Photocathode R&D

An overview of research towards high brightness, high average current electron sources

- Future of photo-injectors lies in high brightness, high average current 100mA (high duty factor)
- Places high demands on the photo-injector
  - Increased laser power
  - Increased QE from the photocathode
  - Increased RF power requirements
- Goal of this research program
  - Investigate and design photocathode to meet the challenges of the future accelerators

Application to the ATF

- Multi-phase research Plan
- First new candidate materials are tested off-line
- Once a suitable candidate has been found it is possible to look into mounting it in the PI
- Presently Mg cathode is in use, QE $2x10^{-3}$

Current Research

- Alkali Antimonide Cathodes
  - Cesium Antimonide and Cesium Potassium Antimonide, choke joint required
- Nb superconducting gun
  - Nb back surface is the cathode
- Lead Cathode
  - Lead coated copper, very similar to Mg cathode currently in use

Photocathode Criteria

- High QE
  - Metals 10^{-4} ϕ ~ 3.6 – 5 eV, requires UV photon
  - Alkali Antimonides 10^{-2} ϕ ~ 2.1 eV, Vis photon
  - Superconductors 10^{-4} ϕ ~ 4.3 eV, requires UV photon
- Robust
- Insensitive to contamination
- Insensitive to vacuum conditions
- Long Lifetime
- Laser wavelength

Alkali Antimonide Cathodes

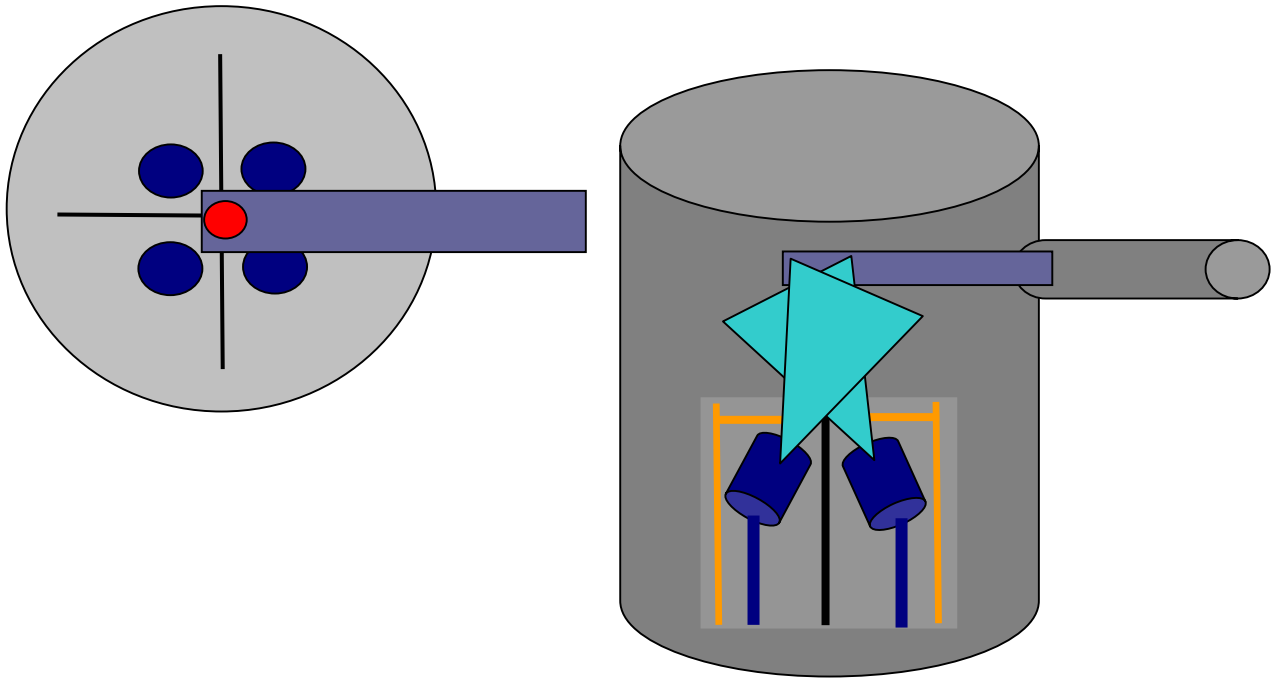
- Cs_3Sb or CsK_2Sb photocathodes
- Low ϕ, eases laser requirements (2nd Harmonic of YAG)
- High QE (presently QE~ .02)
- Lifetime issues
  - Poisoning, Cs ablation

