

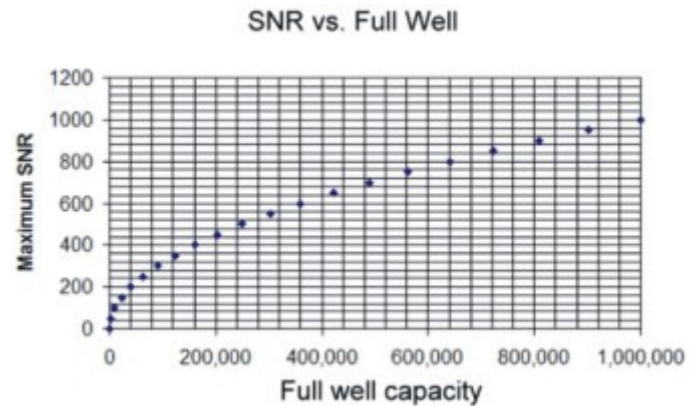
# Signal Noise Ratio

## Signal to noise ratio and full well capacity

Consider an application in which you must measure the light falling on a particular pixel to a precision of 1% (SNR = 100). Even with a perfectly noiseless camera and noiseless detector, the random nature of photons imposes an effective noise level (shot noise) which must be captured in order to make the measurement.

Poisson statistics associated with the nature of photon generation is such that the rms noise is equal to the square root of the (average) number of photoelectrons. Thus, in a perfectly noiseless camera, the number of photoelectrons needed to achieve 1% measurement precision is  $(\text{SNR})^2 = 100^2 = 10,000$  electrons.

In Figure 1, the maximum achievable signal to noise ratio is plotted as a function of signal electrons. From the figure it can be seen that, for the most precise measurements, the CCD must be able to handle large numbers of photons per pixel. The number of electrons which can be contained in a pixel is referred to as the full well capacity, and is one area where scientific grade CCDs differ from CCDs designed for other purposes. The amount of charge a CCD can store in each pixel depends largely on the physical size of the pixel.



**Figure 1** Full well capacity in electrons vs. maximum SNR

Full well capacity in electrons vs. maximum SNR For this reason, scientific CCDs usually have relatively large pixels, as large as 12 to 27 microns on a side. Since the cost of producing integrated circuits is strongly area dependent, non-scientific CCDs are usually made as small as possible with pixel sizes of 8 microns or less, and a correspondingly smaller full well capacity. For example, a consumer grade CCD with a pixel size of 7 microns may have a full well capacity of around 40,000 electrons. In this case, the highest precision possible would be about 0.5%. In contrast, a scientific grade CCD with a full well of 400,000 electrons would allow for over three times more accuracy.