Polarized Electron Source: Status and R&D Activities

Joe Grames

- **Safety Minute**
- **Status of group & CEBAF polarized source**
- **Motivation and plans for this year's R&D activities**

Safety Minute

The majority of root causes for DOE complex laser injuries (2001-2005) were found to be related to:

- Poorly engineered precautions
- Inadequate line management
- Lack of compliance with industry standards

-Special Operations Report, DOE, Feb. 2005

Controlled laser areas often house multiple key controlled laser systems & projects.

Access to the key control can be linked to access to the laser controlled area through the use of a key lock box.

Implemented at our Injector Test Stand by J. Hansknecht (LSS for polarized source).

Center for Injectors and Sources

1 Group Leader – M. Poelker

3 Staff Scientists – <u>J. Grames</u>, M. Stutzman, R. Suleiman

2 Senior Technical Staff – P. Adderley, J. Hansknecht

2 Junior Technical Staff – J. Brittian, J. Clark

5 PhD Students

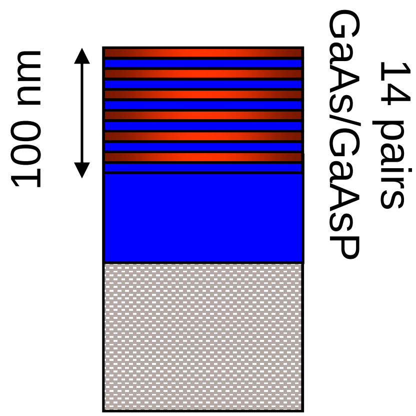
- **J. Dumas* (Joseph Fourier University, France)**
- **A. Jayaprakash* (Old Dominion University)**
- **J. McCarter (University of Virginia)**
- **K. Surles-Law (Hampton University, JLab staff)**
- **A. Hofler* (Old Dominion University, JLab staff)**

* Three new doctoral students

Polarized Electron Source Requirements

Good Photocathode

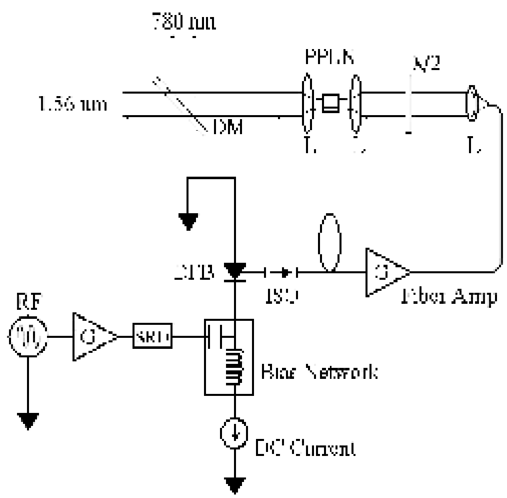
Superlattice GaAs
- No strain relaxation
- QE ~ 1%
- Pol ~ 85%



