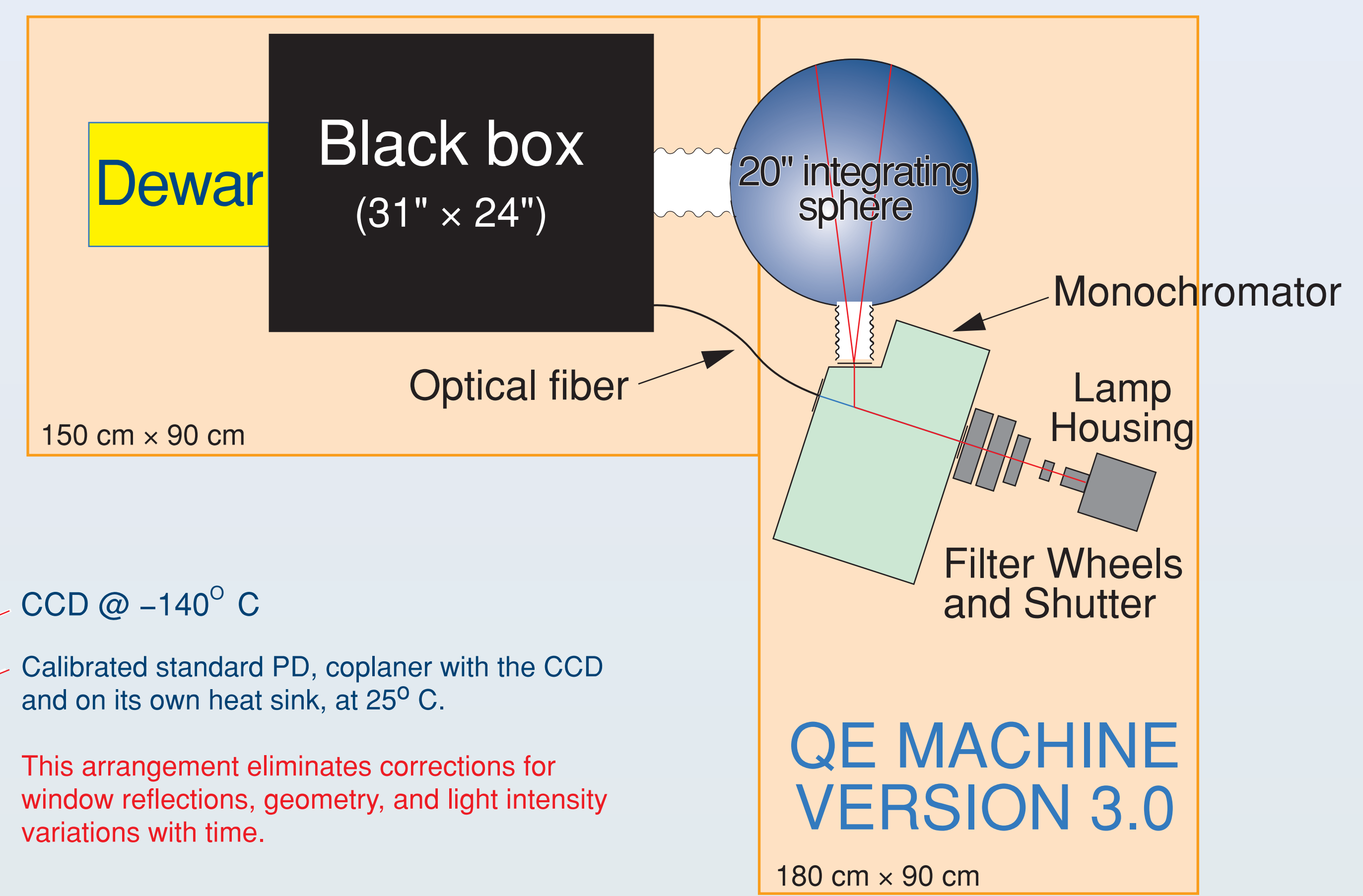