Fabrication Procedure

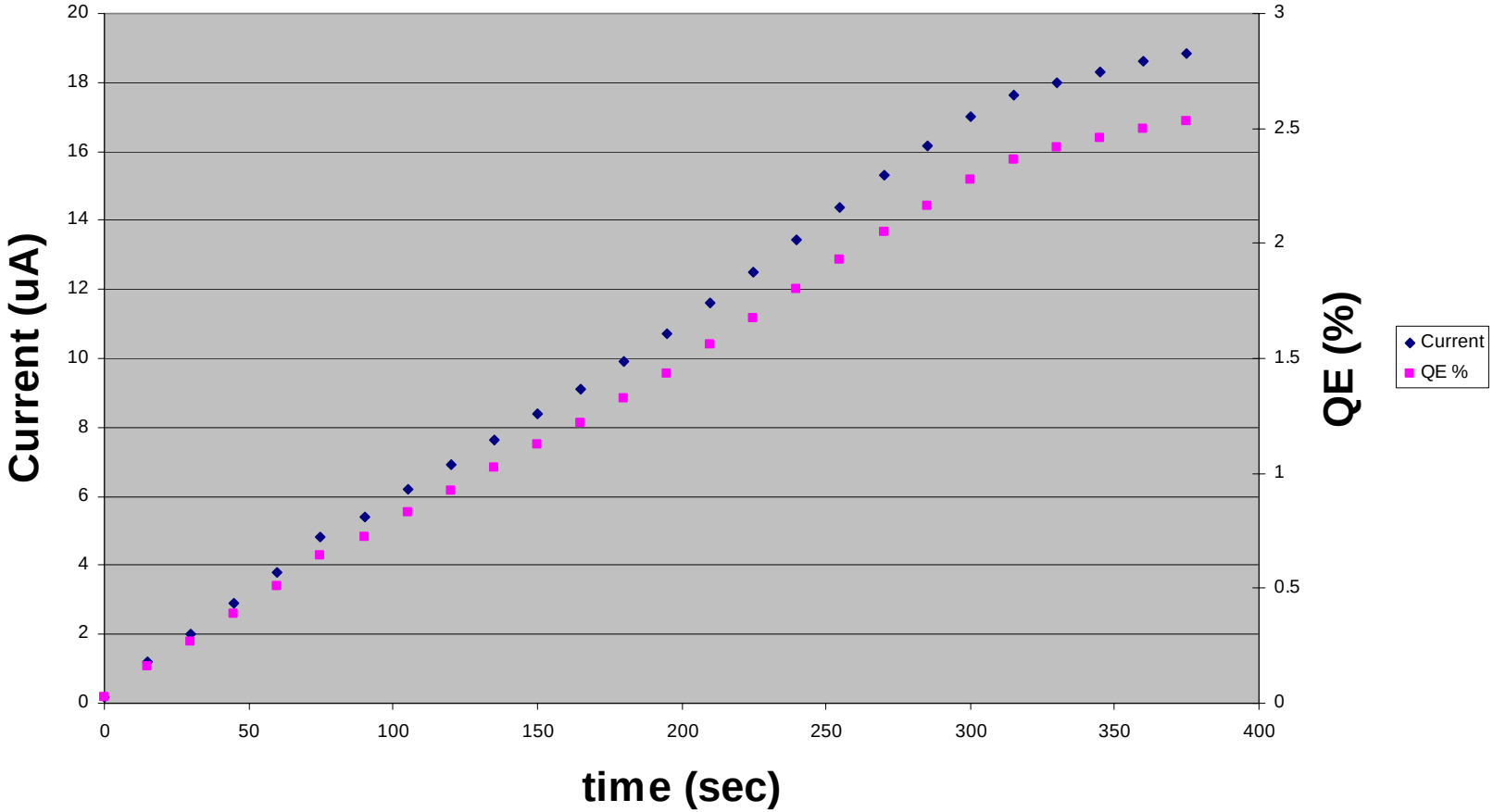
- Chemical Deposition system
- Polished 1” Molybdenum substrate
- Multi-stage deposition process
  - 200 Å Sb, 150 Å K, ~200 Å Cs
- Current is monitored as a function of Cs deposition