Successful HEP SBIR

Good Laser

Fiber-based laser
- RF synchronous
- High Power
- Robust



Telecom Industry

Good Gun

100 kV DC HV Guns
- One plus a spare
- Good vacuum (~10^{-11} T)
- Vent/bake

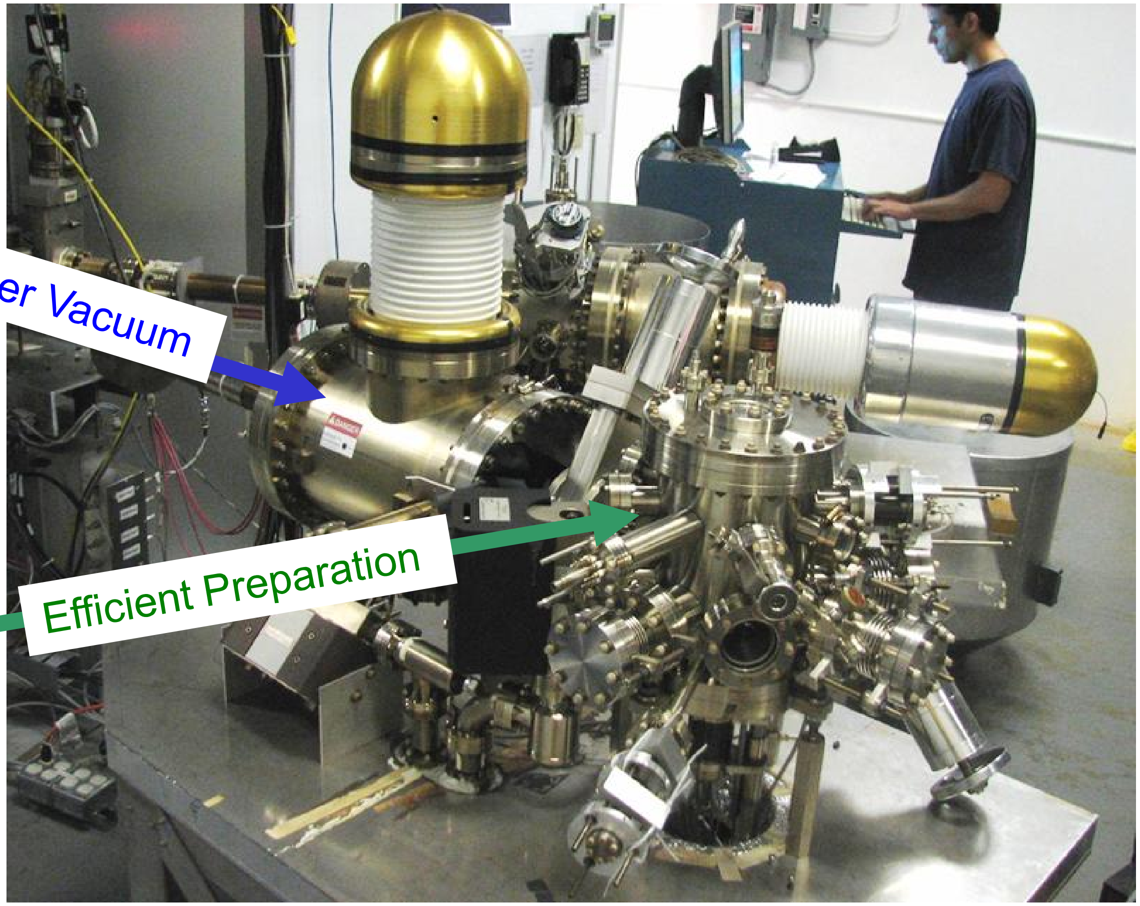
New Load Locked Gun at CEBAF

Installed July 2007 (during summer shutdown)

Operated since September 2007

Key Features:

- Smaller surface area
- Electropolished and vacuum fired to limit outgassing
- NEG-coated
- Never vented
- Multiple pucks (8 hours to heat/activate any photocathode)
- Suitcase for installing new photocathodes (one day to replace all pucks)
- Mask to limit active area, no more anodizing