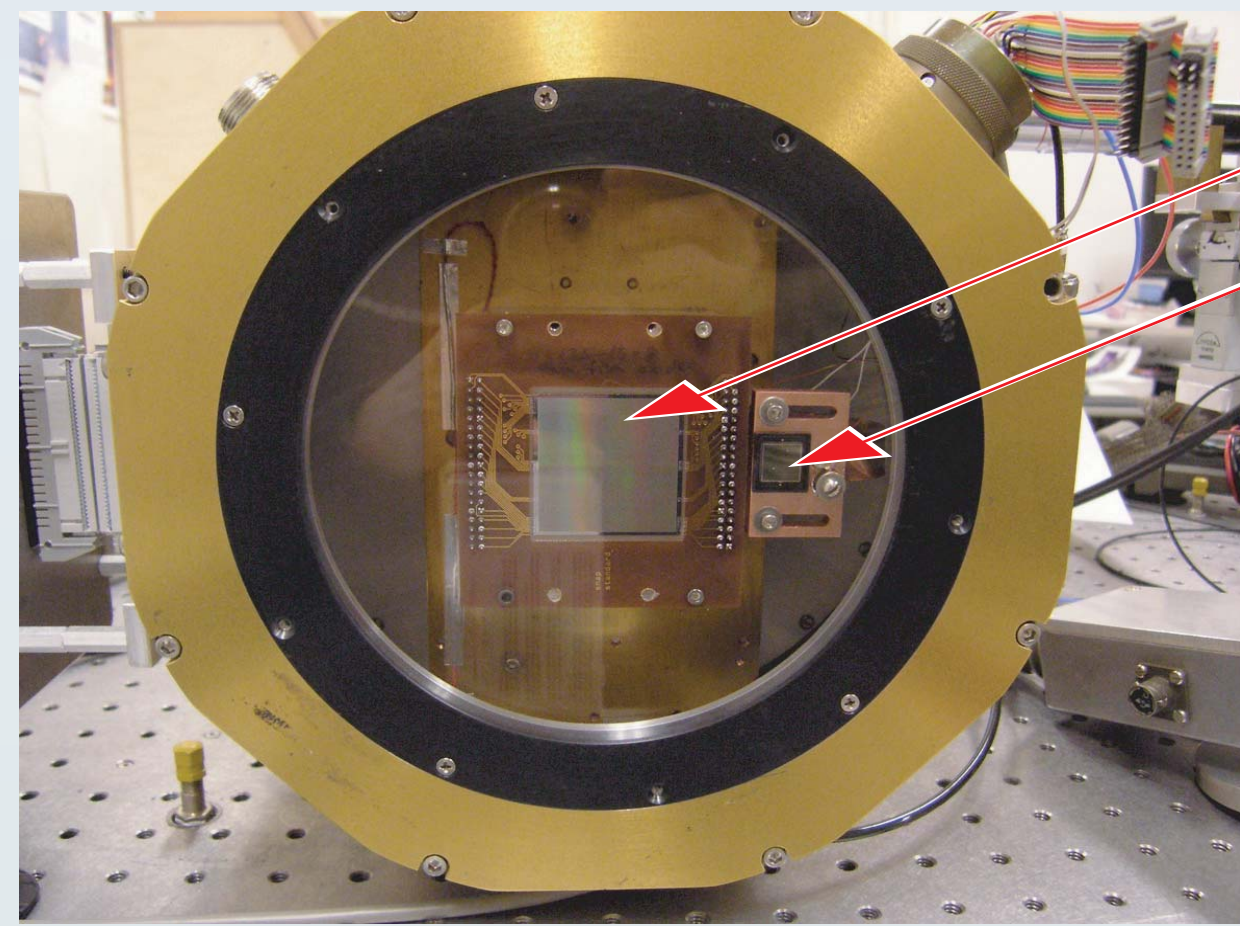