Photocathode Deposition System

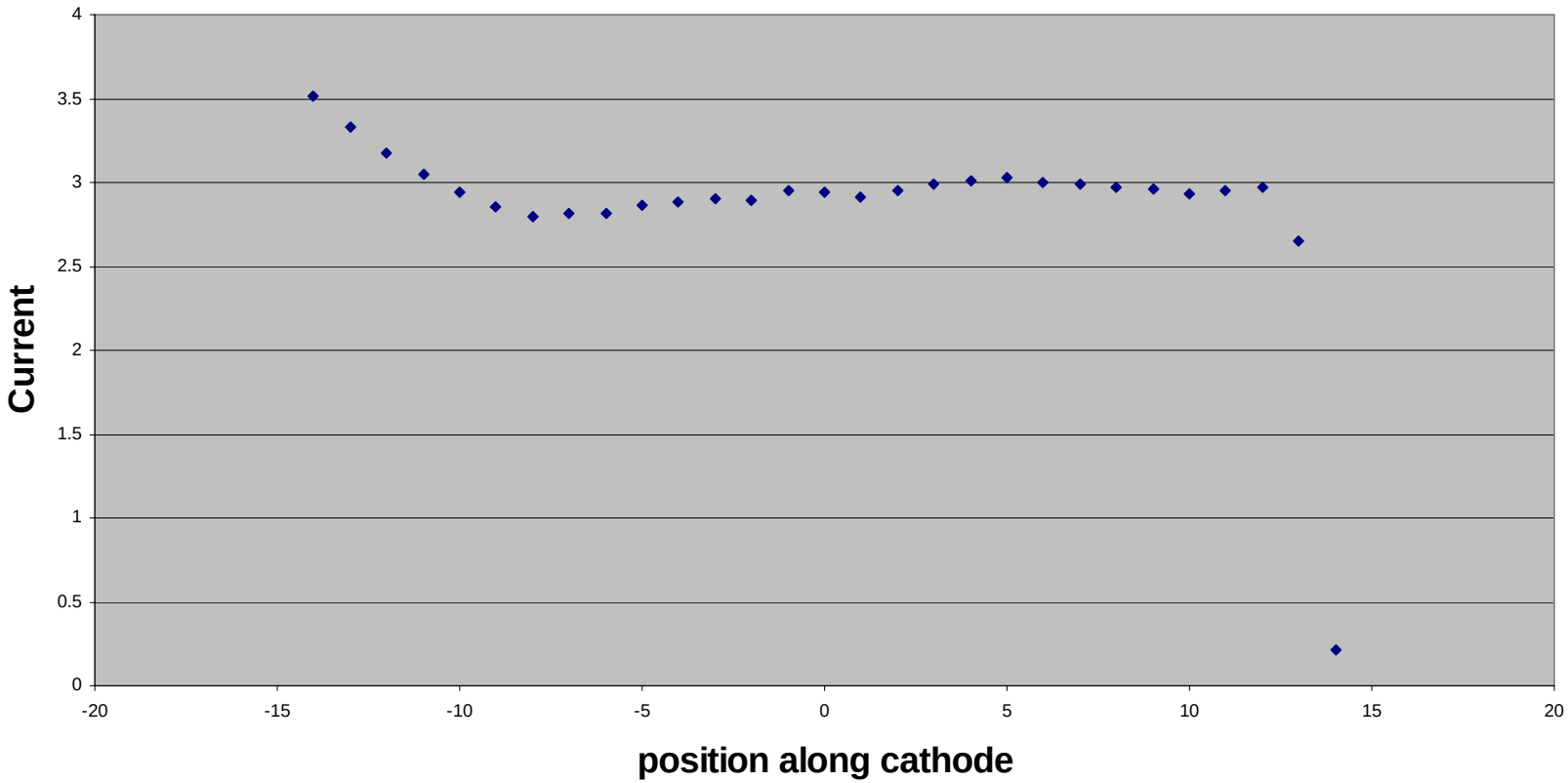
Deposition system



Current vs. Cs Deposition time



Surface Uniformity



Superconducting Materials

Advantages:

- Lifetimes very good, no fabrication, tolerates vacuum better
- SCRF gun
  - Very low RF losses
  - CW operation possible

