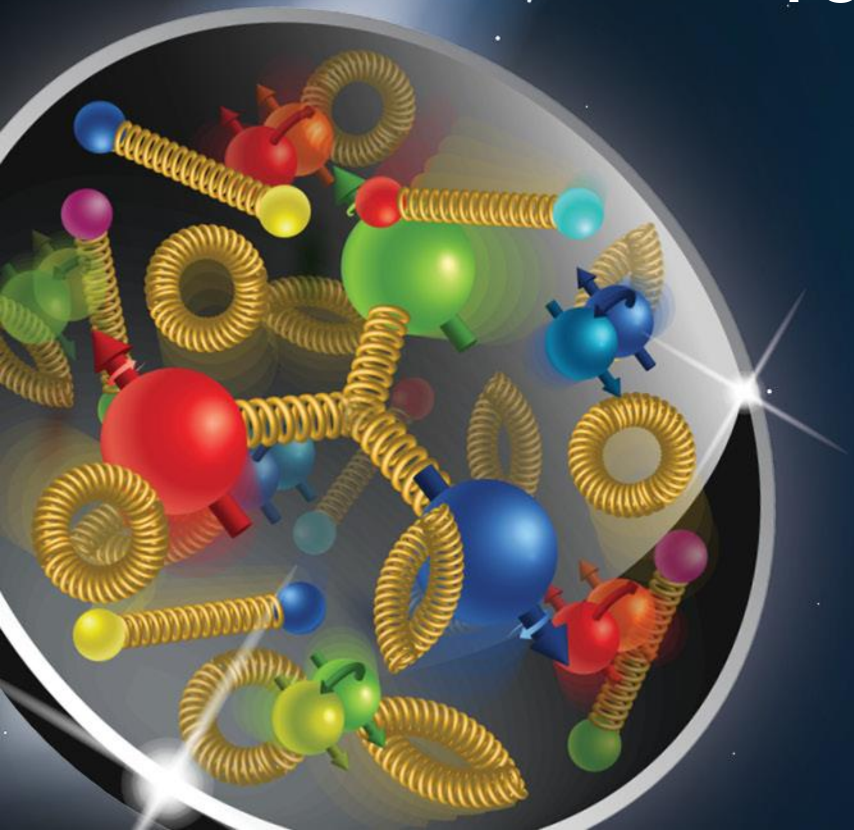
Electron Source Development for the Electron Ion Collider at BNL

Complete Procurement of Components for the BNL Inverted Gun



Nuclear Physics Accelerator R&D
PI Meeting

John Skaritka BNL

November 13-14, 2018

Electron Ion Collider – eRHIC

1

BROOKHAVEN NATIONAL LABORATORY

U.S. DEPARTMENT OF ENERGY | Office of Science

Acknowledgements

I. Ben-Zvi, M. Gaowei, R. Lambiase,

V. Litvinenko, W. Liu, R. Napoli,

O. Rahman, E. Wang, F. Willeke

Our Collaborators from the following companies:

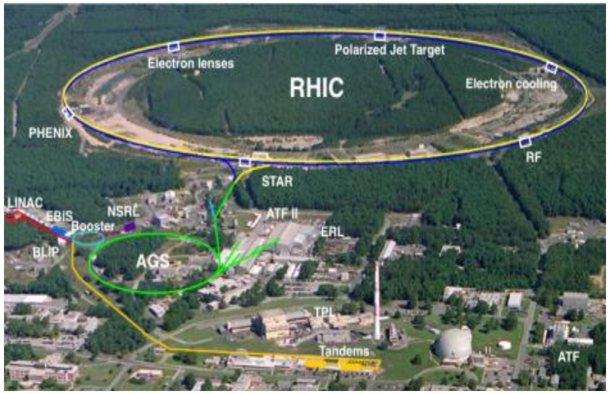
Atlas Technologies, UHV Transfer,

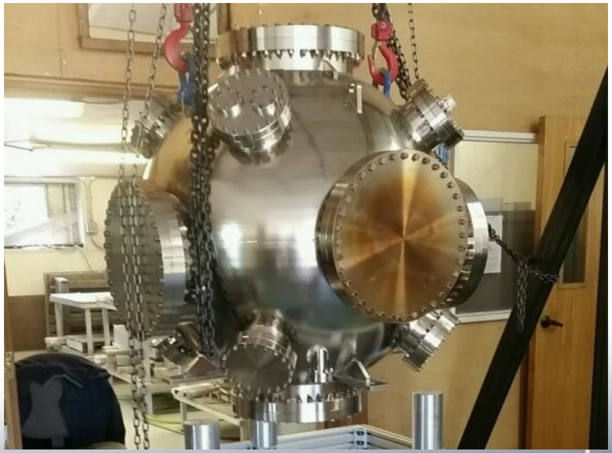
Applied Vacuum , MDC Vacuum,

Pascal Technologies, SAES Getters

Outline: Complete procurement of components for the inverted BNL gun.

- Funding summary and Jones report.
- Layout of e-gun and beam line
- Cathode preparation system
- Views of inhouse system components
- Beam line simulation
- Cathode development and prototype e-gun experiments.
- Cost to date and schedule
- Summary





Complete Procurement of Components for the Inverted Gun at BNL

Funding Source	PI	R&D Report Priority #	R&D Panel Priority Rating	Total $
FY17Additional	John Skaritka	7, 23	Hi-B, Hi-C	$ 335,000

FY-16 Base, BNL - $65,000
FY-17 Additional, BNL- $130,000
FY-17 Additional, MIT- $140,000 Flow through funding

From Page 32 of the Jones Panel Report

The BNL LR concept team has launched a R&D program to address these issues. The team proposes to:

- Upgrade vacuum system of the existing Gatling gun prototype (previous R&D);
  - Use this gun for bench marking of beam dynamic simulations, and optimization and commissioning of the diagnostic beam line, and
  - Complete the build-up of diagnostic beam line and beam dump.
- Build up a single, new inverted gun with optimized geometry, ultra-high vacuum quality for high gun voltage (350 kV) with a large cathode diameter ~25 mm;
  - Fabricate and assemble the new inverted gun with an optimized geometry, ultra-high vacuum quality for high gun voltage (350 kV) with a large cathode diameter ~25 mm Gatling gun.
- Complete laser parameter optimization.
- Perform systematic measurements on the completed gun (FY18).
- Perform the simulation of beam extraction and transport (underway).
- Work out, optimize and simulate the bunch-stacking scheme.
- With the RF kicker electrical design available, work has already started for alternative stacking schemes.

To date there has been some R&D related to different approaches to polarized sources. BNL has supported the development of the Gatling gun (24 photocathodes in a single vacuum enclosure) concept. However, this approach is not the primary one for the BNL LR concept. The Gatling gun will use a single photocathode to benchmark beam dynamic simulations, and optimize and commission the diagnostic beam line and beam dump.

Polarized e-RHIC Prototype Gun

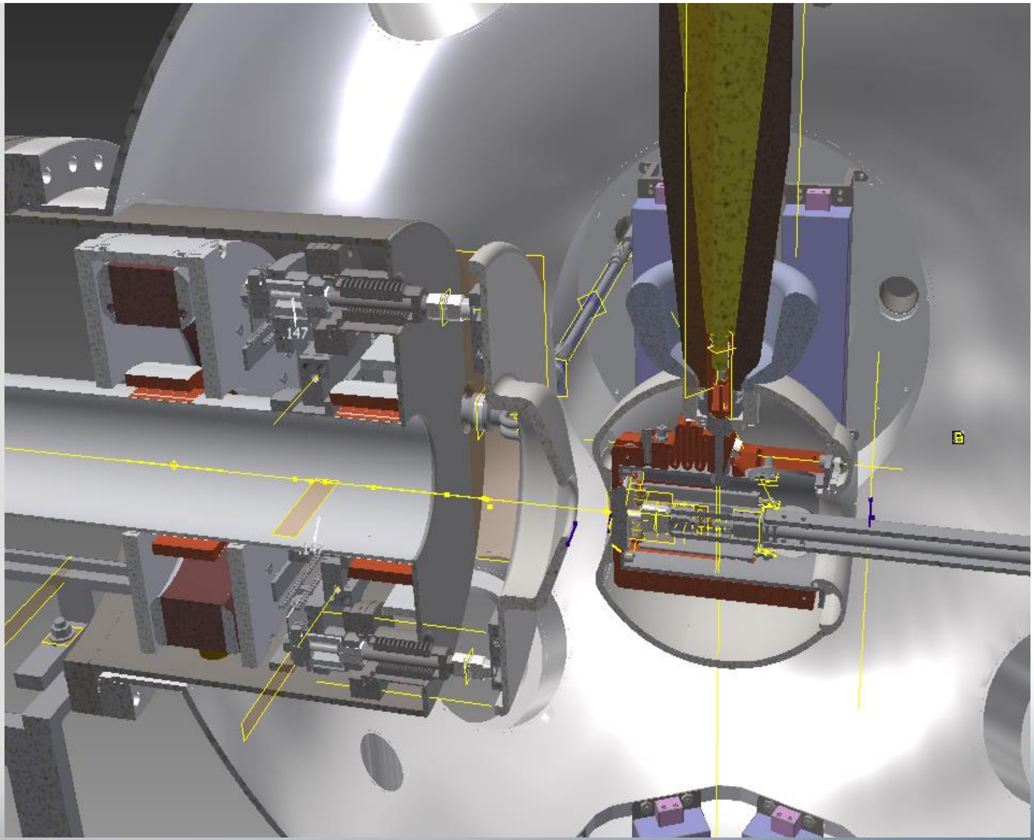
Introduction: Complete procurement and delivery of all components and the necessary infrastructure improvements for the inverted gun system to bench test and integrate the individual components to allow the installation and testing of the eRHIC prototype electron source and experimental beam line in the source development laboratory at Stony Brook University.