THE LBNL QUANTUM EFFICIENCY MACHINE

or: What can we do with a large dark box?

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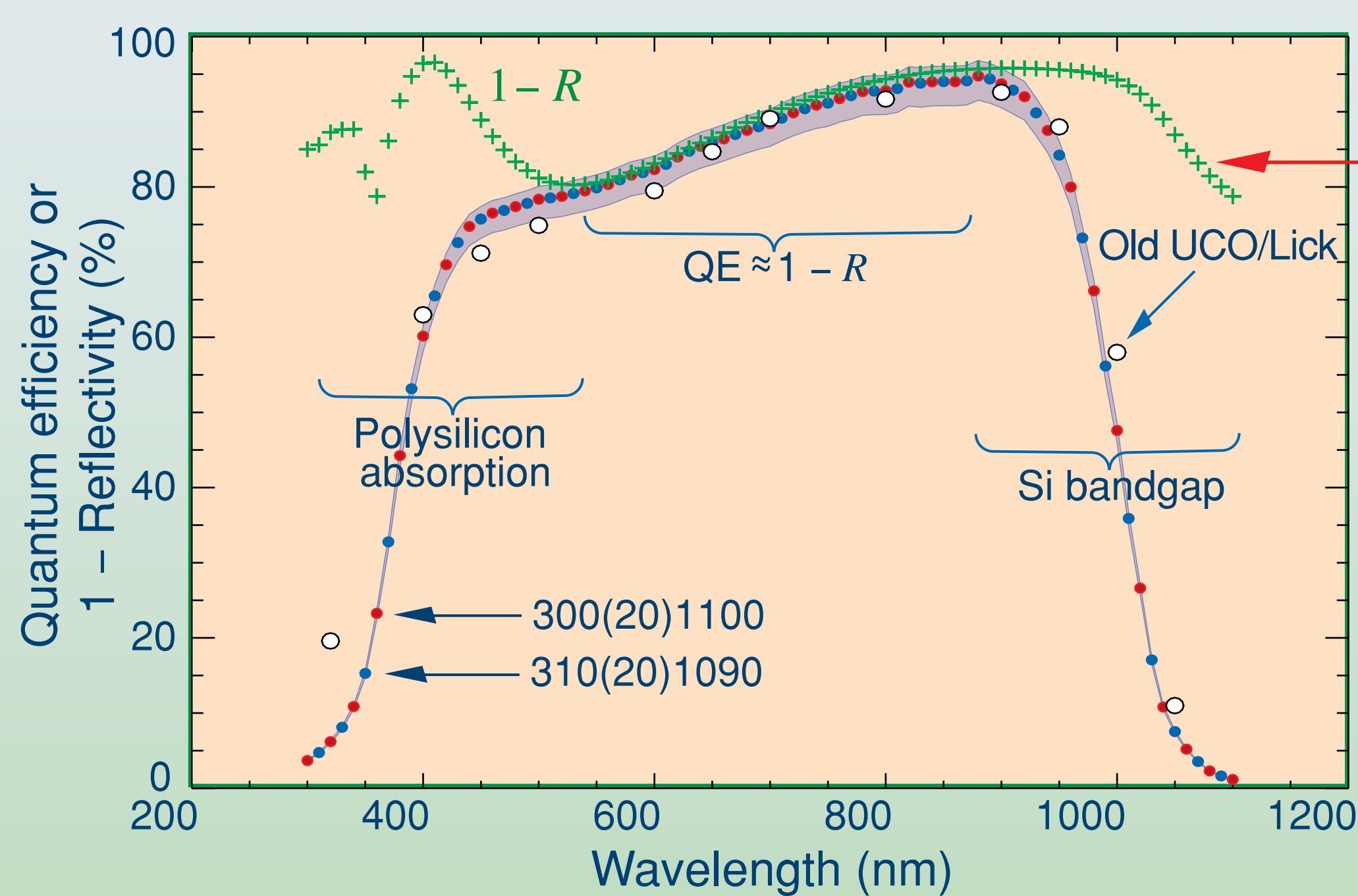
- Light from the Xe arc lamp goes through two filter wheels, which pass selected 150 nm bandpasses. The light is dispersed by the MS257 monochromator, and then forms a spot on the wall of the integrating sphere.
- The homogenized light from the sphere exits through a 4-inch port at right angles to the incoming light.
- It illuminates the exit port of a dark box about 1 m from the integrating sphere exit port.
- The CCD and a calibrated reference photodiode are inside the dewar (shown below) attached to the dark box.



Measure CCD quantum efficiency

This is the primary function of the QE Machine.

"Typical QE scan" of a proto-SNAP CCD. Red dots mark 10 nm bands scanned upward by 20 nm steps; blue marks an interleaved downward scan. In part, this serves as a stability check.