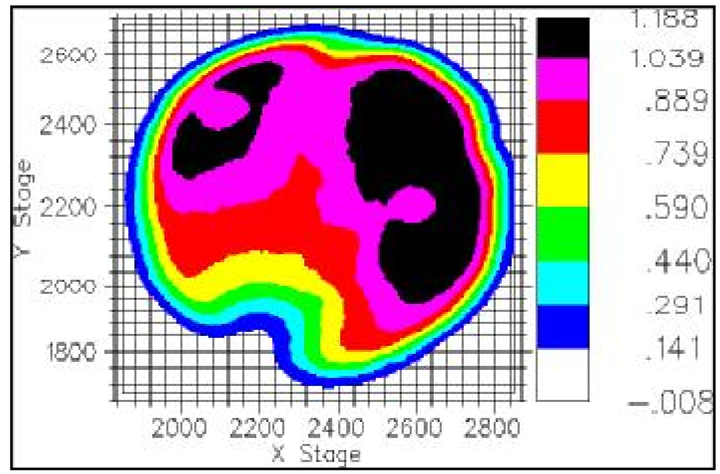


1 milliAmp demo from High-P Photocathode*

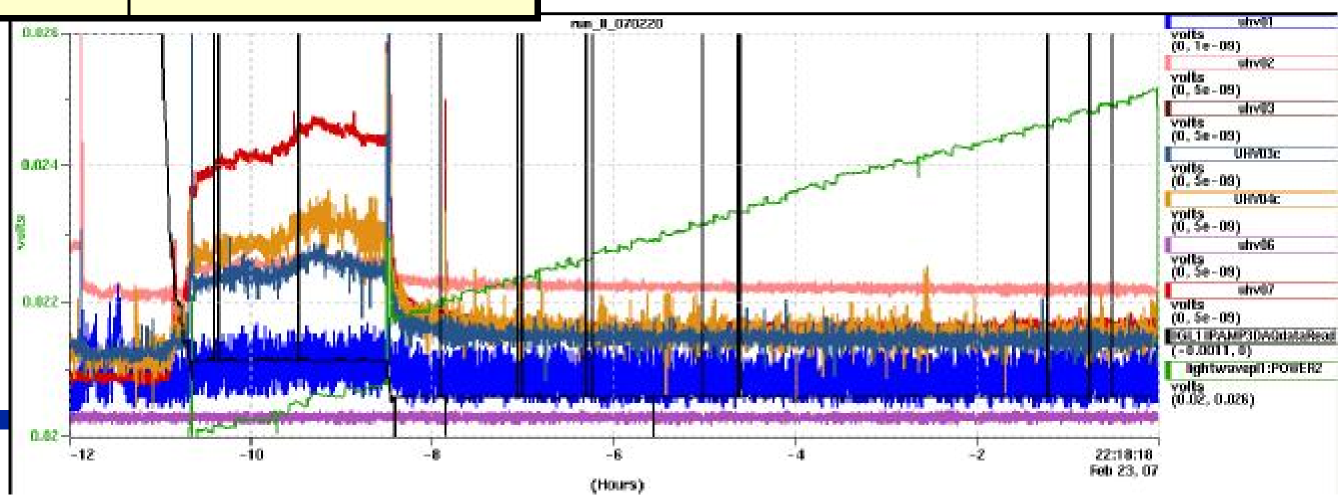
Parameter	Value
Laser Rep Rate (CW)	**499 MHz**
Laser Pulse Length	**30 psec**
Wavelength	**780 nm**
Laser Spot Size (FWHM)	**450 μm**
Average Current	**1 mA**
Run Duration	**8.25 hr**
Extracted Charge	**30.3 C**
Charge Lifetime	**210 C**
Areal Charge Lifetime	**160 kC/cm²**

*** Note: did not measure polarization**

High Initial QE [%]