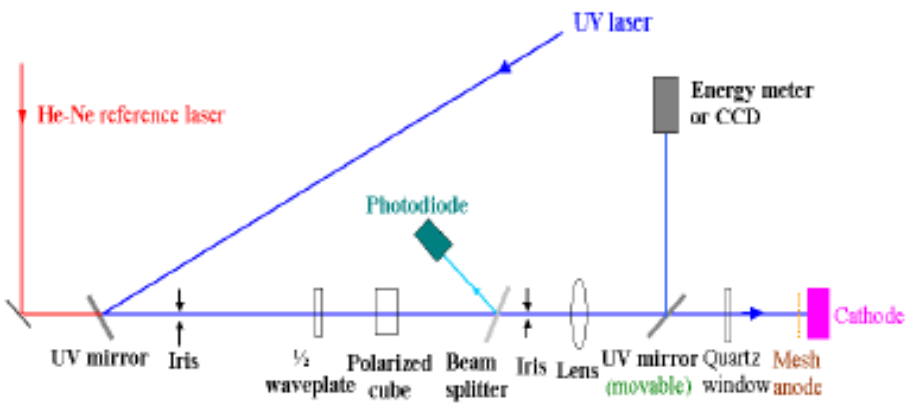
Disadvantages:

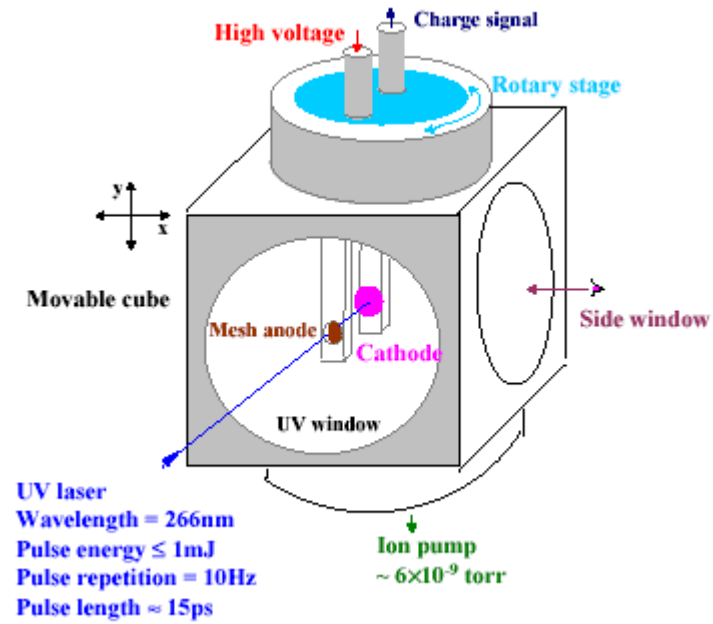
- QE, 10^{-4}
- UV light required

Nb sample

- Nb, RRR=250 6mm long x 9mm diameter
  - Surface polished, cleaned, BCP, diamond polish
- Quantum Efficiency (w/ 1 MV/m field):
  - Before laser cleaning, 266 nm: 8.4×10^{-7}
    248 nm: 2.2×10^{-6}
  - After laser cleaning, 266 nm: 6×10^{-5}
    248 nm: 1×10^{-4}

Test set-up


UV laser
He-Ne reference laser
Energy meter
or CCD
Photodiode
Cathode
UV mirror
Iris
½
waveplate
Polarized
cube
Beam
splitter
Iris
Lens
UV mirror
(movable)
Quartz
window
Mesh
anode


High voltage
Charge signal
Rotary stage
y
x
Movable cube
Mesh anode
Cathode
Side window
UV window
UV laser
Wavelength = 266nm
Pulse energy ≤ 1mJ
Pulse repetition = 10Hz
Pulse length ≈ 15ps
Ion pump
~ 6×10⁻⁹ torr

