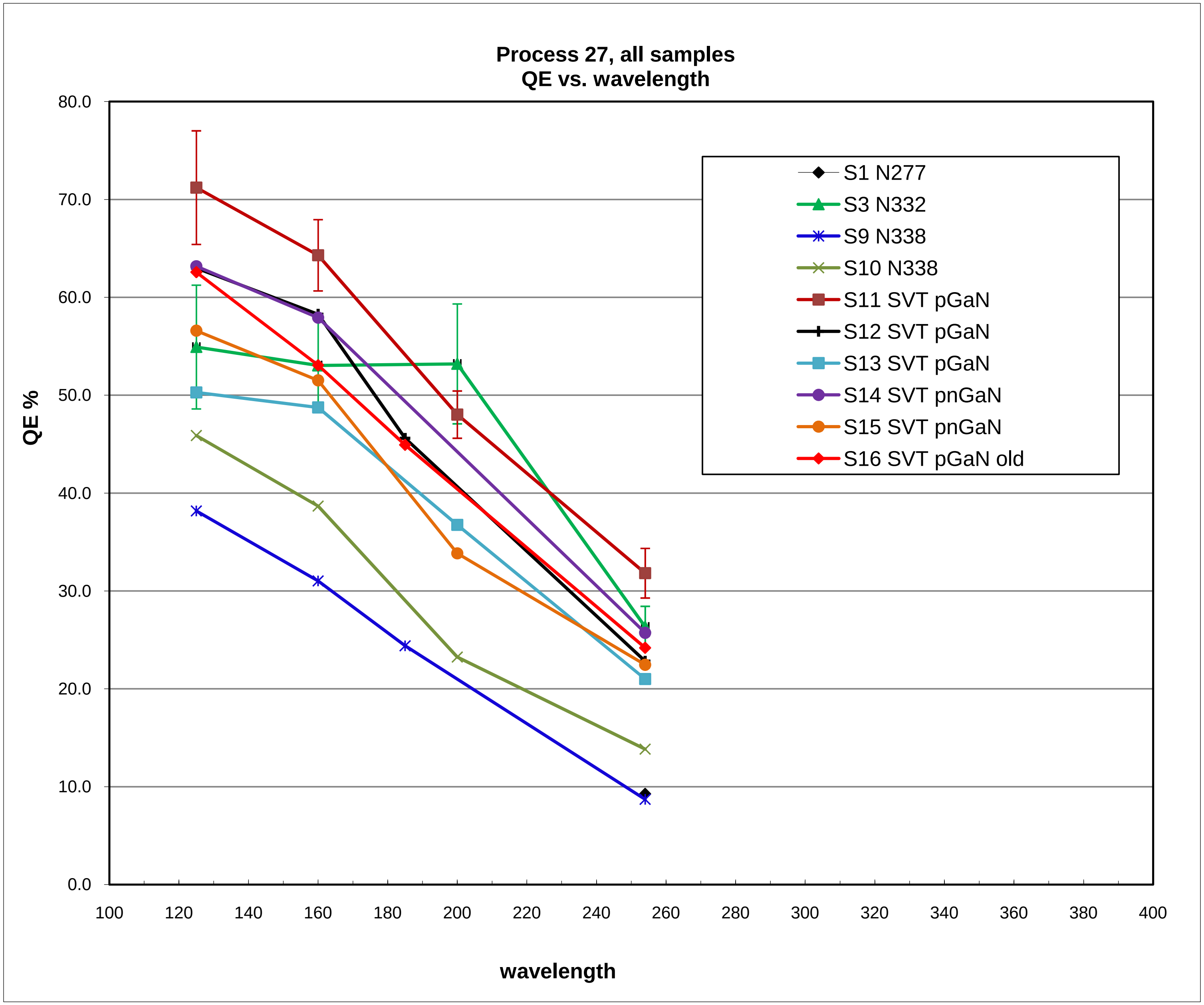
GaN Photocathodes and EBCMOS Detectors for UV Astronomy

Bruce Woodgate, Tim Norton (GSFC) and Charles Joseph (Rutgers U.)