Polarized Gun Design Specifications

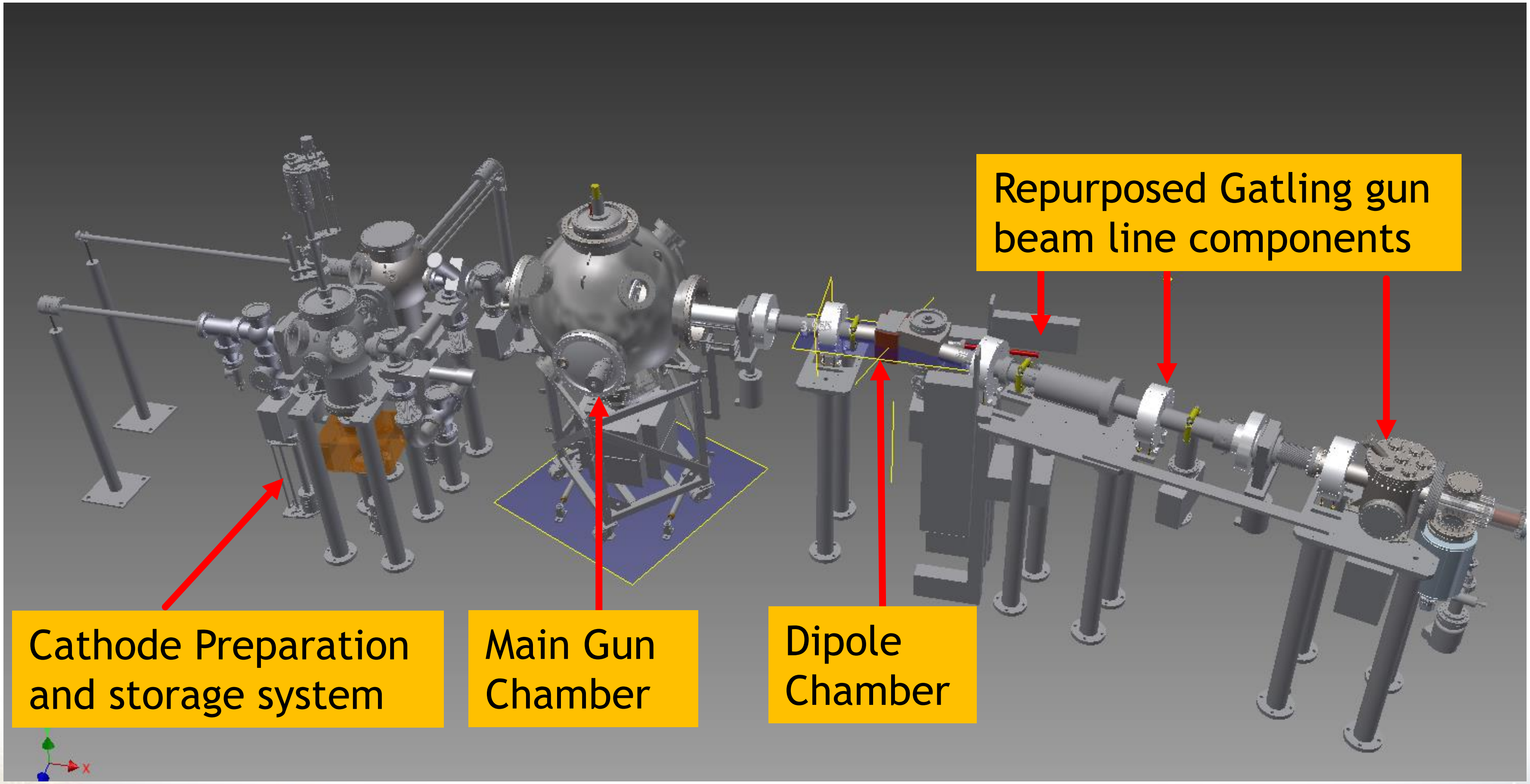
- High average current (6~50 mA), high bunch charge (5.3 nC) large cathode inverted gun for L-R eRHIC source.
- High bunch charge for R-R eRHIC source.

Experimental items:

- Achieve and measure XHV
- High power laser
- Eliminate ion back bombardment
- Surface charge limit measurement
- Lifetime as the function of charge
- Beam halo reduction studies
- Cathode cooling

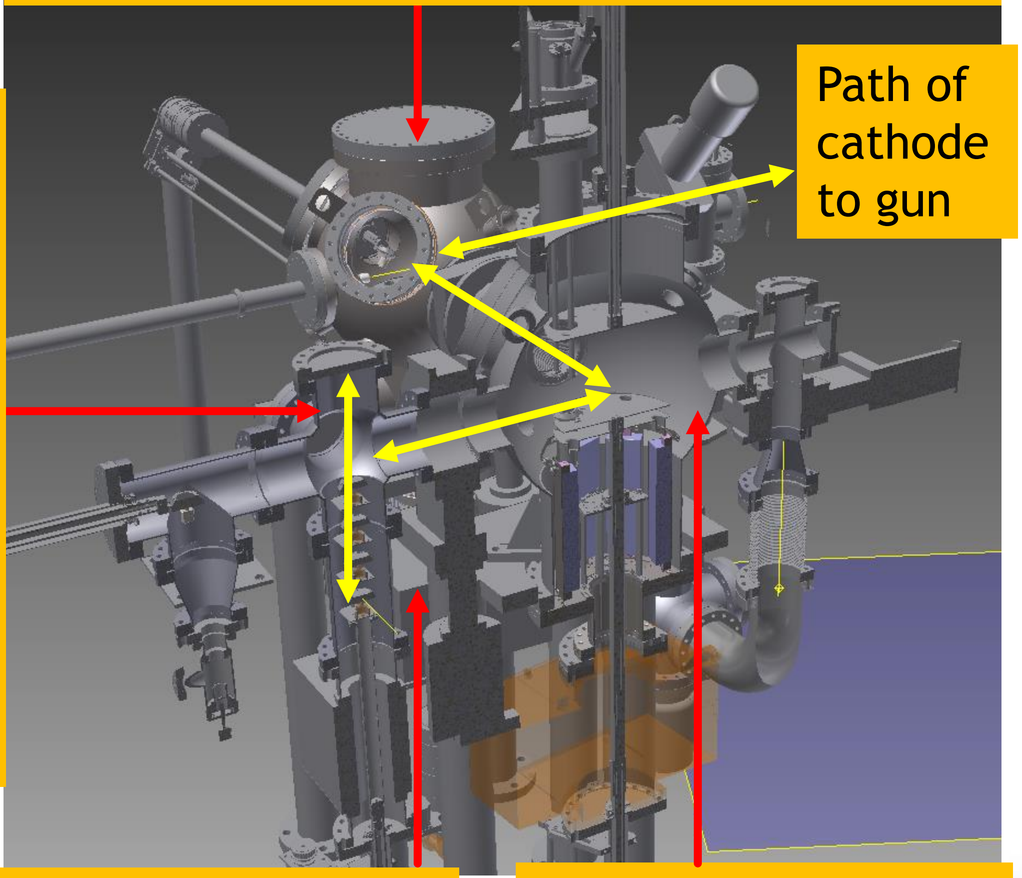


The eRHIC Prototype Electron Source and Experimental Beam Line at Stony Brook University