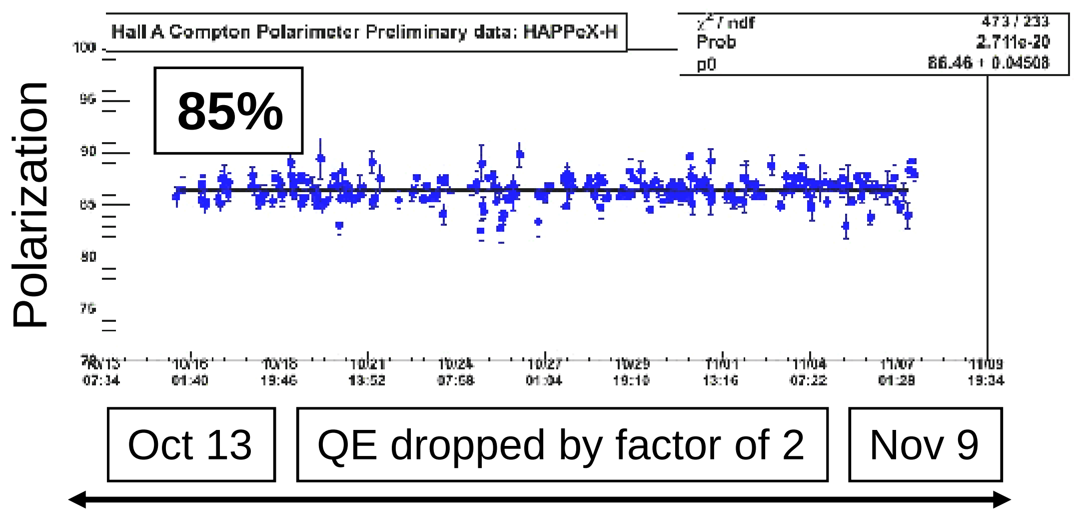
Vacuum signals
Laser Power
Beam Current



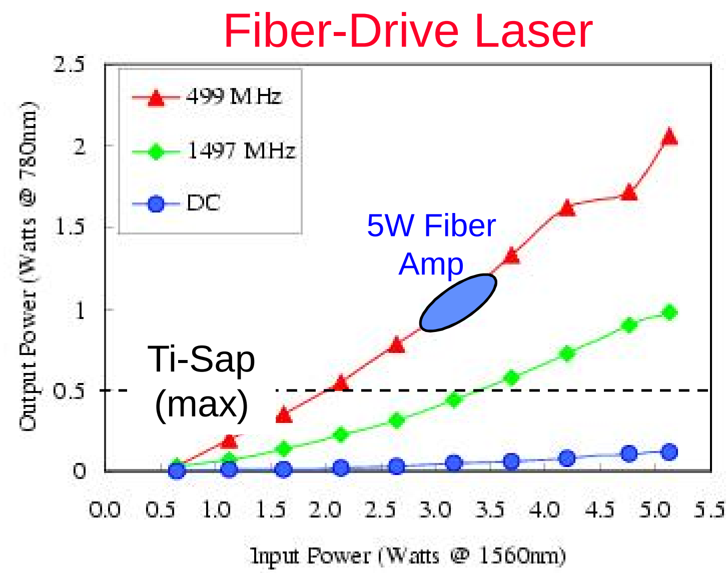
CEBAF Operations

- **Superlattice Photocathodes, polarization ~85% > 80%**
- **Fiber-based drive lasers: powerful and reliable**
- **Load-lock gun key features: transferred to CEBAF**
- **Photocathode lifetime at CEBAF *less* than at Test Lab**

State of the Art → State of the Process



No depolarization over time!



Parity Violation Experiments: Q_{weak} & PREX

"Parity Quality Beam" = identical beam properties in both helicity states

- **Laser Table => Isolated & controlled helicity reversal**
  - **Isolate electronics & eliminate ground loops**
  - **Setup Pockels cell (HAPPEx method) & fast 250 Hz reversal**
  - **Calibrate feedback loops for charge and position asymmetry**
- **Electron Gun => Uniform quantum efficiency**
  - **Restore long photocathode lifetime (>200 C) to sustain ~15 C/day**
  - **Use photocathode efficiently (15 minutes to use fresh spot)**
  - **Exchance photocathode quickly (4 days reduced to 8 hours)**
- **Beam Transport => Preserve PQB**
  - **Match beam from source to experiment**
  - **Maintain >80% transmission (new RF controls, 60 Hz reduction)**

Parity Violation Specification Summary

Helicity-correlated asymmetry specifications

Experiment	Physics Asymmetry	Max run-average helicity correlated Position Asymmetry		Max run-average helicity correlated Current Asymmetry	
		Spec	**Achieved**	**Spec**	**Achieved**
HAPPEx-I	**13 ppm**	**10 nm**	**10 nm**	**1 ppm**	**0.4 ppm**
G^0 Forward	**2 to 50 ppm**	**20 nm**	**(4 ± 4) nm**	**1 ppm**	**(0.14 ± 0.3) ppm**
HAPPEx-He [2004] HAPPEx-He [2005]	**8 ppm**	**3 nm**	**3 nm** **20* nm**	**0.6 ppm**	**0.08 ppm** **0.1 ppm**
HAPPEx-II-H [2004] HAPPEx-II-H [2005]	**1.3 ppm**	**2 nm**	**8** nm** **1 nm**	**0.6 ppm**	**2.6** ppm** **0.1 ppm**
PREX	**0.5 ppm**	**1 nm**	**-**	**0.1 ppm**	**-**
Q_{weak}	**0.3 ppm**	**20 nm**	**-**	**0.1 ppm**	**-**

*** Results affected by electronic crosstalk at injector.**

**** Results at Hall A affected by Hall C operation. Spec was met in 2005 run.**

Future CEBAF Photoinjector Improvements

Design and build compact gun operating at 200 kV

- **Improve use of beam for Qweak & PREX**
  - **Use inverted ceramic insulator**
  - **Field emission reduction via EP/BCP and HPR**