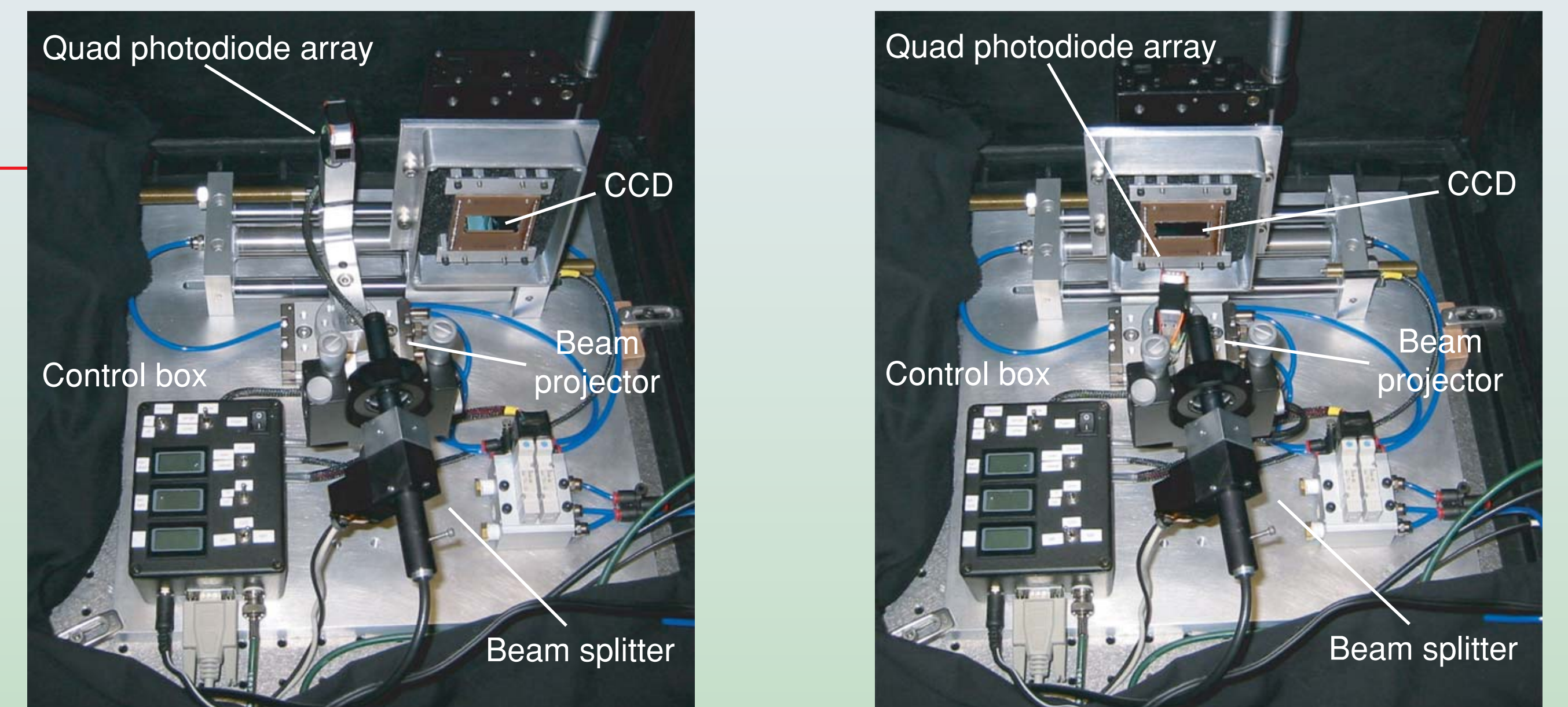


Reflectivity measurement on the same CCD, plotted as 1-R

Measure reflectivity

We consider measurement of reflectivity (R) to be a necessary part of a QE determination: $1-R \geq QE$ everywhere, and $1-R = QE$ in the broad central region where the internal QE is essentially unity. It is an invaluable "sanity check." In addition to a variety of beartraps in direct methods,