DBR/SSL GaAs Cathode Preparation

Fresh cathode pucks loaded into load-lock, transferred to Activation chamber then to Storage chamber
Activation Surface heat cleaned at 580 Celsius, Deposited Monolayer of Cs- Oxygen to achieve NEA (Negative Electron Affinity) – ‘Activation’
Distributed Brag Reflector(DRB) GaAs:
QE – 5% at 780 nm
Strained Superlattice (SSL) GaAs:
QE – 1% at 780 nm
then transferred to Storage chamber vacuum : 10^{-12} Torr (critical)
and then transferred to Gun Chamber



List of Major Component Purchases

- Gun shroud component purchases, including heat treatment .
- High voltage ceramic feedthrough.
- Additional NEG, Ion, TSP and UHV turbo pumps system components.
- Main gun chamber system components
  - Reentrant Flange for anode actuator.
  - Large custom flanges designed to minimize H2 content with NEG array assemblies
- The Anode and the components for the anode actuator assembly,
- Beam line dipole chamber
- Cathode preparation chamber system components
- Cathode storage chamber system components
- XHV compatible magnetic manipulators
- Assorted vacuum components
- VAT gate valves and additional hardware

Polarized eGun Component Development

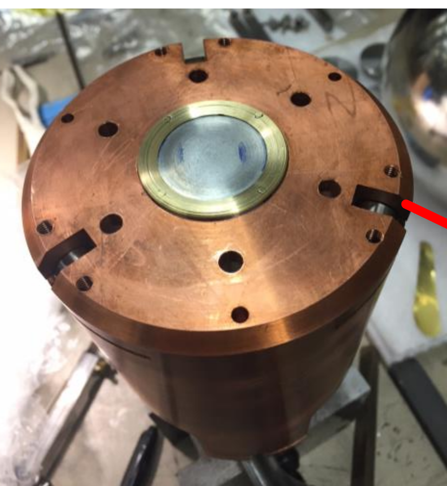
Inverted Gun Polished Cathode Shroud

Cathode Activation Chamber, (Stainless)

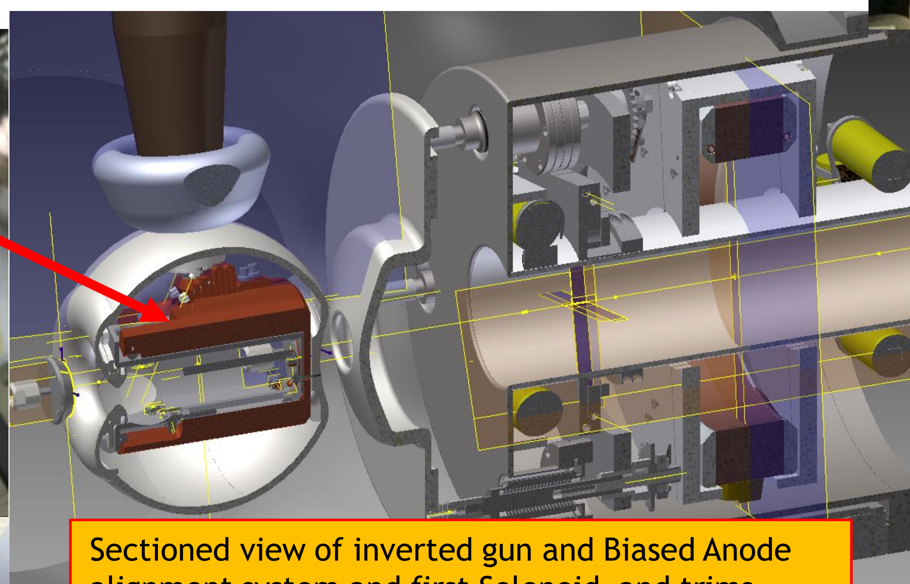
Cathode Storage Chamber, (Titanium,)

Gun Vessel was vacuum fired and In earlier tests has already achieved

10^{-12} T0rr level vacuum

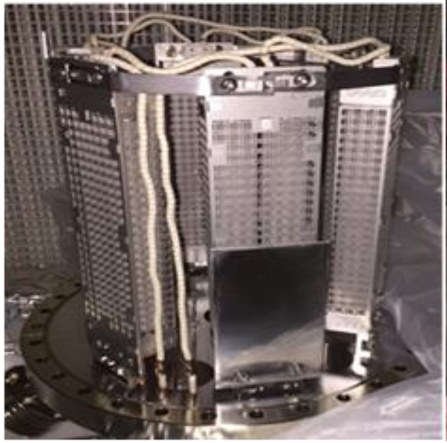


Cathode Puck in Copper heat sink

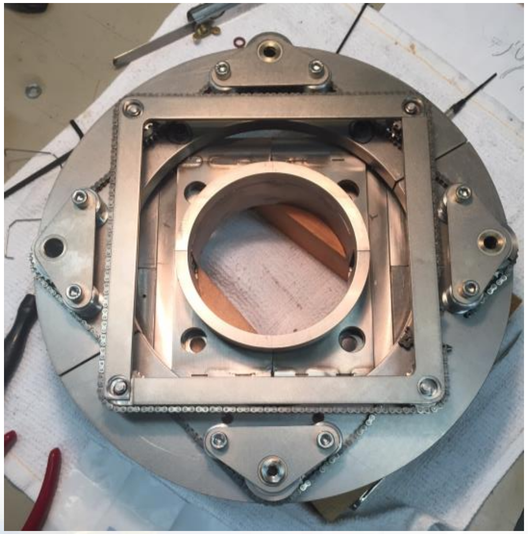


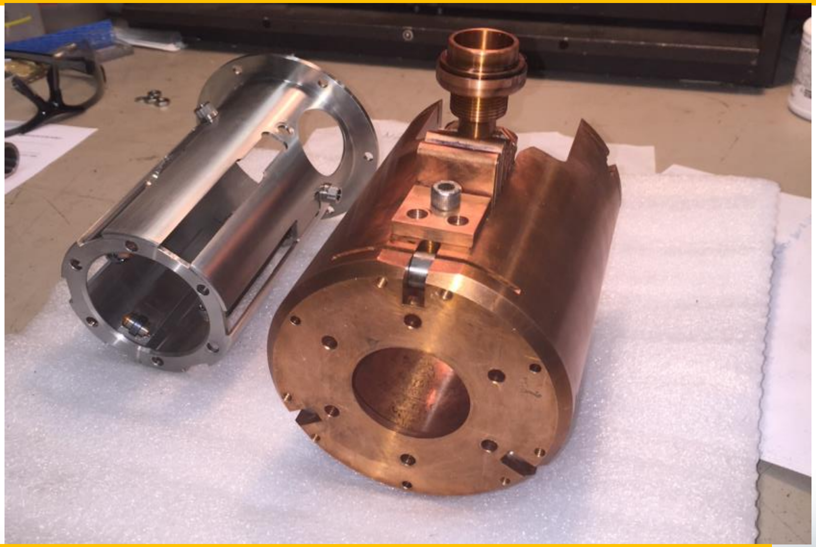
Sectioned view of inverted gun and Biased Anode alignment system and first Solenoid and trims

Additional Source Component Development



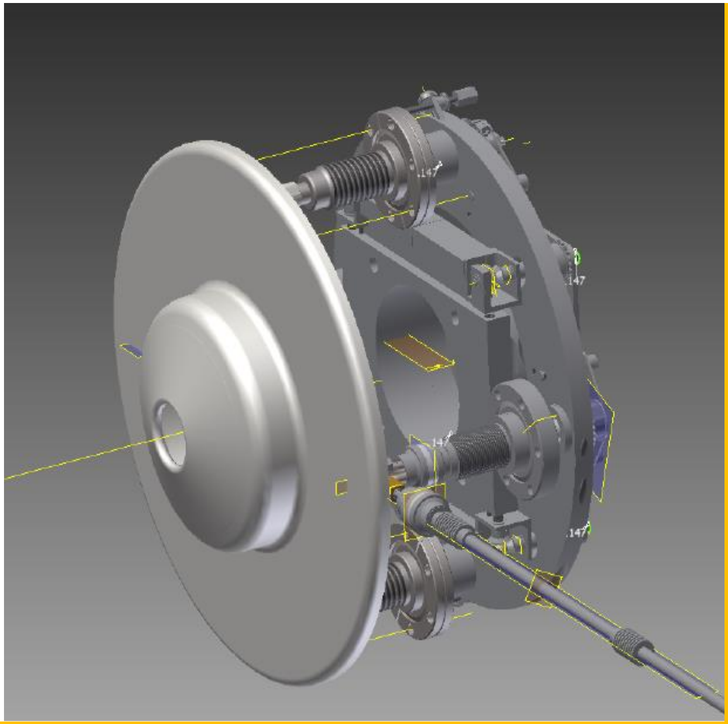
From left to right: Anode, NEG Pump cartridge assembly and 450 KV connector





Anode alignment system, Cathode spring capture cage and copper heat sink with active cooling/heating

Anode and Anode Actuator System



The anode is electrically isolated and will be biased to divert ions from the beam line to reduce collisions with the cathode.