Aug 30, 2011

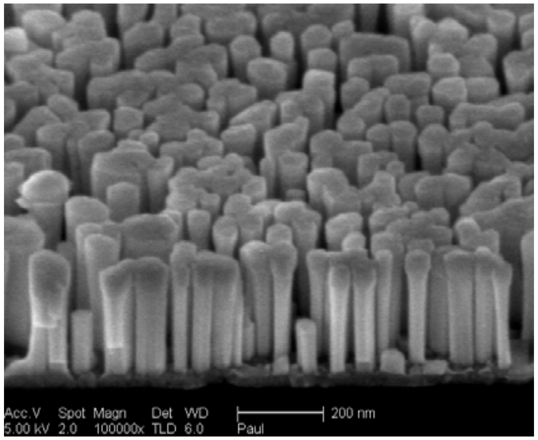
August 2011 GaN photocathode results – process 27

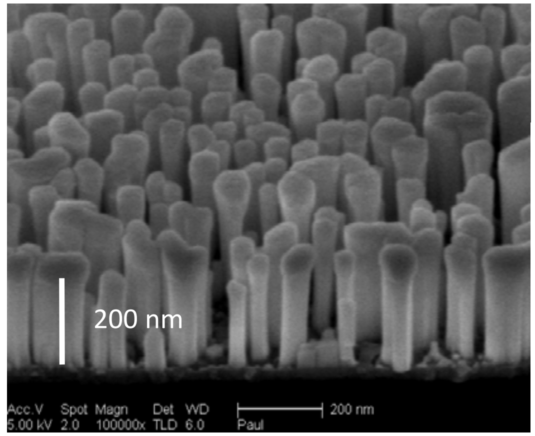


Nanowire structuring

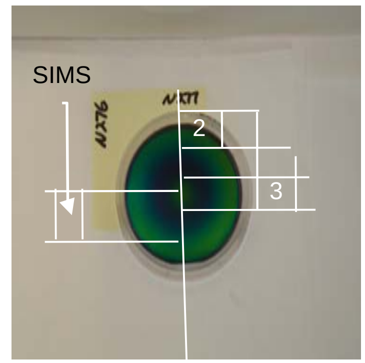
- **Nanowires may lead to higher QE due to :-**
- **Higher absorption – lower reflectivity – analogous to "Black Silicon"**
- **Much higher crystal purity – higher diffusion length and QE**
- **Can match a variety of layers eg Silicon MCP and Ceramic MCP substrates** – less dependence on substrate crystal matching.
- **Surface escape barrier lowering from Electric Field concentration**

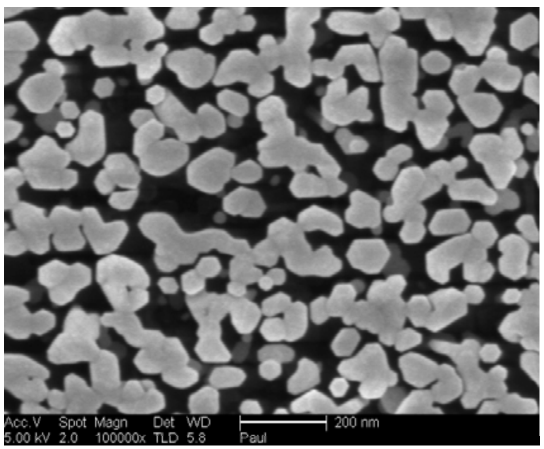
New NIST material - N277 morphology

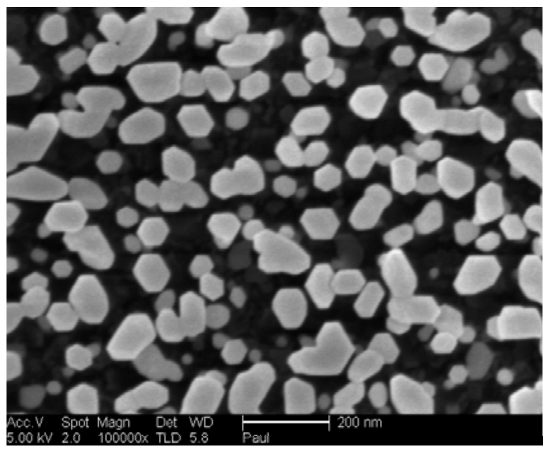




Growth Conditions :-
Mg cell: 360 °C, then 370 °C
Substrate: 782 °C ,then 637 °C
Time: 3h, then 1 h







N277_p12.tif, r = 30mm
Coverage ≈ 0.63

N277_p09.tif, r = 20 mm
Coverage ≈ 0.48

Using high QE opaque photocathodes in a detector

High QE opaque photocathodes can be used most directly for imaging with electron bombarded CCD or CMOS detector readout such as the EBCCD flown on IMAPS (Jenkins et. al., 1988; Joseph and Jenkins, 1991).