More on these in a moment…

Develop modeling expertise

- **Cathode/anode design, Wien filter spin rotator, etc.**

Increase laser power

- **Improve doubling efficiency (1560 nm to 780 nm)**

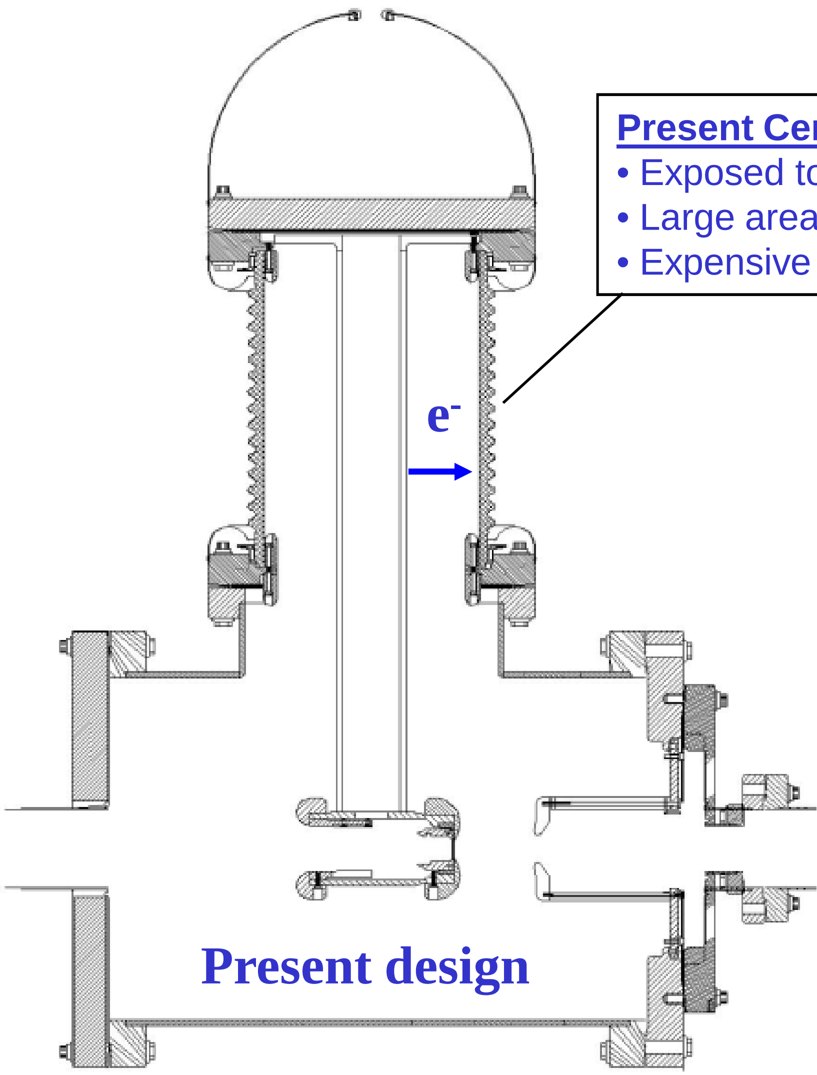
Improve gun vacuum

- **Reduce out-gassing rate by high temperature baking**
- **Understand limitations of pumps and gauges**