To provide accurate alignment between the cathode and anode axis. The isolated anode is mounted to an actuator that provides X, Y, pitch and yaw. An additional feature can shift the anode an additional 7mm in X to experiment with techniques that may reduce the damage caused by Ion back bombardment.

The anode actuator was successfully assembled and bench tested at Stony Brook University

Recent Progress and Parts on their way or at BNL

Main Gun Chamber

Main Gun Chamber outgassing measurements completed

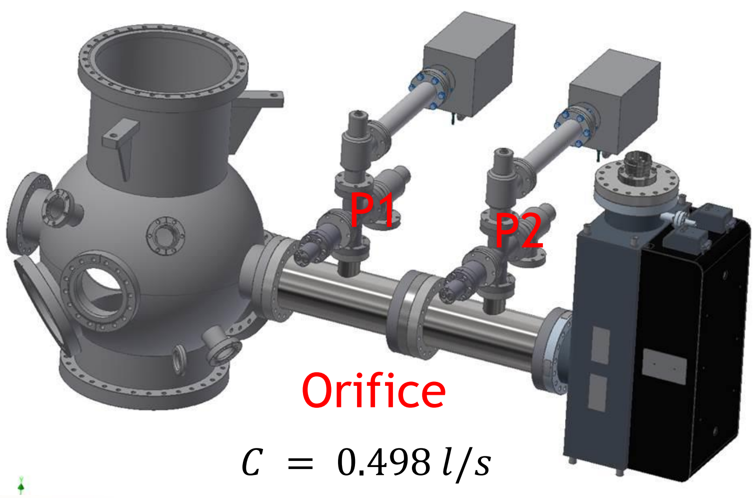
Cathode Prep. NEG

Beam line component assembly

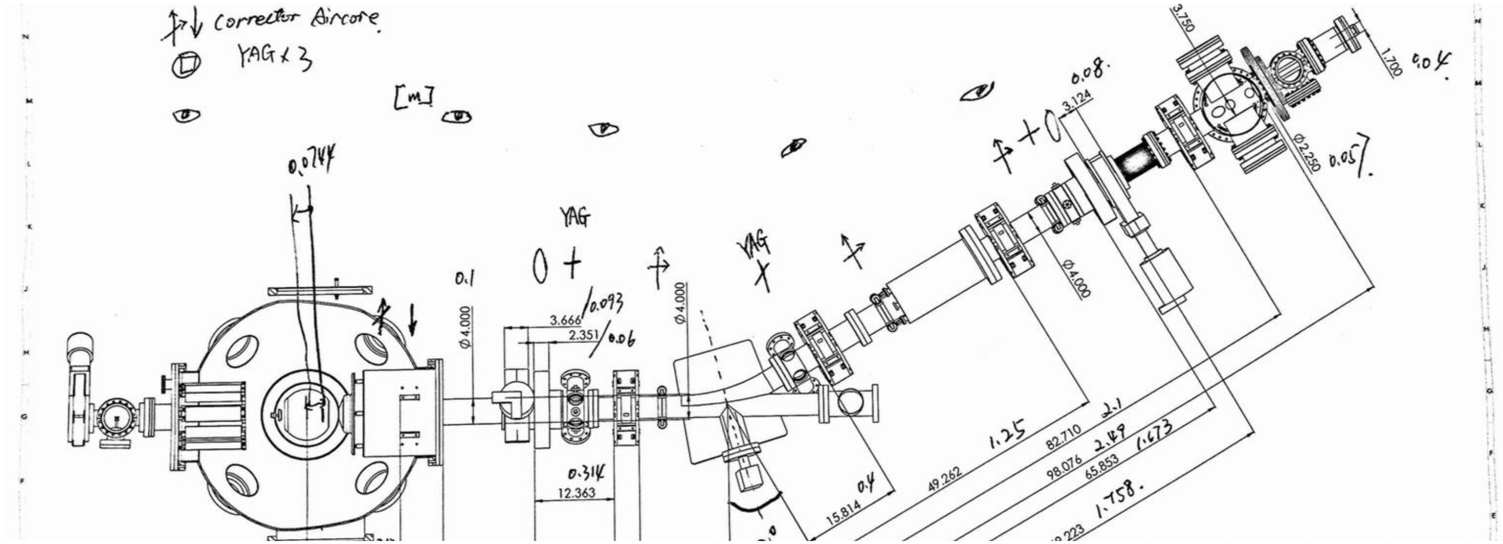
Outgassing Measurements

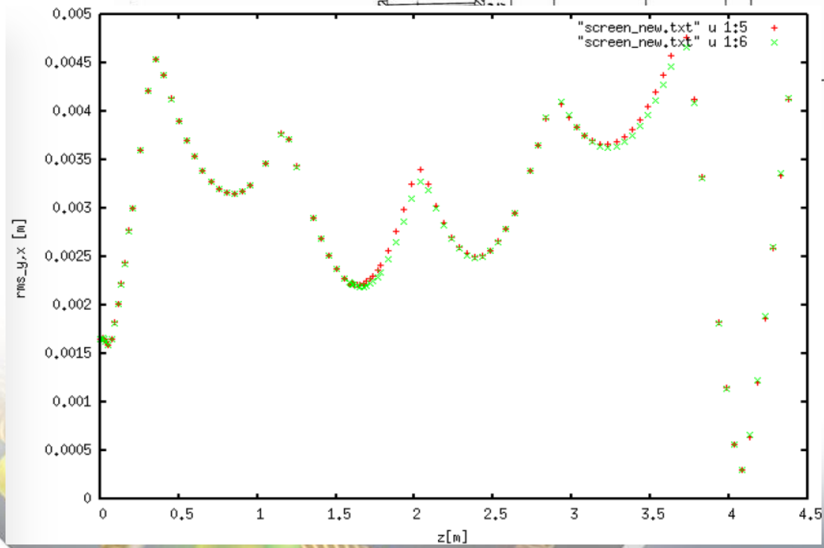
- The outgassing rate for stainless steel chamber was done, its outgassing rate is about $1.026 \times 10^{-13}\ torr \cdot l \cdot s^{-1} \cdot cm^{-2}$. With this outgassing rate, the predicted vacuum pressure should be about $1.0 \times 10^{-12}\ torr$ under the pumping by the NEG and ion pump with pumping speed of 9000 l/s

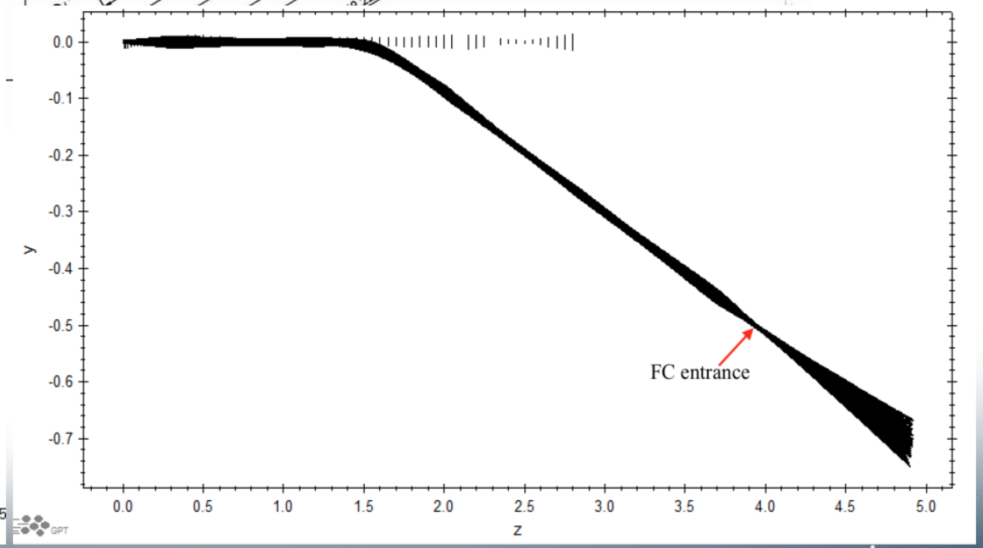
$$q = C(P_1 - P_2)/A = 1.026 \times 10^{-13}\ torr \cdot l \cdot s^{-1} \cdot cm^{-2}$$



Simulation of e-beam from the prototype gun through the experimental beam line







Source Development Lab at Stony Brook University

Over the past 2+ years extreme vacuum and e-source development has been taking place using a Laboratory in the Stoney Brook University Physics Department

Faraday Room housed the e-source (Gatling Gun) a high voltage power supply and a large earth's field canceling Helmholtz coil.

