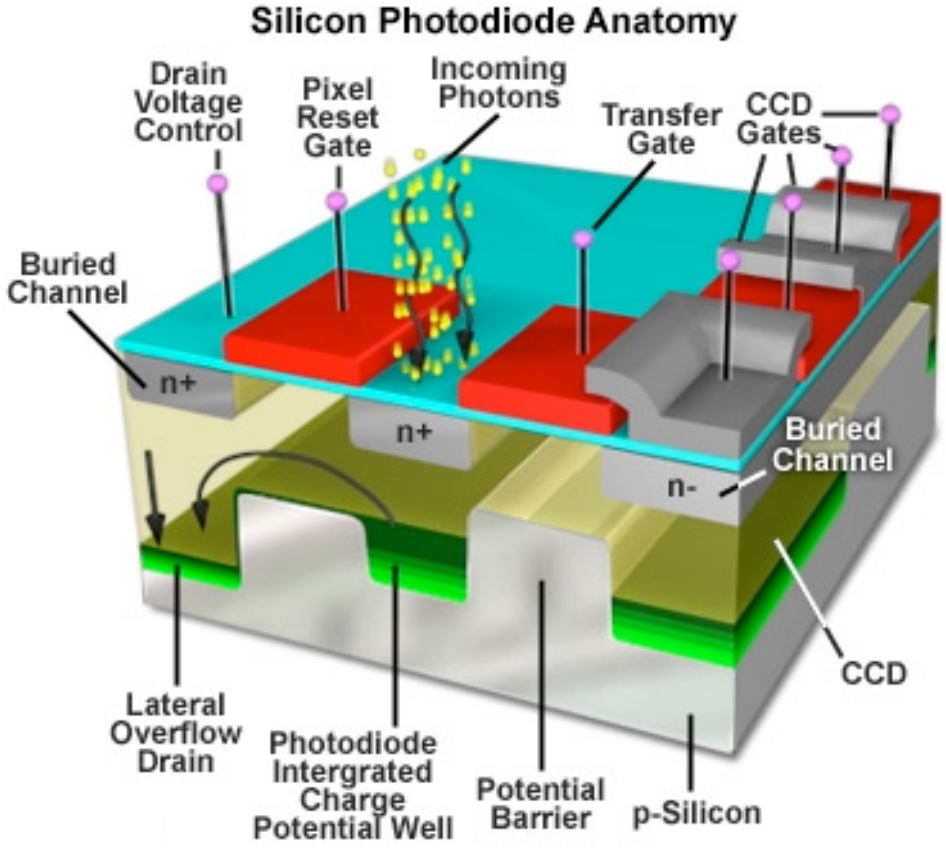
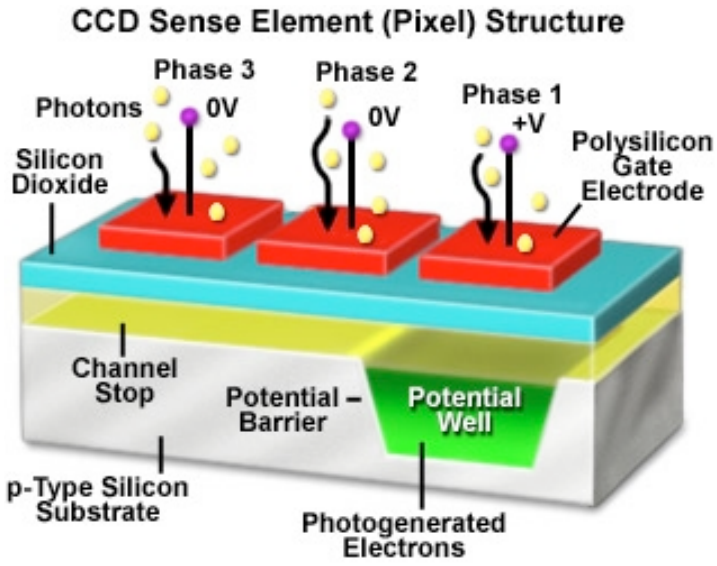
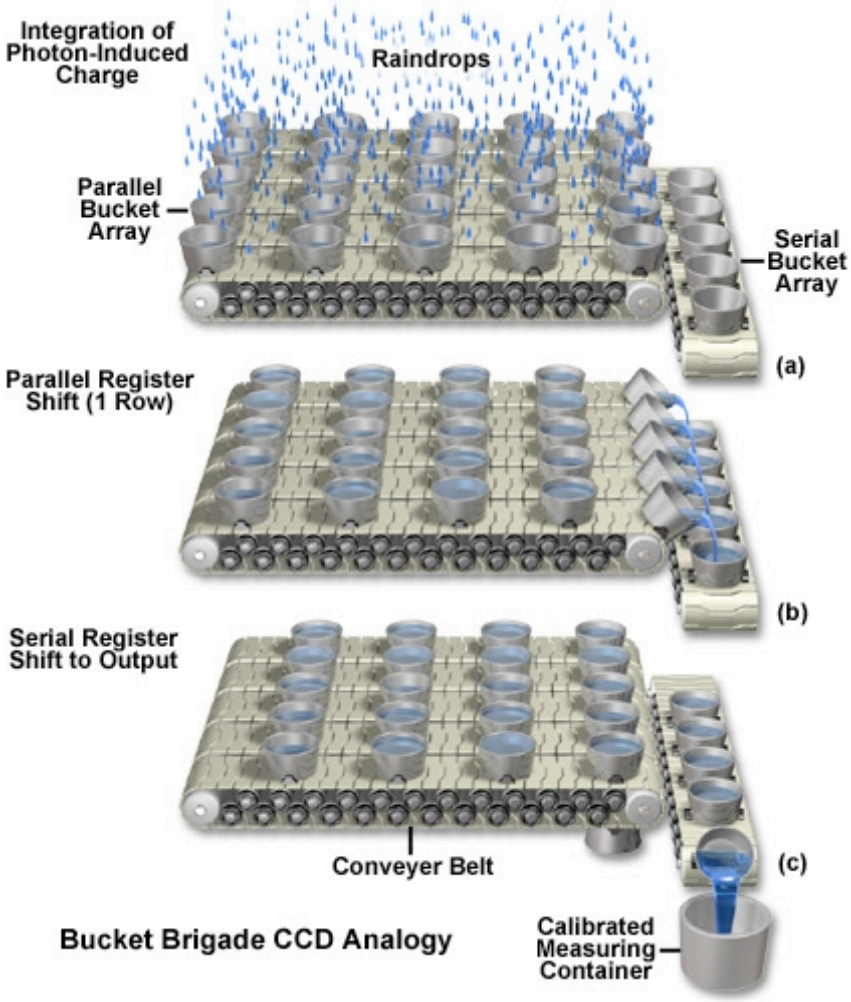