Complete polarimeter projects

- **Finish "1%" study of 5 MeV Mott, commission 500 keV Mott**

Build Higher Voltage Inverted Gun

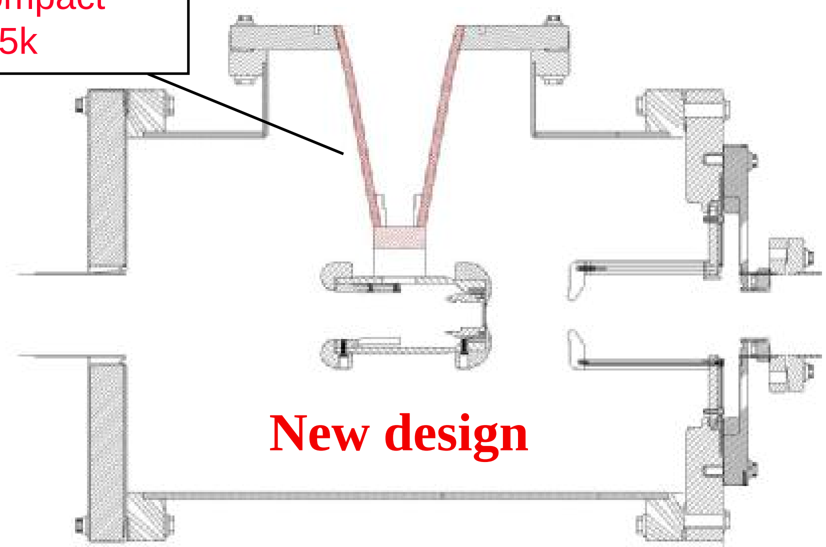


Present Ceramic
- Exposed to field emission
- Large area
- Expensive (~$50k)

