Issues in the design of systems incorporating electron bombarded CCDs

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ABSTRACT

Single electron detection is desirable in systems incorporating EBCCDs. The sources of noise in single electron counting are discussed and an expression is given for the total noise. The effect of charge spreading is taken into account. Radiation hardness is also critical for charge coupled devices used in the electron bombarded mode. Two types of damage in CCDs are caused by keV electron irradiation: a flatband voltage shift and an increase in interface state density. A flatband voltage shift is more catastrophic to device performance than an increase in interface state density, especially for MPP devices.

Applications for EBCCDs

- Two dimensional photon counters
- Image intensifiers
- High performance CRT-based instruments
  - -- Streak cameras
  - -- Scan converters

Performance advantages

- High sensitivity (gain)
- High spatial resolution
- Low noise

Operating conditions

- Room temperature
- Video readout rates

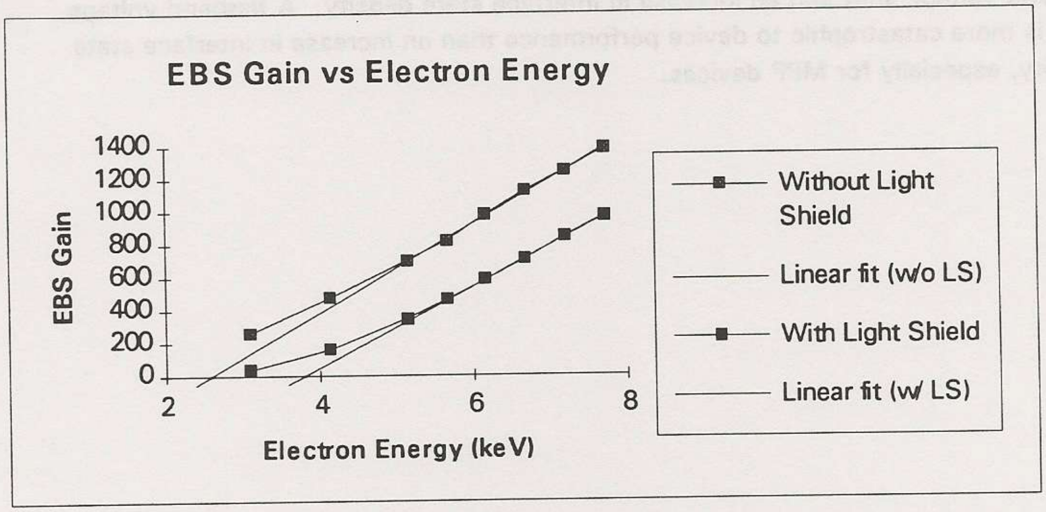
EBS Gain

Number of e-h pairs *created* = E_b/3.64 eV ± sqrt(F*N)

where F = Fano factor (.1-.2)

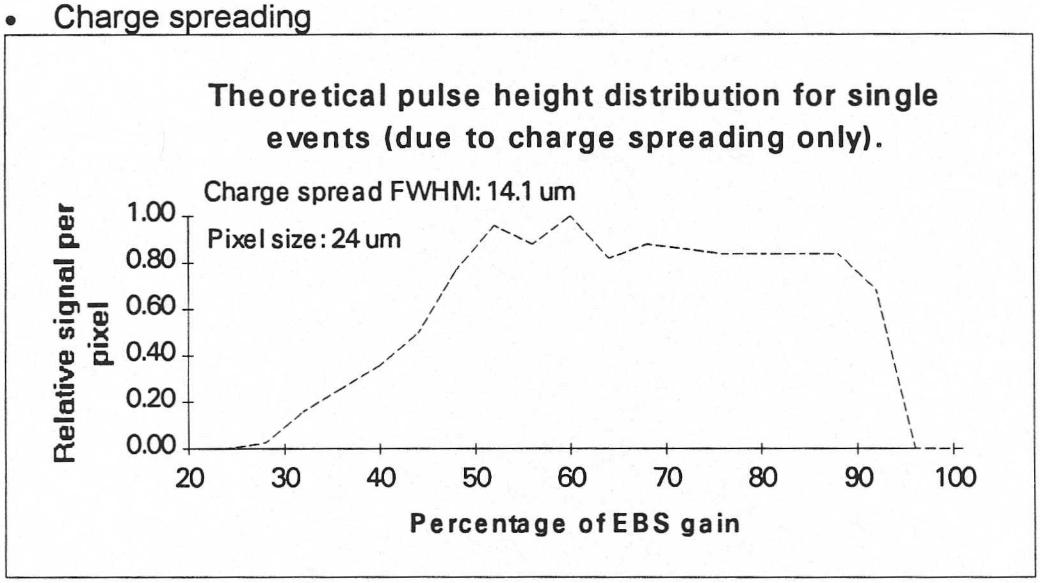
N = # e-h pairs

Number of electrons *collected* = Gain ± ???



Sources of noise during single electron detection

- Noise per event
  Fraction of collected charge times noise on gain
- Dark current shot noise
  Square root of the number of dark current electrons/pixel
  Worst for room temperature, long (1 second) integrations
- Dark current fixed pattern noise
  Pixel to pixel dark current non-uniformity can be subtracted
  But... that increases shot noise by the square root of 2
- Read noise
  100 - 200 electrons per pixel at 10 Mpixel/s
- Unwanted optical signal
  Depends on:
  - Spectrum of scene imaged
  - Transmission of photocathode & faceplate
  - Electron-optical magnification
  - Scattering & diffraction of intervening optics
  - Quantum efficiency of photocathode and CCD
- Charge spreading



Types of electron bombardment caused radiation damage

Flatband voltage shift

- X-rays create electron-hole pairs in the gate insulator.
- The holes are trapped leaving a net positive charge.
- The positive charge changes the potential under the gate (unless the device is pinned).
- A changed potential means well capacity is lost.

Increase in interface state density

- Interface states make it easier for electrons to "jump" from the valence band to the conduction band.
- Dark current is proportional to the interface state density.
- Interface states can also trap charge

MPP operation may suppress damage effects

- Inversion of the surface populates the interface states with holes, suppressing dark current generation.
- But... a flatband voltage shift can bring an MPP device out of inversion