The oblique magnetic field allows separation of the input window from the CCD or CMOS anode *, and is the only known method of directly using the opaque photocathodes with their demonstrated high QEs*.

Novel magnet designs that dramatically reduced the weight and volume were first introduced by Lowrance and Joseph (1991).

A ruggedized version of the EBCCD has been developed in a sealed tube (C. Joseph, PI), offering 25-30% peak QEs with Cs_2Te compared with ~10% for MAMA (HST) and ~9% for GALEX (NUV), both MCP detectors.

The new EBCCD package has a reduced weight by a factor of 3, bringing the weight and volume of the EBCCD well below the weight of most MCP detectors.

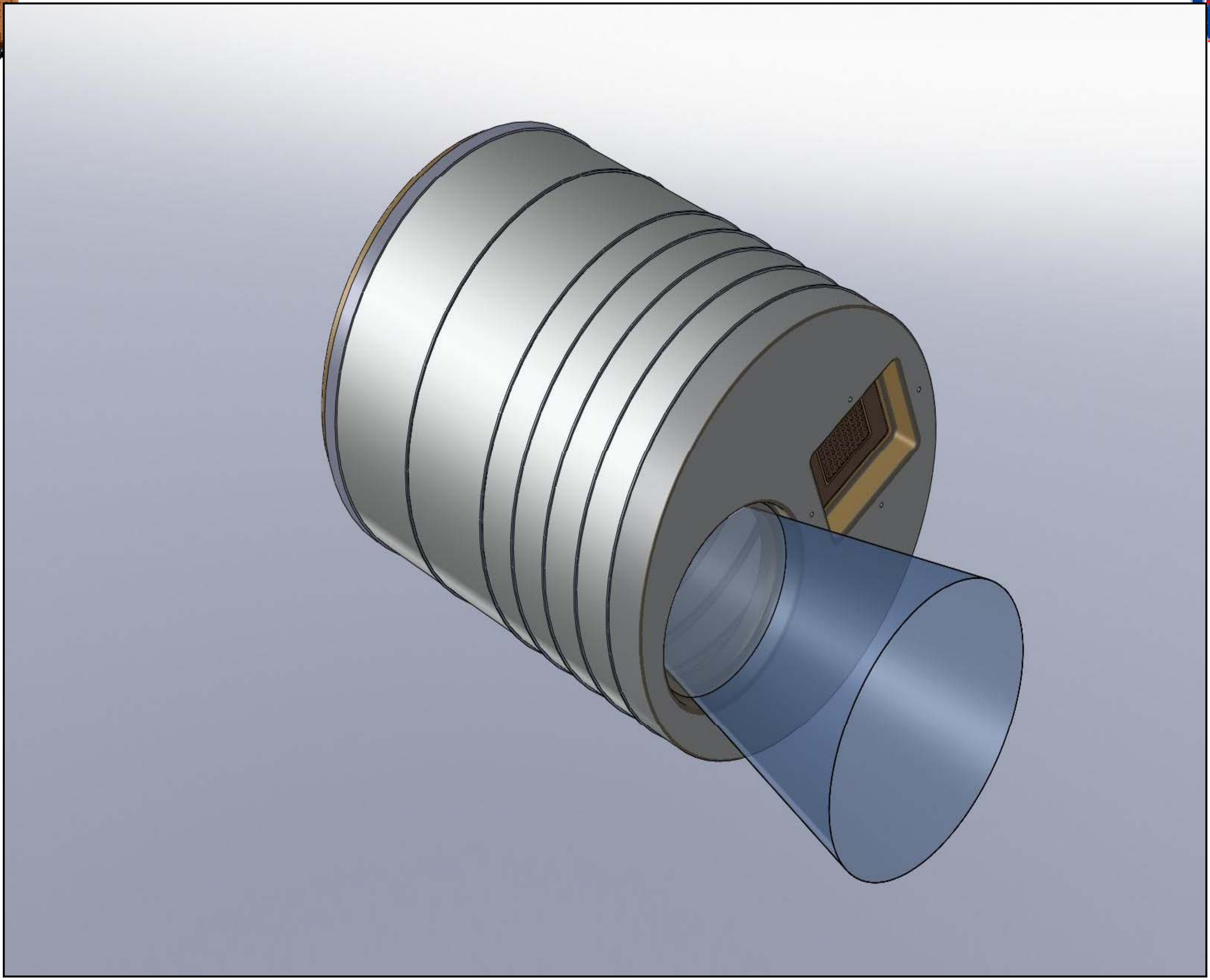
Magnetically focused EB readout configurations are expected to have significantly improved lifetime characteristics compared to MCP based detectors since there is no active, large area source of both neutral and ionized contaminants which may be deleterious to the photocathode.