Present design

Medical x-ray technology

New Ceramic
- Limited FE
- Compact
- ~$5k



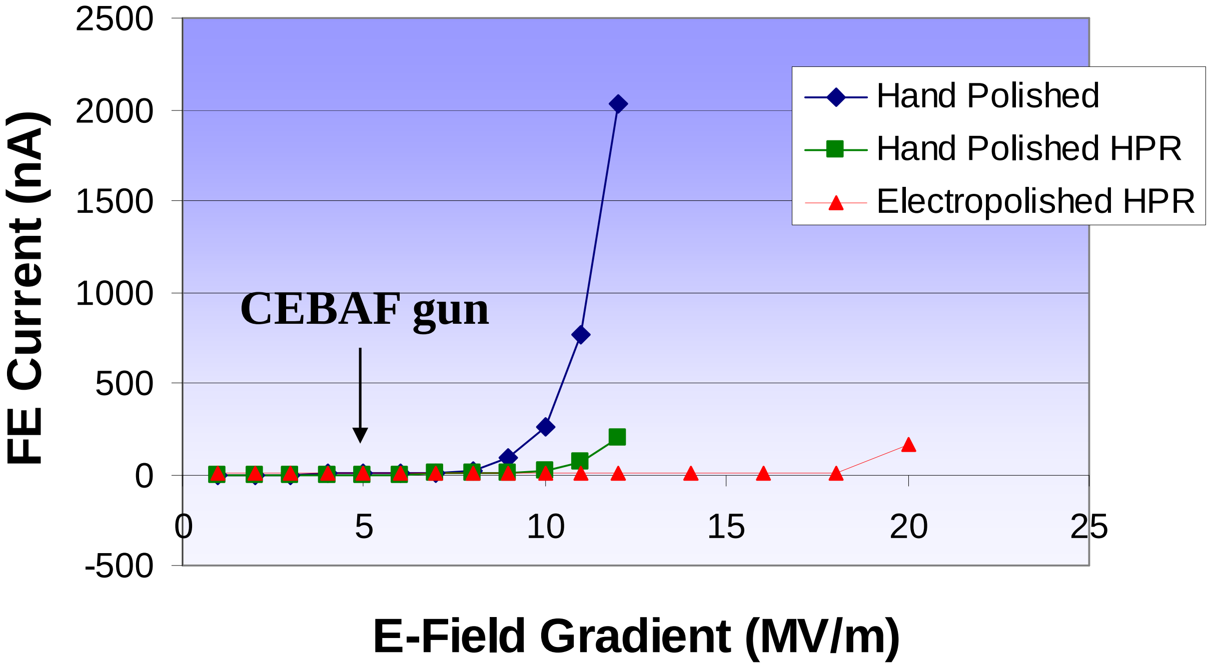
New design

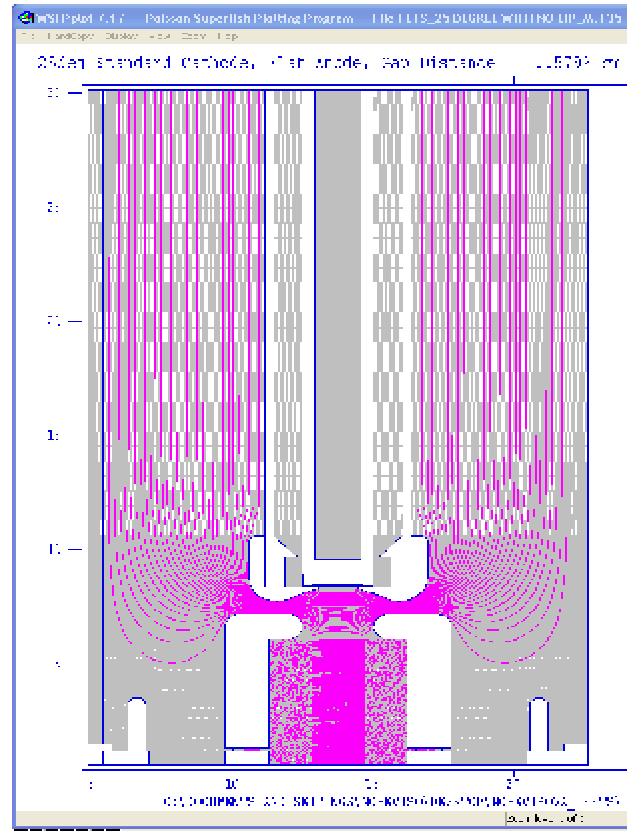
Eliminate Field Emission

Implement the SRF-cavity technique "high pressure rinsing"

<u>Recent work of Maria Chevtsova, Ken Surles-Law with shaped electrodes</u>

FE from Handpolished 304 SS Cathode Electrode with ~6 mm gap





Ken is collaborating with SRF Institute to build single crystal Niobium electrodes.

Improve Gun Design

- **Want to "get it right" the first time**
  - Previously, primary effort has been for photocathode (more polarization) or laser (more power) development.
  - Presently, opportunity to focus on gun design (cathode/anode) and beam handling (first few meters of polarized source).

- **Educating modeling expertise (PhD students)**
  - Ken Surles-Law: 200kV gun
  - Ashwini Jayaprakash: ILC gun
  - Jonathan Dumas: polarized e+ source
  - Alicia Hofler: RF gun & genetic algorithm

R&D using our Core Competencies

- **High Average Current Guns**
  - Polarized (EIC, e+ source) and Unpolarized (ERL, FEL) Sources
- **High Bunch Charge & Peak Current Guns**
  - Polarized (ILC, CLIC) and Unpolarized (FEL) Sources
  - Evaluate surface charge limit of high-P photocathodes
- **High Beam Polarization**
  - Polarization dependence on QE for strained superlattice
  - Two photon absorption experiment (P~100%)
- **High Power RF Synchronized Lasers**
  - Hall C Compton fiber-based high power green laser (532nm)
- **Extreme High Vacuum**
  - Limiting factors of ion pumps and gauges at best vacuum

Recent Articles & Papers

- **"GaAs Photogun Charge Lifetime Dependence on Drive Laser Beam at High Average Current (<1mA)", J. Grames, P. Adderley, J. Brittian, J. Clark, J. Hansknecht, D. Machie, M. Poelker, M. Stutzman, K. Surles-Law, to be submitted to Phys. Rev. ST Accel. Beams.**
- **"Electron Sources for Accelerators", C. Hernandez-Garcia, P.G. O'Shea and M.L. Stutzman, Physics Today, February 2008, p.44-49.**
- **"Design of a High Intensity Positron Source", J. Dumas, Master's Thesis, Joseph Fourier University, Grenoble, France, June 2007.**

Recent Conferences & Workshops

- **"CEBAF Load Lock Polarized Electron Source", J. Grames & M. Poelker, 4th Electron-Ion Collider Workshop, Hampton University, May 19-23, 2008.**
- **"A Road Map to Extreme High Vacuum", P. Adderley & G. Myneni, Bhabha Atomic Research Center, Mumbai, India, November 28-30, 2007.**
- **"High Intensity Polarized Electron Sources", M. Poelker et al., Polarized Sources and Targets Workshop, Brookhaven National Laboratory, September 10-14, 2007.**
- **"A Biased Anode to Suppress Ion Back Bombardment in a DC High Voltage Photoelectron Gun", J. Grames et al., Polarized Sources and Targets Workshop, Brookhaven National Laboratory, September 10-14, 2007.**
- **"DC Photogun Vacuum Characterization through Photocathode Lifetime Studies", M. Stutzman et al., 17th International Vacuum Congress, Stockholm, Sweden, July 2-6, 2007.**