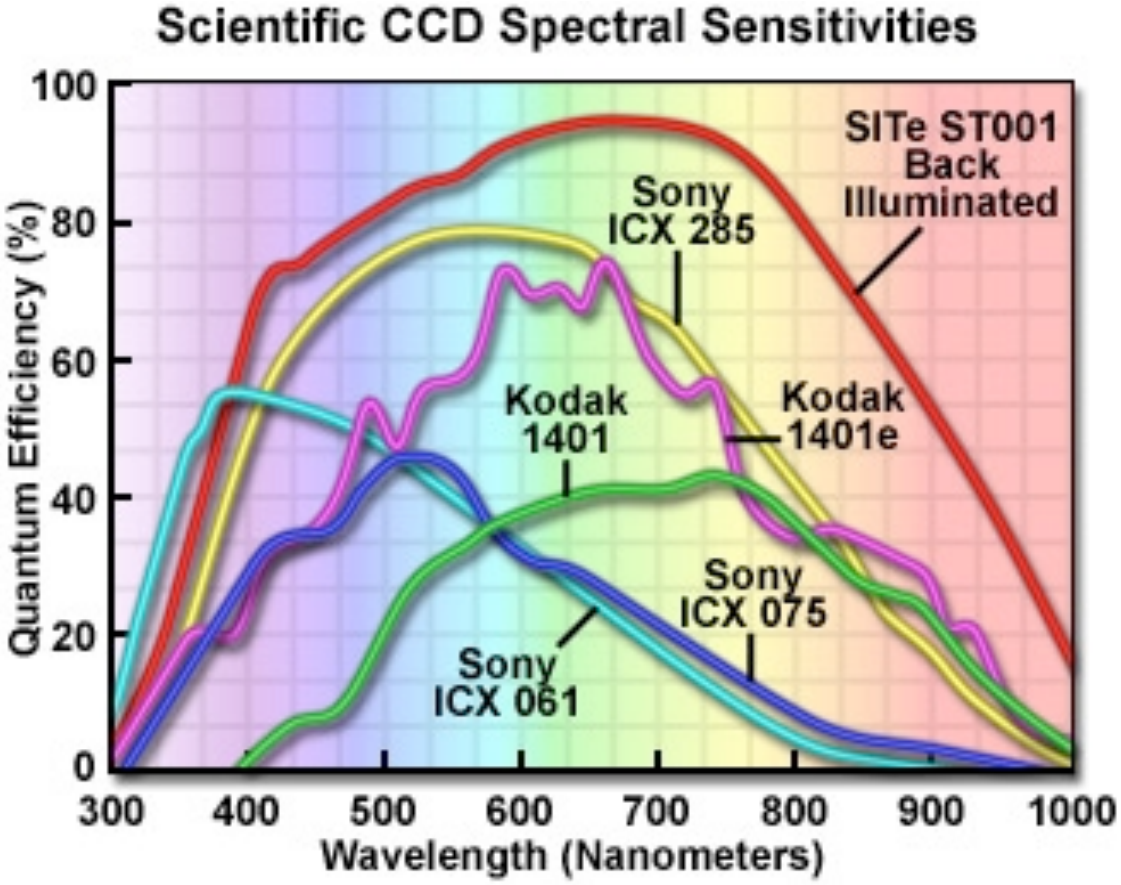
Diagram of a CCD photodiode element (typically a 15 micron square).

