Pixelated light sensors at ~ GHz

- Pin diodes are slowed down by their own capacitance and by the drift time inside the GaAs.
- With a diode bias of V Volts, for every photoelectrons V eV are dissipated
  - =>heating
- Possible Solution:
  - => Use photocathodes

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Negative electron affinity P.C.

- They have a layered semiconducting structure that boosts the quantum efficiency by ejecting the photoelectrons into the tube vacuum.
- Only ~ev/p.e. dissipated in semiconductor

Photocathodes for 1.06 Wavelength

- The cutoff wavelength is usually determined by the bandgap of the absorbing material
- The QE is dependent upon the degree to which the material can be made into a negative affinity device
  - Inversely dependent upon the bandgap and affinity
- Dark count is inversely dependent upon the bandgap of the material
  - Smaller bandgap materials have higher dark counts
- The larger the spectral range required the lower the overall efficiency of the detector

Long Wavelength Photocathodes

- To obtain spectral response to 1.06 μm the simplest approach is the use of InGaAs with In concentration of ~20%
  - Uniform composition material will lead to low spectral response (~6% total QE with ~0.5% at 1.06 μm has been demonstrated, advanced activation processes may increase these values)
    - Loss in QE of lower bandgap material is usually attributed to change in work function due to bandgap and affinity
  - Layered structure with GaAs termination will increase QE but run the risk of "brushlines" (uniform thin lines of low photoresponse)
    - Some loss in QE due to internal electrical barriers within the photocathode structure
  - Uniform "brushlines" can effect the overall photoresponse of the device to a small degree unless they are to such an extent that they would be visible with the naked eye on the bonded glass structure

Approaches to Reach 1.06 μm in order of increasing risk

- GaAs based system with doping of In to levels to create material of the composition $In_{0.2}Ga_{0.8}As$
  - Used advanced cathode structure so that activation can be on InGaAs or GaAs surfaces
- InGaAs on sapphire to mitigate chance of stress lines due to lattice mismatch
  - Requires growing material on foreign substrate
- GaSbAs on InP
  - Requires activation of a non-GaAs based material system if InP is left on surface

Photo-Current limits

- On Quartz the energy deposition is limited to ~10 microA/cm2 for times above 10 seconds due to power limitations.
  - No power density limitations for short bursts, only total energy density limitations
- On Sapphire the better thermal conductivity should improve this limit by >x10 (untested)

Vacuum tube advantages

- Photoelectrons can be accelerated, focussed and decelerated on segmented metal anode electrodes
- Easy pixelization, no stray capacitance problem, high speed (>>GHz) possible
- ns gating easy
- Synchronous modulation possible
- Possibility of variable (HPD) gain, between 1 and 1000

  if metal anode is replaced by fast (GHz) silicon diode

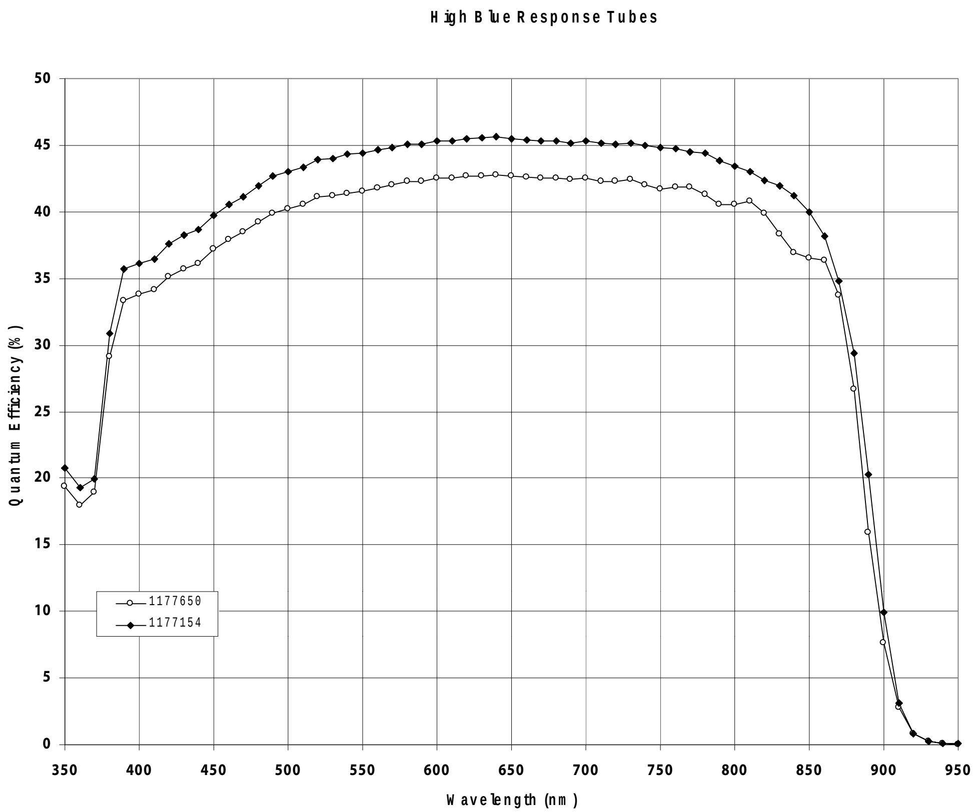
Approach

- ITT would be able to fabricate internally the first approach listed.
- For the last two approaches ITT would sub-contract to a fabrication house experienced in the growth of the material in question
  - In house facilities would be used to complete the processing of the device
  - If approach were successful, ITT would then attempt to develop the growth capability in house

ITT Cathode Fabrication is Flexible

- The next two view graphs show the spectral response of photocathodes grown, fabricated, and activated at ITT
- The first view graph shows a high blue response cathode using a high bandgap window layer on the GaAs activation layer
- The second view graph shows an extended red photocathode structure based on InGaAs material system
  - Two curves show the extended red behavior of In doping
  - One curve shows a standard GaAs spectral response

UV Blue Photocathode Response



Special cathodes using GaAs activation surfaces but obtaining high QE in the blue region of the spectrum

Simple Extended Red GaAs Based Photocathode Response