Back-thinned CMOS detectors are preferred to CCDs because of faster framing, lower power, and improved radiation tolerance.

Therefore we plan to couple our GSFC high QE opaque GaN and KBr photocathodes into Rutgers EBCMOS detectors.

EBCMOS Detector Tubes

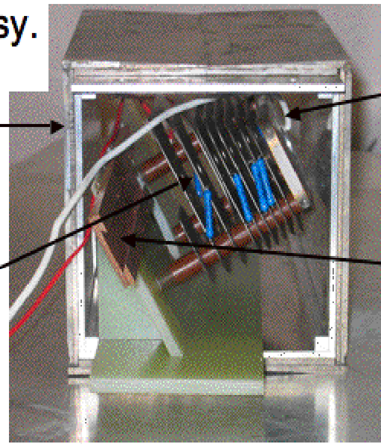
Rutgers EBCCD/EBCMOS detector



Rutgers/GSFC Bread-Board EBCMOS Detector

Demountable Tube Assy.
Side View

UV Light enters here, horizontal to the plane of the table.



Photocathode sits on a "top-hat" piece, to be bolted back here.

Rail for CCD/CMOS chip. The chip can be mounted on a Copper slide and moved into position.

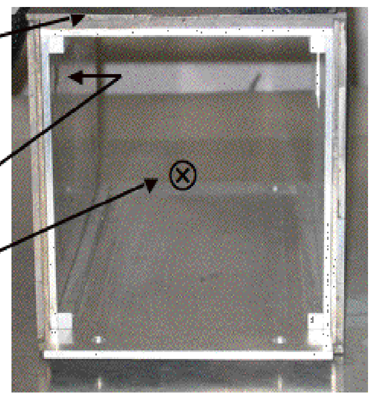
HV Electrodes with resistor chain. (Half of the resistors are on the far side.)

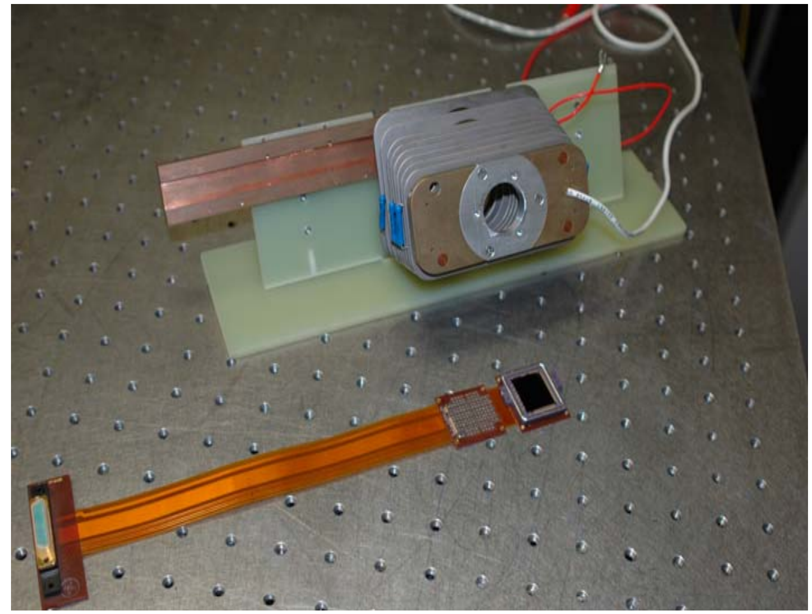
Side View of Magnet Assembly.