This work expanded our knowledge of extreme vacuum and GaAs photocathode sources as well as yielded a PHD for Stony Brook student Omer Rahman who now works in our e-source group

To advance to the next level of development a much cleaner laboratory is needed

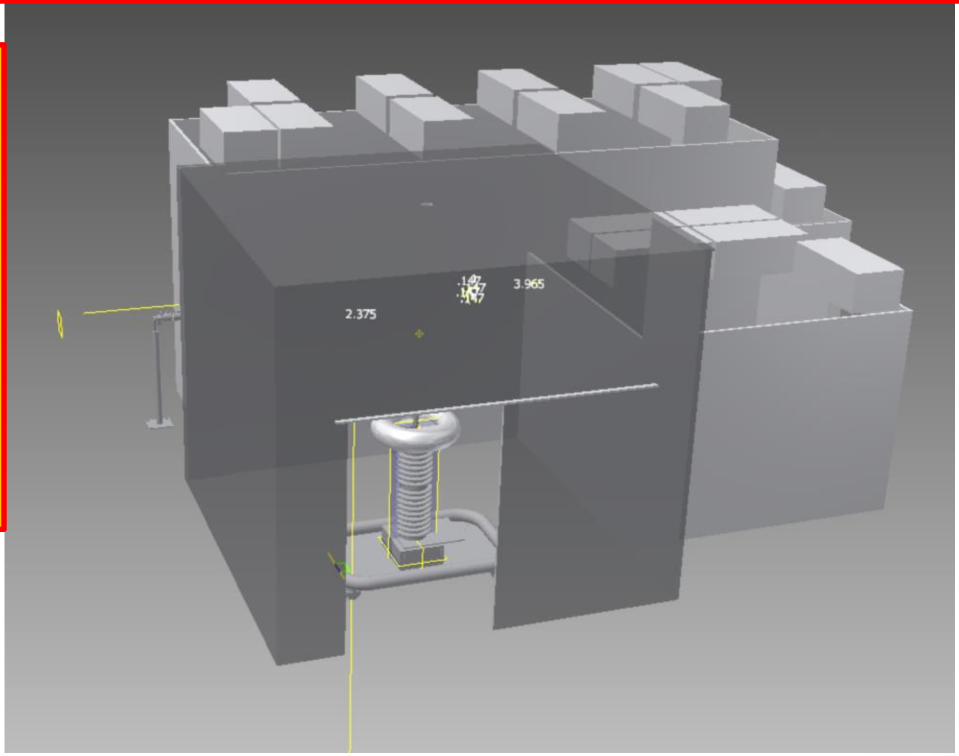
List of Infrastructure Improvements

- Expansion of available laboratory space.
- Additional shielding added around laboratory space.
- Introduction of HEPA filters to gun enclosure to create a class 100 or better, clean room around gun, and cathode preparation system.
- HEPA filters installed in laser room and gowning space
- Expansion of clean room space to the end of the beam line.
- New higher power interlock switch and power routing for 400KV supply.
- New "Kirk Key" high voltage safety interlock system.
- Additional entry way into gun enclosure with laser safety interlock system.
- New fully grounded safety cage with all metal floor and remotely operated grounding bar for high voltage supply.
- Installation and successful testing of high voltage power supply.
- Purchase of high voltage cables with resistor stack.

Laboratory Improvements at SBU

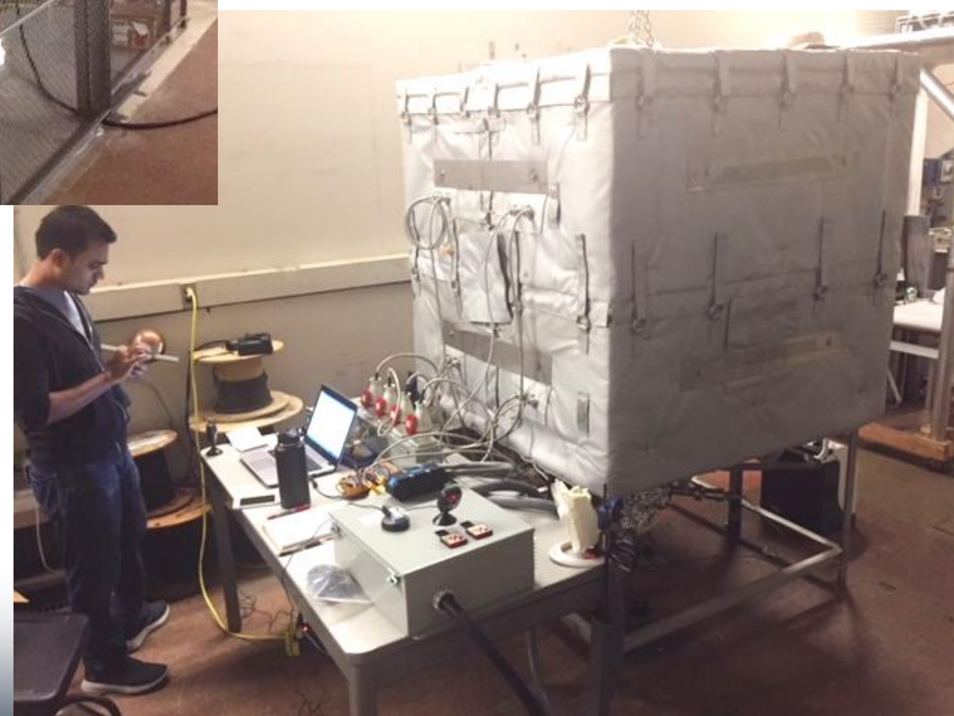
HEPA filters and appropriate improvements have been added to the source enclosure to provide a class 100 or better environment for extreme vacuum components assembly and improved laser operations.

The high voltage supply capability will be increased to allow gun conditioning of up to 400,000 Volts. A new safety cage was needed to house the new supply.



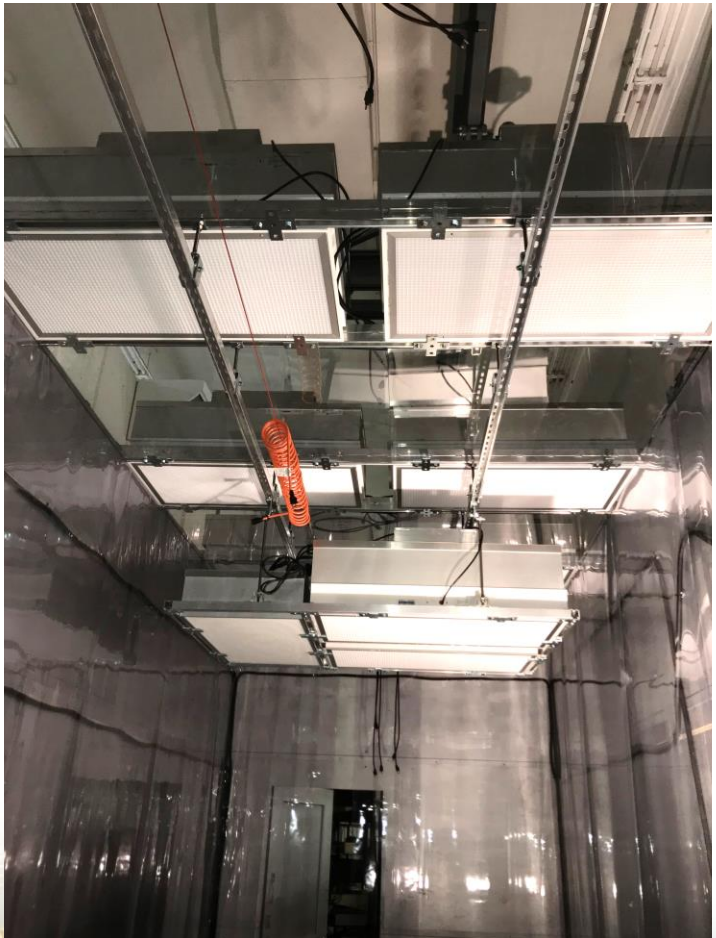
Status of Improvements to Source Lab Infrastructure

- 400kV power supply system has been installed and tested.
- Safety cage with Kerk key interlock system has been installed and tested.