ALL OF THEM INVOLVE BLIND FAITH IN THE REFERENCE PHOTODIODE CALIBRATION



Reference position: Light from optical fiber is focused onto photodiode

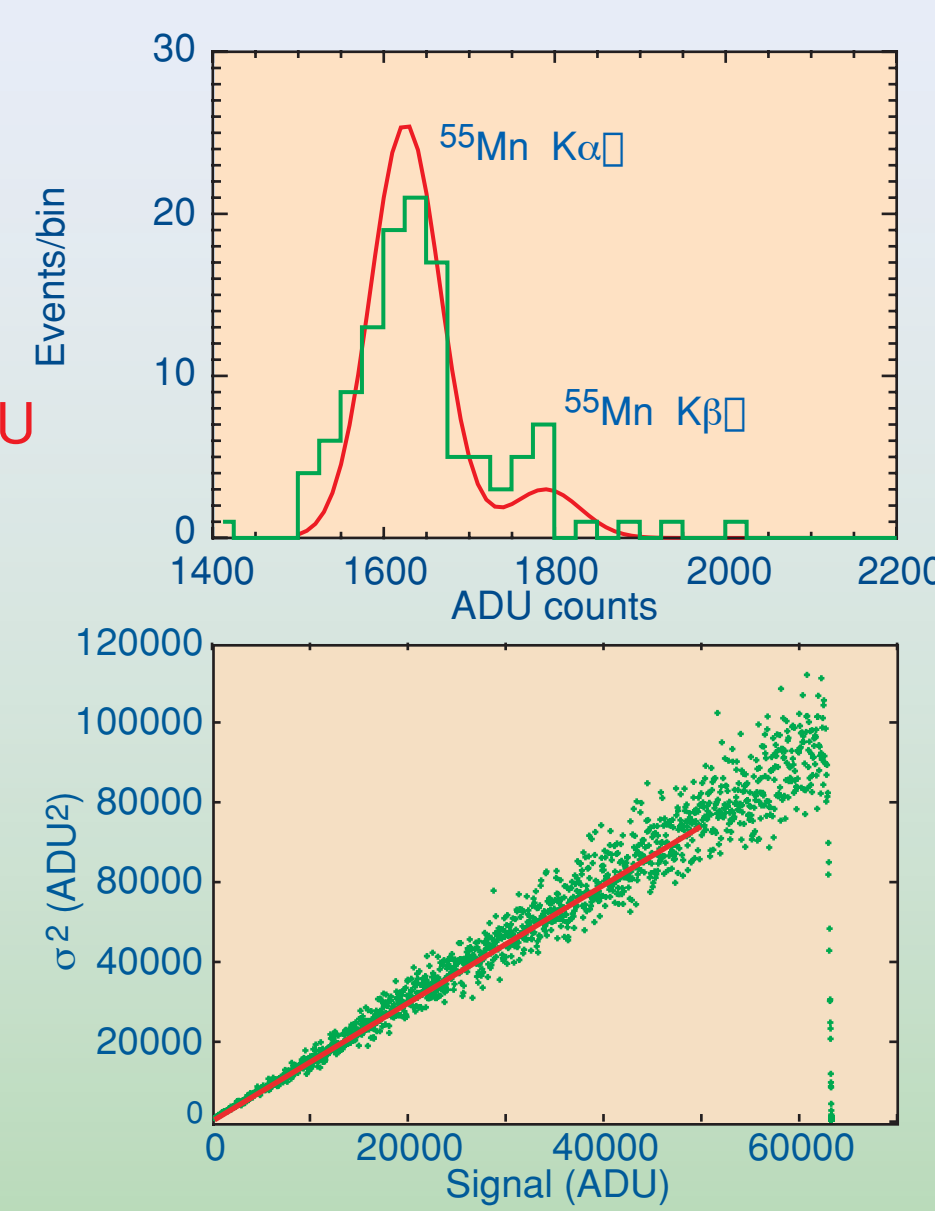
PD arm swings around, CCD carriage moves over

Reflection position: Light reflects from CCD before reaching the photodiode

Calibration:

