CAN ELECTRON MULTIPLYING CCD TECHNOLOGY REPLACE THE PMT?

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In biological applications, the laser confocal microscope (LCM) is often employed to detect the location of fluorescent marker molecules. Under these conditions, signal levels from bright areas are often <20 photons/pixel (from the detector, assuming a 1.6 µs pixel time) while that from dark areas are likely to be <1 photon/pixel. Although this data rate limits the speed at which information can be derived from the specimen, saturation of the fluorophor, photobleaching of the dye, and phototoxicity often prevent it being increased by simply using more laser power.

Currently, most LCMs use photomultiplier tubes (PMT) as photodetectors. Although, at room temperature, PMT dark current is negligible compared to this data rate, PMT quantum efficiency (QE) is quite low: depending on the photocathode material, 15-30% in the blue/green but only 0.5-3% in the range of 700-800 nm. The low red sensitivity is particularly important because it has become evident that living cells seem to be relatively less sensitive to red/near-IR light and hence there is increased interest in operating in this part of the spectrum(1). In addition, the charge multiplication process that occurs in a PMT produces multiplicative noise which reduces the "effective" QE by an additional 30%(2).

By contrast, a modern, rear-illuminated, scientific-grade, electron-multiplier charge-coupled devices (EM-CCD) can now routinely readout the signal from a square sensor ~20 µm on a side with an effective QE of 45%, a read noise of only <0.04 e/pix and no multiplicative noise. For this reason, we have begun to develop, a single-pixel, Si sensor, called the EM-CCDiode, employing the same readout techniques used to sense charge in an EM CCD(3). This work is an outgrowth of previous work using conventional CCD technology (4).

Initial experiments will employ a current 128 x 128 sensor, suitably masked so that only the bottom right pixel is illuminated and readout. Charge in other pixels will be dumped.

Eventually, we hope to fabricate special sensors with 3x3 or 5x5 pixel arrays linked to an EM readout system. The resulting detector should be far more compact, efficient and reliable than the PMT it replaces and will have the added flexibility of providing data at 3 different pinhole sizes simultaneously and also providing on-line optical alignment data.

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