Signals & Noise HomeworkW8

(1) The example of quantum efficiency of a photoconductor given in class had no reflection loss at the back side. The more general case has reflection loss at both front and back. Show that the quantum efficiency of a photoconductor that has reflectivity R at both the front and back faces, absorption coefficient a, and thickness d, is given by:

$$\mathbf{QE} = \frac{(1-R)(1-e^{-ad})}{1-\mathrm{R}e^{-ad}}$$

Hint: recall the McClaurin series $\frac{1}{(1-x)} = \sum_{0}^{\infty} x^n$

Draw a diagram of the reflections, and show your math.

(2) The charge transfer process in a CCD is not perfect. You must leave enough time to coax most all the charge along to the next electrode. This wait time must be long compared with the thermal transfer time τ. If you cool high purity silicon to 170K, τ becomes short, about 12 nanoseconds. The fraction of charge lost per transfer is exp(-*t*/τ) where *t* is the time spent moving the charge packet to the next electrode. *t* is called the clocking time, and for a 3-phase device there are three electrodes per pixel. Suppose you have a 2000x2000 pixel CCD which you cool to 170K and read out a full image in 2 seconds. You thus do 2000 parallel (x3) x 2000 serial (x3) charge transfers in 2 sec.

What is the parallel register clocking rate in Hz?
What is the serial register clocking rate in Hz?
What is the fraction of charge lost per parallel register transfer?
For an *m* phase CCD the charge transfer efficiency CTE per pixel is:

CTE = [1-exp(-*t*/τ)]^*m*

Using these numbers, how many "nines" does the CTE have (i.e. 0.99995 has 4 nines)?

(3) In the previous example you of course send these electrons into a sampling capacitor and then into an amplifier. There are four sources of noise originating within the camera. Can you say what they are? Hint: there is loss (see previous problem), and there are discrete charges.

(4) The above noise occurs only on readout. You use this somewhat noisy CCD camera to do photometry of a faint star with sky background light. In fact the background light is far brighter than the star. You can choose your integration time t_{int}, and to be efficient this is long compared with the readout time. If the flux (number of photons/sec) from the star is n_s and from the sky is n_{sky}, what is the S/N ratio in the case of <u>no</u> camera noise? Now for the real case: What condition must you have between all the noise sources for maximum signal-to-noise ratio? Hint: there are now 5 noise sources, one of which depends on t_{int} and is thus under your control.