Note: the source magnets have cladding magnets surrounding these with the thickness of the strength & thickness of the cladding magnets increasing from the center line.

Entrance hole for the UV photons to enter.

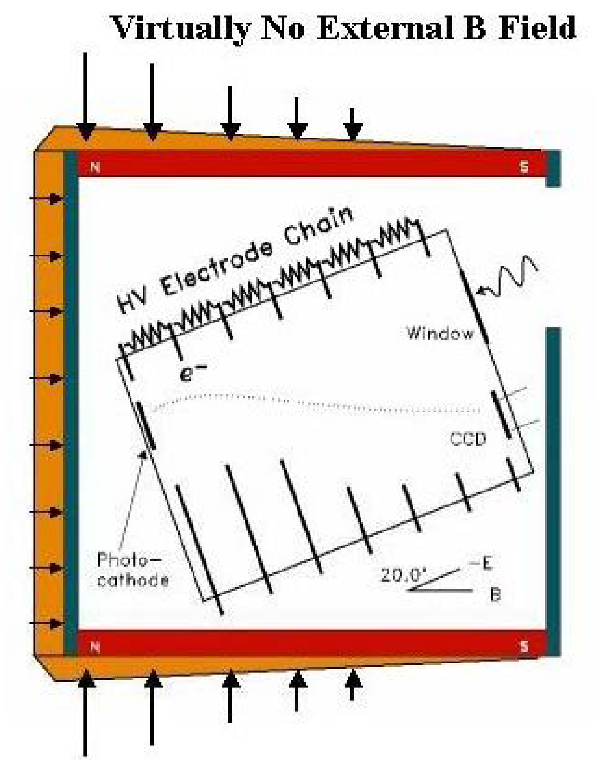
The assembly holding the electrodes, sensor chip, and photocathode all slide into the magnets shown here from an orientation into the page.

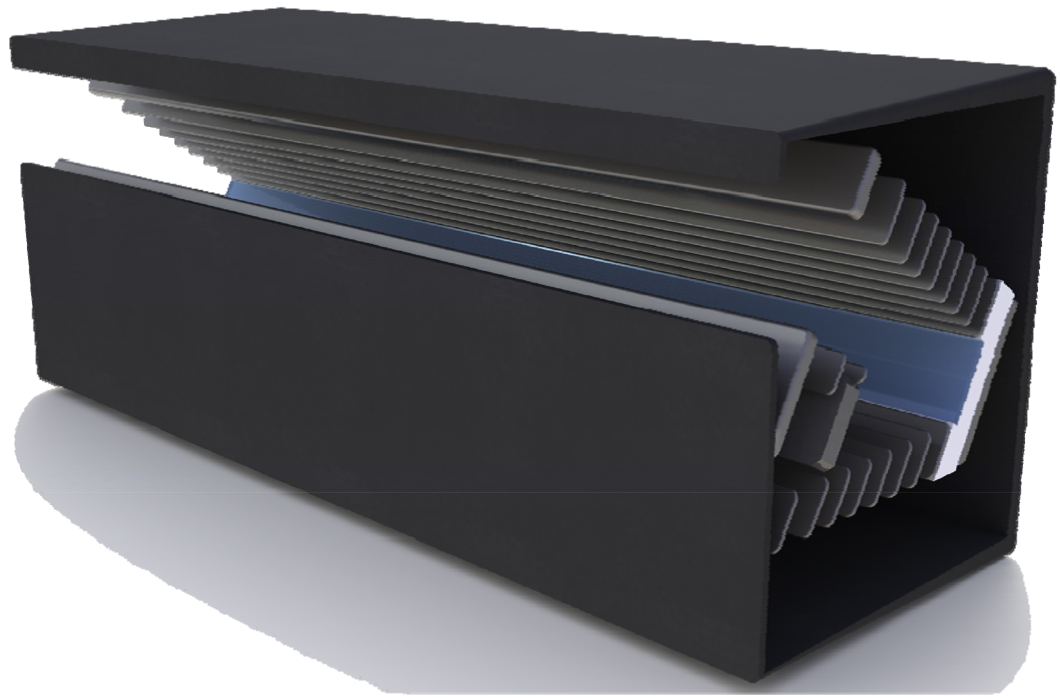




Bread-board electrodes with ISIE11 EBCMOS Sensor and Flex cable harness.