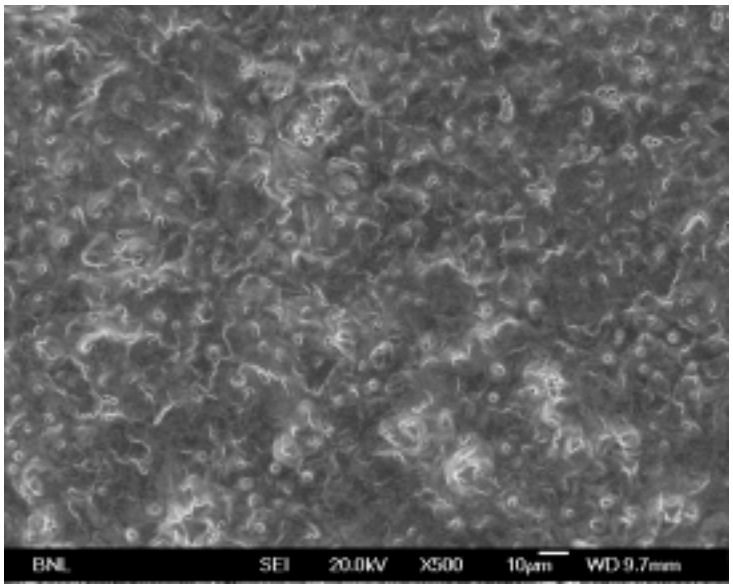
Superconducting Gun

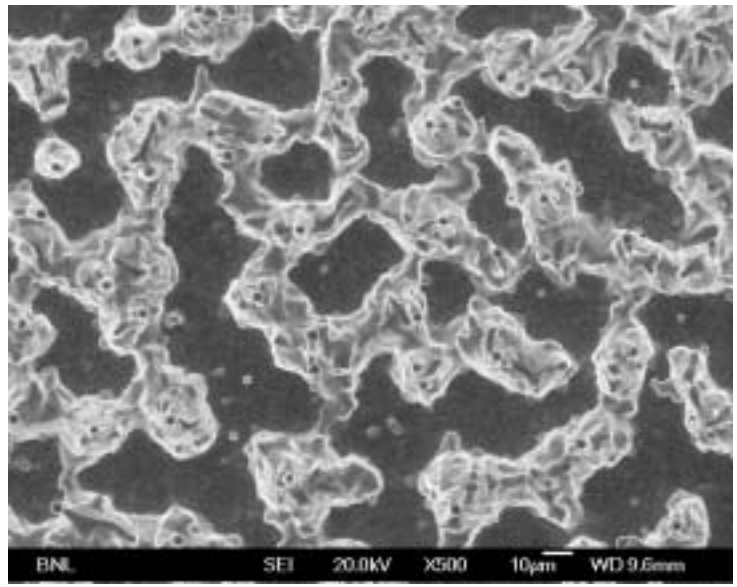
- ½ cell Nb gun operating at 1.3 GHz
- Laser irradiates cathode at 81.25 MHz
  - Duty factor of 1/16th
- SCRF gun reduces RF power dissipated to cavity, thus reducing power to drive cavity

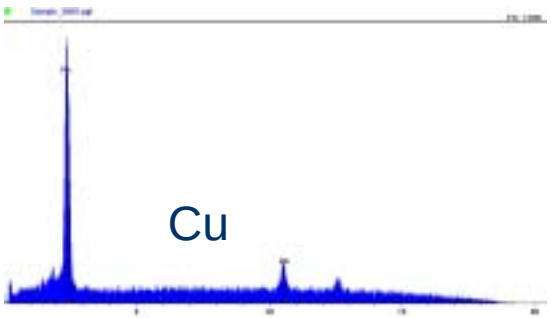
New Metal Photocathode: Lead

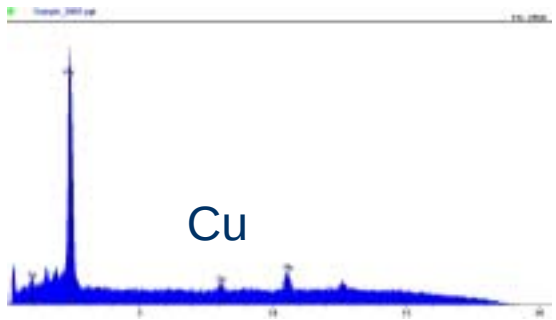
- Copper substrate electroplated with ~7 μm lead
- Standard Super-conductor preparation techniques
- Quantum Efficiency (w/ 1 MV/m field):
  - Before laser cleaning, 248 nm: 1.9×10^{-5}
  - After laser cleaning, 248 nm: 1.2×10^{-4}
    266 nm: 7.6×10^{-5}
    193 nm: 1.3×10^{-3}

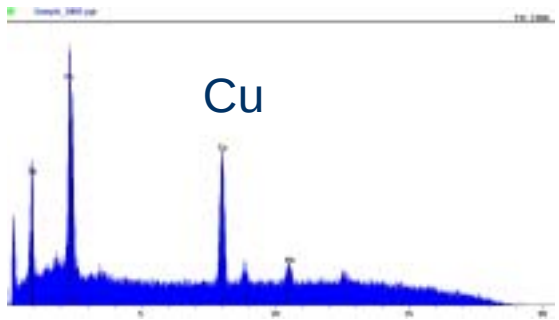
Lead surface cleaning effect











Conclusions

- Three different photocathode projects are underway
  - Each has it's own merit, and by pursuing all three we should be able to design a photo-injector capable of delivering ~100 mA average current at a high repetition rate.
- Superconducting injectors are looking promising
- By increasing the QE the laser requirements can be relaxed

Acknowledgements

- David Pate
- Marc Montemagno
- John Walsh