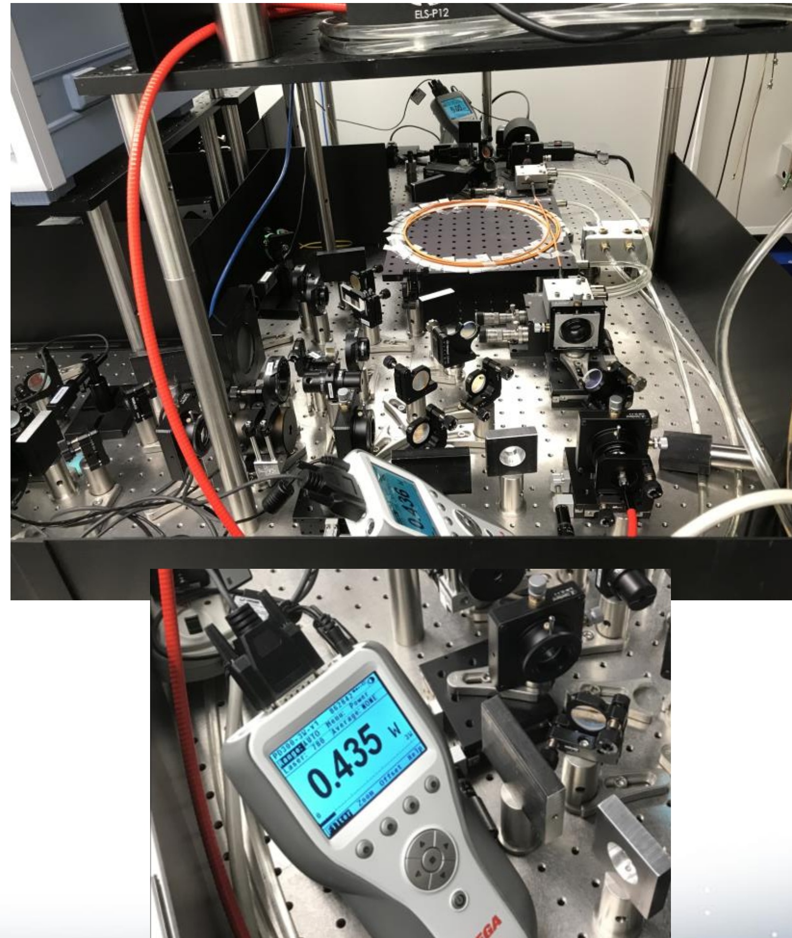


- 400+ C, 1.8 M^3 bake out oven is being used to reduce hydrogen content in the walls of the chamber vessels for the prototype gun system.

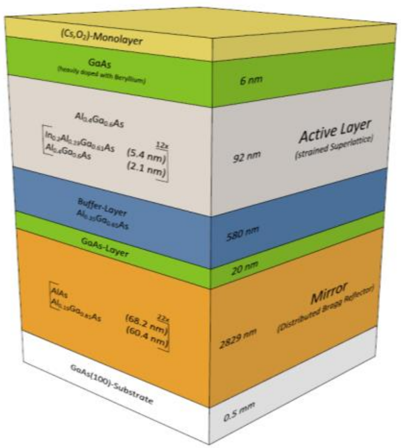
New source lab. clean room for particle-free assembly of high voltage gun components is complete and ready for beam line component installation

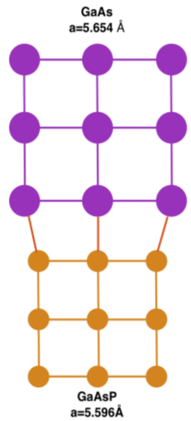


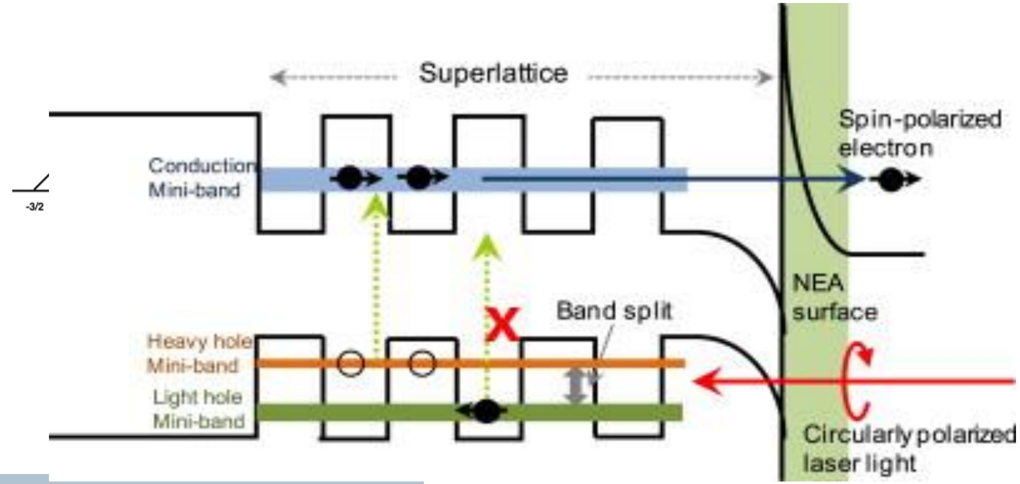
The circularly polarized fiber optic cathode drive laser has reached its first milestone. We anticipate a 20X improvement in the next few months.



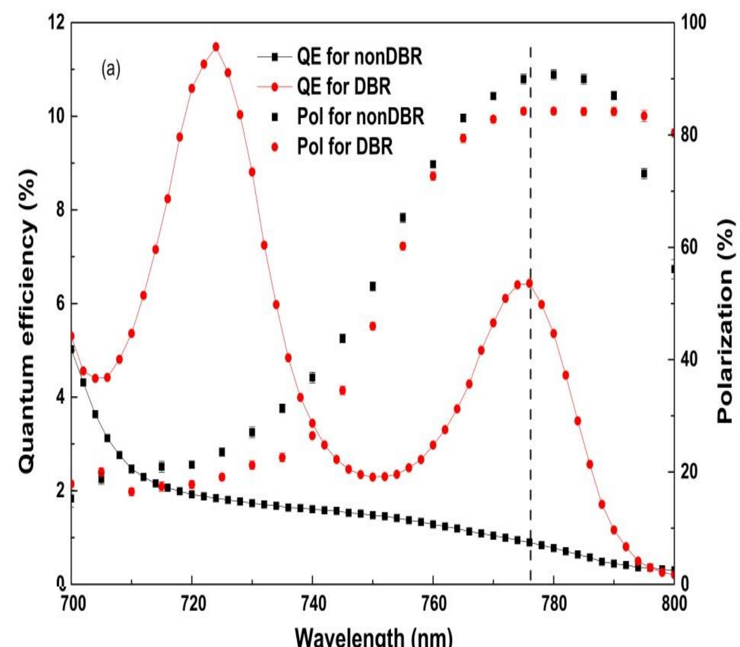
Super-lattice GaAs Photocathode Development







- Typical Superlattice GaAs produce 80-90% polarization QE of about 1%.
- DBR super lattice GaAs photocathode QE is greater than 5%.
- Achieved 86% polarization.
- Vacuums of $10^{-11}$to 10^{-12} Torr are needed just to achieve minimal results.
- Operating vacuum of 10^{-13} Torr is needed for high current/ bunch charge operation.