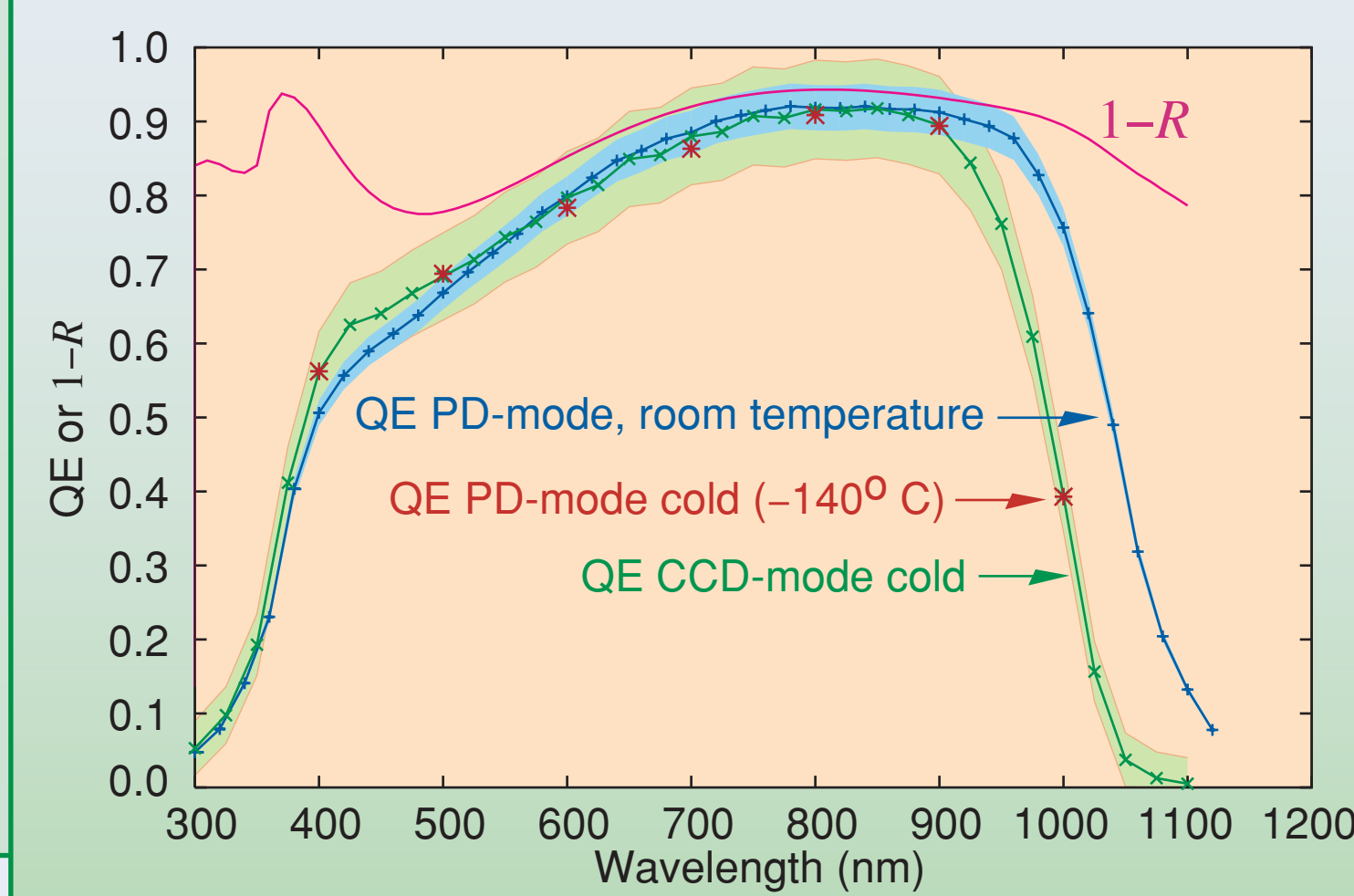
Problem is to find the number of ADU counts associated with one electron.

- Traditionally, calibrated with the 5.90 keV K-alpha Mn x ray associated with ^{55}Fe decay. But conversion from eV to ADU is temperature-dependent.
- Or use the "fast photon transfer method." The photon transfer method uses the fact that if there are $\langle n \rangle$ electrons per pixel, the fractional variance is $1/\langle n \rangle$. The "fast photon transfer method" is a tricky way to do it in one exposure.



Measure quantum efficiency of CCD

(wired as a CCD, any temperature)



The CCD's reset MOSFET is connected to the serial register, and the photocurrent is measured between the reset drain and ground. A 30 V substrate voltage ensures total depletion.

Currents in the CCD cum PD and the calibrated photodiode are measured; their ratio, with area corrections, is essentially the QE ratio.

Wavelength scans are made as in the CCD mode measurements.

Note bandgap shift with temperature

Measure the intrinsic point spread function

The "Spot-o-Matic" spot projector

A long focal-length microscope objective is used to focus light from an optical fiber (not shown) from the monochromator axial port onto the CCD. The beam size (rms) is $1.3 \pm 0.1 \mu\text{m}$.

Define a fiducial region which can totally contain the projected spot. Scan across until the spot is totally outside the region. The profile maps the integral of one projection of the point-spread function. This measurement does not depend on pixel size.