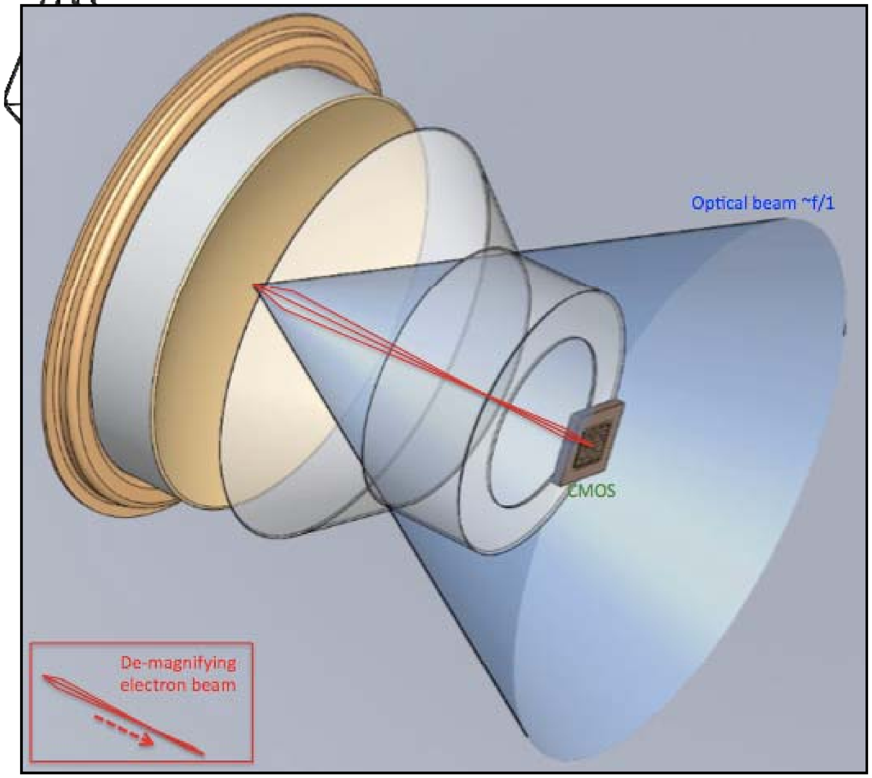
Rutgers Open Window (KBr/CsI) Magnetically Focused Detector – Rowland circle (from Lowrance, Joseph, Leupold, Potenziani, 1991)