Lifetime study on Cs_2Te(CsO) coated GaAs

A study of an electron affinity of cesium telluride thin film

H Sugiyama[1], K Ogawa[2], J Azuma[2], K Takahashi[2], M Kamada[2], T Nishitani[3], M Tabuchi[4], T Motoki[5], K Takashima[5], A Era[5] and Y Takeda[6]

[1] Accelerator Laboratory, High Energy Accelerator Research Organization (KEK), 1-1 Oho, Tsukuba, Ibaraki 305-0801 Japan.

6th International Particle Accelerator Conference IPAC2015, Richmond, VA, USA JACoW Publishing
ISBN: 978-3-95450-168-7 doi:10.18429/JACoW-IPAC2015-TUPWA062

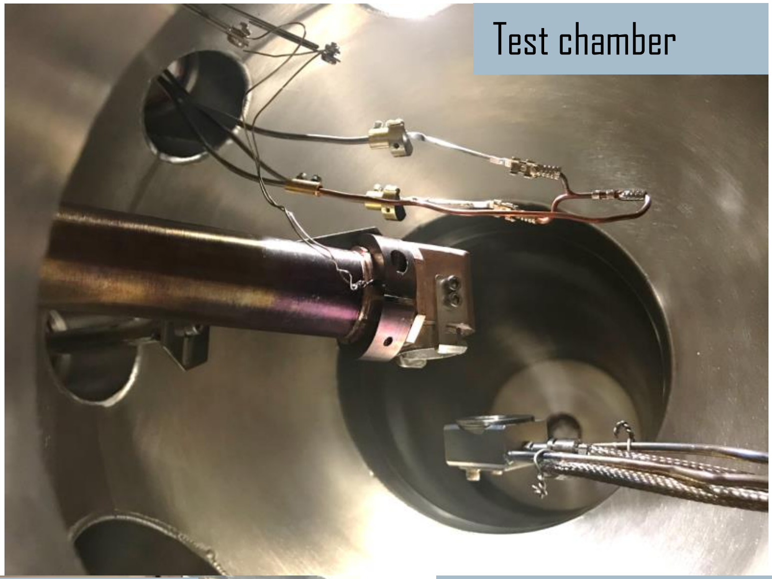
GaAs PHOTOCATHODE ACTIVATION WITH CsTe THIN FILM

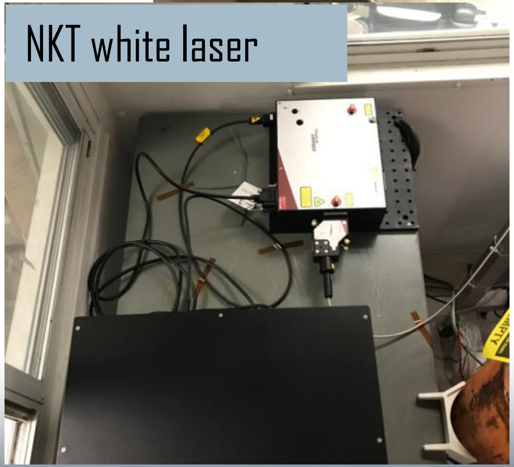
Masao Kuriki[#1], Yuji Seimiya[#2], Kazuhide Uchida[#3], HU/AdSM, Higashi-Hiroshima, Japan
Shigeru Kashiwagi, Tohoku University, Sendai, Japan

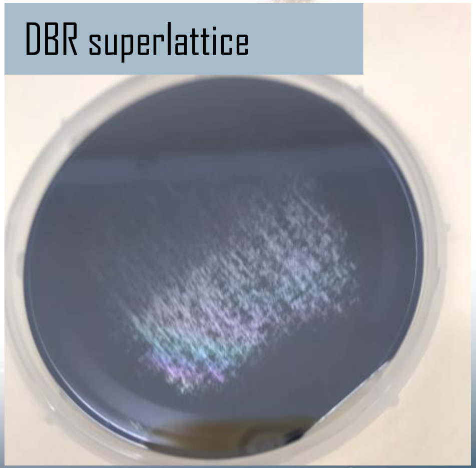
Rugged spin-polarized electron sources based on negative electron affinity GaAs photocathode with robust Cs_2Te coating

Jai Kwan Bae, Luca Cultrera, Philip DiGiacomo, and Ivan Bazarov

Citation: Appl. Phys. Lett. **112**, 154101 (2018); doi: 10.1063/1.5026701

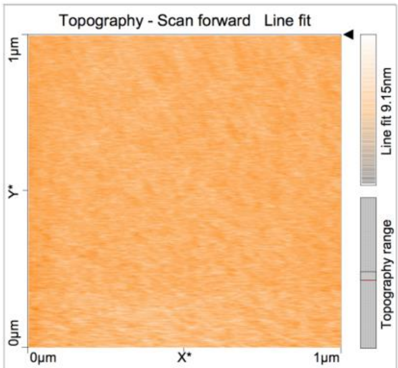

Test chamber


NKT white laser

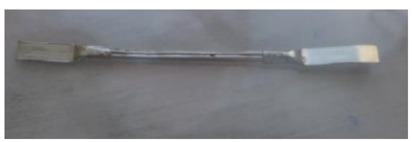

DBR superlattice

We are studying the coating for GaAs with other robust materials.

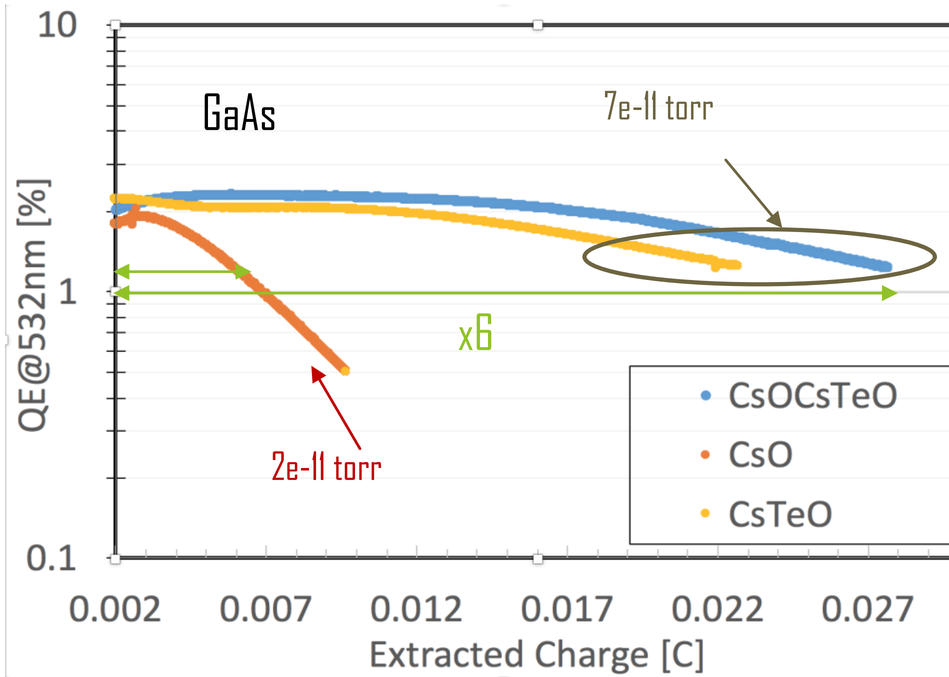
Lifetime study on $Cs_2Te(CsO)$ coated GaAs