The photoelectron pixels get pushed off the chip and are read one at a time.

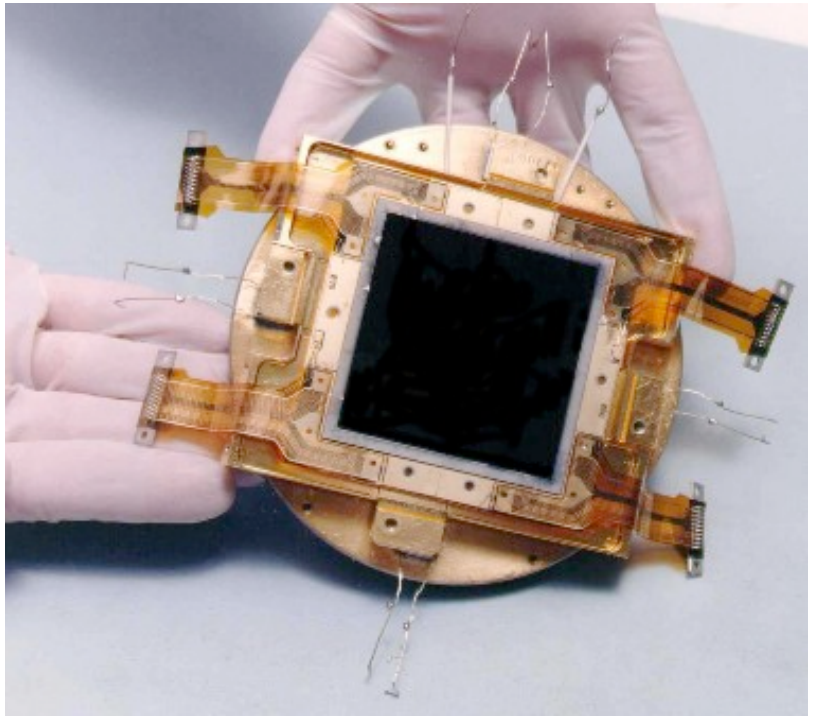




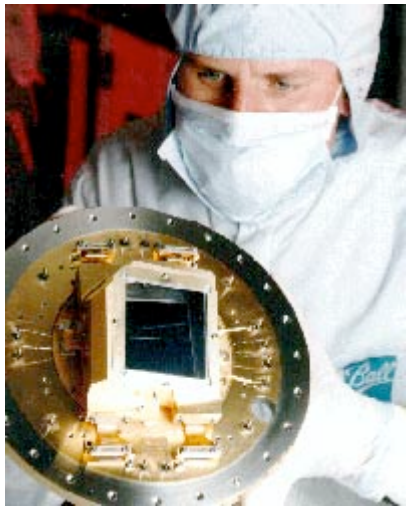
Si CCDs only measure photons with energies larger than Eg (1.1 eV or 1130 nm).



Wide field CCD Camera on the Hubble Telescope



8 Megapixel Camera
(4K x 2K 15 micron pixels)



Another
8 MP camera

Photoelectrons vs. Conduction Band Electrons

From AP:
Boyle and Smith's 1969 discovery at Bell Laboratories in Murray Hill, New Jersey "revolutionized photography, as light could now be captured electronically instead of on film," the Academy said. It described the technology as having built on Albert Einstein's discovery of the photoelectric effect, for which he was awarded the Nobel physics prize in 1921.

Notice that the AP doesn't mention that the Nobel Academy is stretching the truth: the photo-ejection of electrons from a metal surface is a different process than the photo-excitation of Si valence electrons into the conduction band.

But now YOU know the difference!