Quantum Efficiency and Optical Sensitivity

Optical sensitivity quantifies the minimum light level which can be detected above the camera's read noise. For a given exposure length, the two factors which effect sensitivity are: 1) how many signal photoelectrons are generated within a pixel for a given illumination level, and 2) how many photoelectrons needed to be reliably detected over the cameras inherent noise floor.

The percentage of incident light which is converted into useable signal electrons is referred to as the Quantum Efficiency or QE. Figure 1 shows a typical CCD QE curve. A key aspect to note in Figure 1 is that the QE is a function of illumination wavelength. This dependence on wavelength means that a camera with a high QE in the green (550nm) wavelengths may have a substantially lower QE in the far red (800nm) or vice-versa. A common point of confusion results when a manufacturer simply states that they have a QE of, say, 40%. This statement is, by itself, meaningless and potentially misleading. Unless the wavelength is specified, QE is not properly defined. Figure 2 shows a typical QE curve as a function of wavelength.

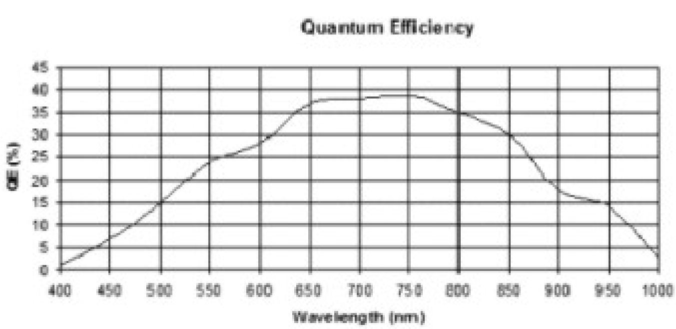

Figure 1. Typical Quantum Efficiency Curve

The second parameter which directly impacts camera sensitivity is the read noise of the camera. Lower read noise means that the camera needs fewer photoelectrons to overcome the read noise level. Thus, a camera with 25 electrons of effective read noise will require half as many photoelectrons to produce an image than a camera with a 50 electron read noise floor.

This is an important point because many camera users make the erroneous assumption that a camera with high quantum efficiency will automatically be more sensitive than a camera with low QE. For example, assume you are evaluating two cameras - each with a 200,000 electron full well capacity.

	Camera A	**Camera B**
Full well capacity	200,000 electrons	200,000 electrons
Quantum Efficiency (550nm)	80%	20%
Dynamic Range	200:1	4,000:1
Read noise	1,000 electrons	50 electrons

Camera A has a QE of 80% at 550nm and a dynamic range of 200:1. Camera B has a QE of only 20% at 550nm and a dynamic range of 4,000:1. It would seem at first glance that the camera with 80% QE would be the most sensitive because it is 4 times more efficient at converting the selected wavelength of light to signal electrons. However, this neglects the fact that the inherent read noise floor of camera A is 1,000 electrons (200,000 electrons/200) whereas camera B has a read noise floor of 50 electrons (200,000 electrons/4,000). Thus, although camera A is four times more efficient in capturing the light, camera B requires 1000/50 = 20 times fewer photoelectrons to generate the same video signal. The end result is that the camera with four-times lower QE is actually 5 times more sensitive than the other camera!