540 ºC heat treatment
Roughness:1.8-3.9 nm

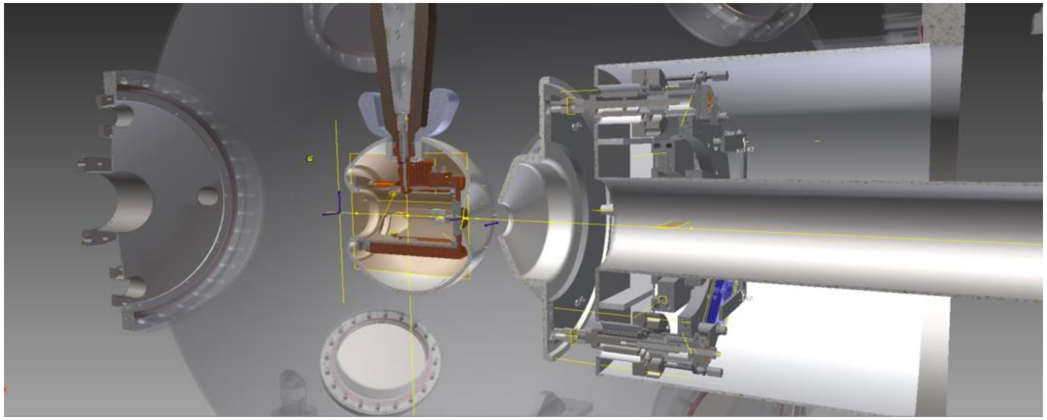


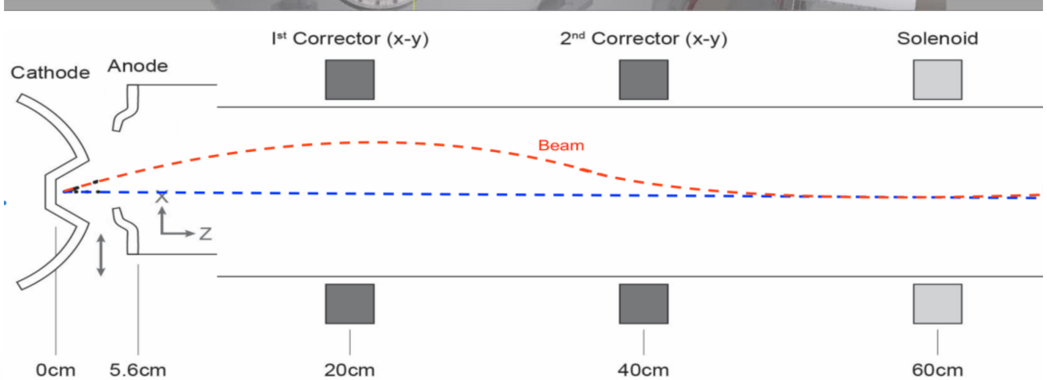
Te source in SAES dispenser

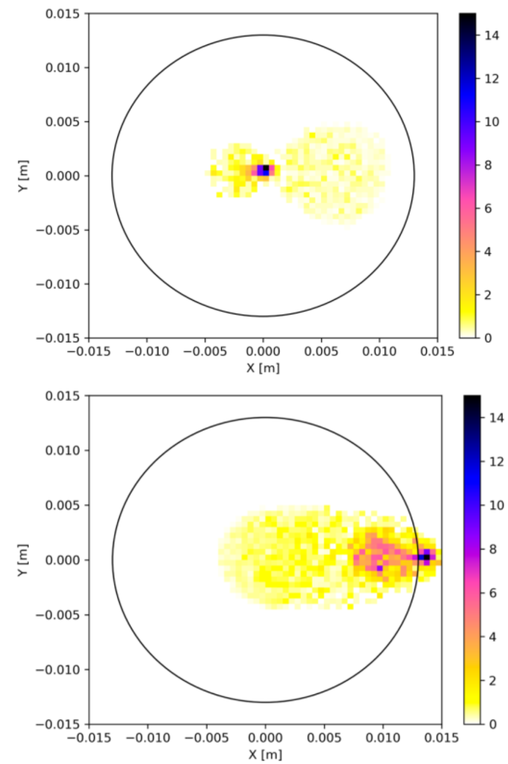


- At 532nm, lifetime using Cs_2Te is 6 times longer than conventional activated GaAs.
- We are measuring GaAs/GaAsAl superlattice lifetime with 780nm now. Preliminary results show Cs_2Te coated cathode lifetime at 780nm is slightly better than CsO coated one.

Extend the lifetime by kicking electrons







- Lifetime will be at least doubled with off-center anode scheme.
- Emittance increases only 20% compare to centered laser/anode.

Cost Summary to Date

	FY10+FY11	FY12+FY13	FY14+FY15	FY16+FY17	Totals
a) Funds allocated				335,000	335,000
b) Actual costs to date				284,529	284,529

Schedule

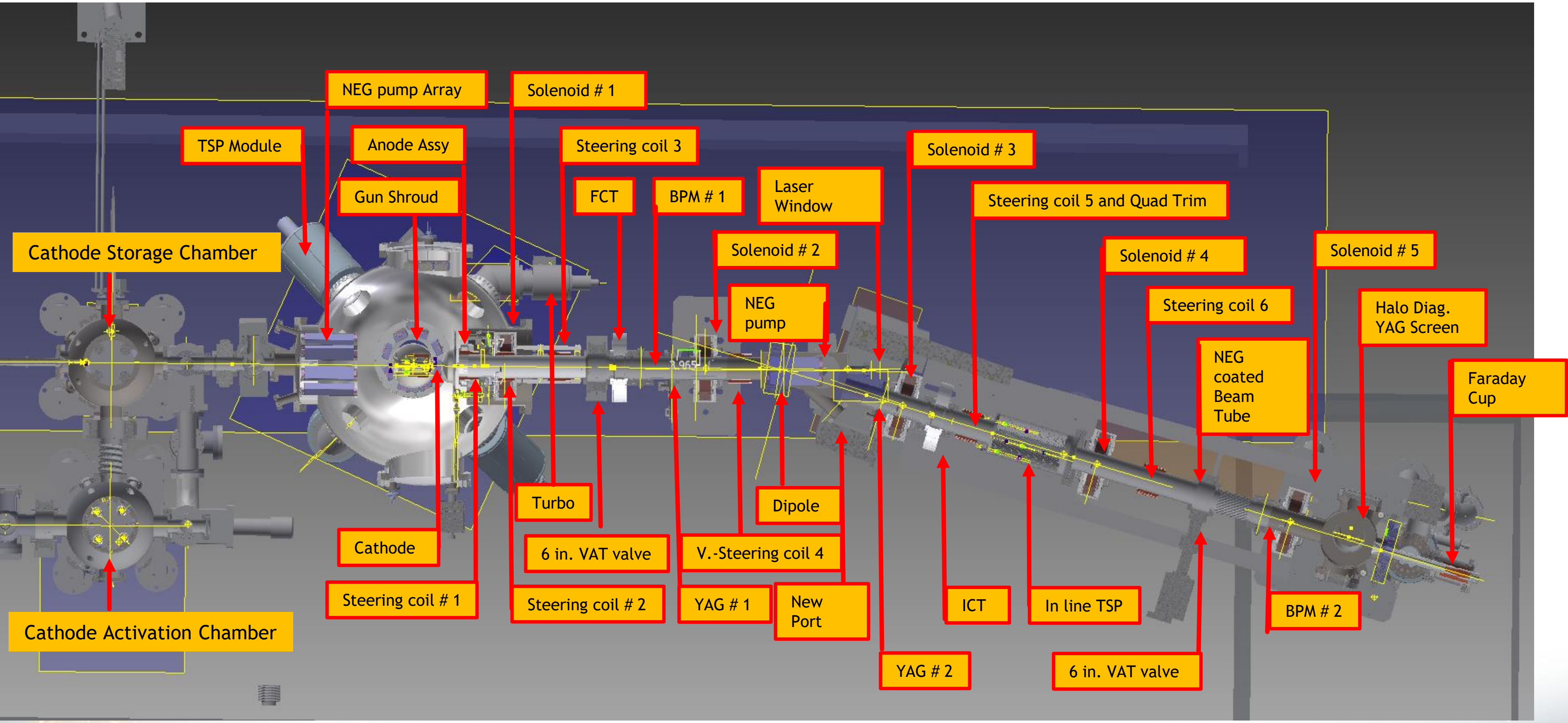
Activity	Start Date	End Date
Building 912 Infrastructure		September 30, 2020
Gun System Installation	March 28, 2017	May 11, 2018
Beam Test	December 15, 2017	July 23, 2018
High Charge Gun Design	January 1, 2017	September 16, 2018
Second High Charge Test	September 16, 2018	July 6, 2019
High Current High Bunch Charge Studies	October 31, 2018	January 30, 2019

Follow on Work and Near Term Schedule

- We plan to complete beam line assembly in the laboratory at Stony Brook University by the end of 2018.
- We will begin bake out of gun and beam line system components in January 2019.
- We expect to produce large cathodes by March 2019
- With the Laser and high voltage feedthrough systems e-beam will be available by May 2019.
- Subsequent gun e-beam testing will last a minimum of one year until spring 2020 to demonstrate gun performance for eRHIC for the following experiments
    - High current testing goal 6.2 mA and cathode life study.
    - High bunch charge for Ring-Ring operation.
    - Optimized cathode composition to extend cathode Life
    - Polarized and non-polarized high current beam studies

Thank you for your attention !

Prototype DC Gun and Beam Line system component Layout



Fabricated All Required Solenoid Completed