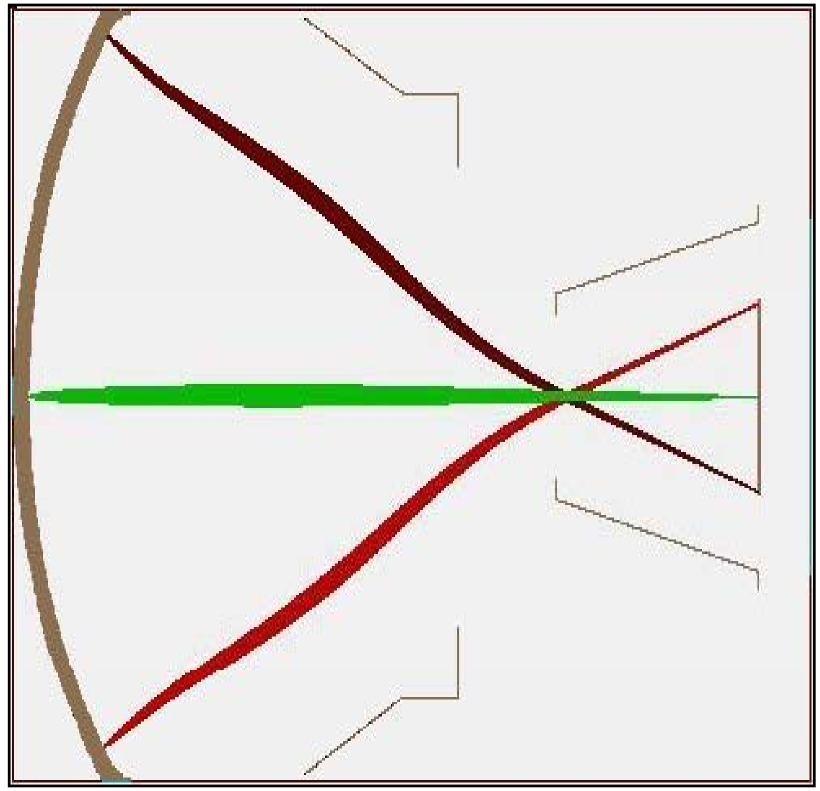


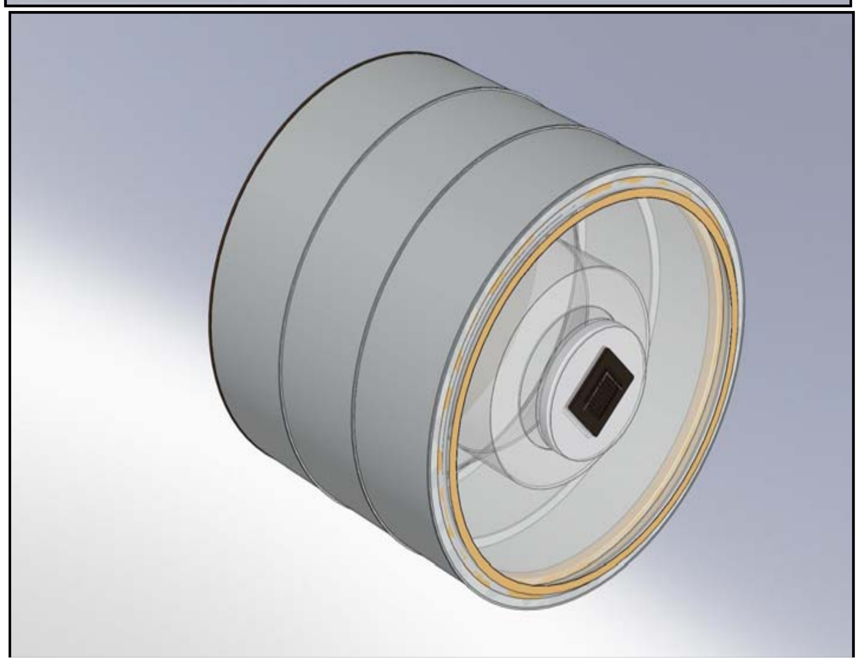


Intevac 2k x 2k back-thinned EBCMOS are 2-sides buttable for a **2k x nk** detector

Future f/1 large area electrostatic demagnifying tube design







Top-Left – Large area de-magnifying tube concept, with 6 inch diameter photocathode, wire mesh focusing anodes and 2k x 2k EBCMOS sensor.

Top-Right SIMION electro-optical simulation of inverter tube design – 10 kV applied voltage, transverse emission energy, 2 eV, PSF : 60 – 75 microns (fwhm)

Bottom-left – CAD representation of high QE, high Etendue tube design, Kovar-Ceramic,,MgF_2 window, In-Bi seal.

Future GaN photocathode development strategies

- GaN has proven to be a very efficient photocathode in opaque mode at wavelengths < 150 nm, QE > 70% at 121nm, demonstrated by GSFC, NWU, UCB and Hamamatsu.
- There is considerable room for improvement at wavelengths > 150nm.
- Strategies to improve include – higher purity, low defect material, leading to longer electron diffusion lengths, improved Mg p-doping profiles towards the photoemissive surface and nano-structuring of the material leading to higher electron escape probabilities.
- Replacement of the Cs layer with tailored heterostructures including InN cap layers would allow windowless operation and simultaneous high QE at shorter wavelengths.