Polarized Electron Sources for the ILC

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ILC Polarized e-Source Considerations

Shared Challenges (compared to CEBAF experience)

- Photocathode material – polarization > 80%
- High QE, Ultrahigh vacuum requirement
- Machine-friendly gun design to minimize downtime: reliable load lock
- High voltage and high field gradient: no high voltage breakdown, no field emission + a desire to extend operating voltage beyond 100kV.
- Cathode/anode design: manage ALL of the extracted beam

Unique Challenges (compared to CEBAF experience)

- High bunch charge and high peak current: space charge and surface charge limit
- Injector design with sub-harmonic bunching
- Drive laser, high energy pulses

Recent Developments at CEBAF

- CEBAF load-locked gun
  - Improved vacuum and accelerator-friendly ops
- Commercial strained-superlattice photocathode
  - Consistent 85% polarization, ~ 1% QE
  - Demonstration of sustained 1mA operation
- High Voltage R&D (just beginning: K. Surles-Law)
  - Reduce field emission
  - Push value of “routine” operation beyond 100kV
  - Reduce complexity and cost of HV insulator
- Cathode/Anode Design (just beginning: A. Jayaprakash)
  - Optimize geometry to support loss-free beam delivery across entire photocathode surface

Space Charge Limit

Peak current at ILC photocathode ~ 6 A
Assume laser spot size 1cm
Current density j = 7.6 A/cm^2

Space Charge Limit (Child's Law)

$$j_0 = \left(2.33 \times 10^{-6}\right) V_0^{3/2} / d^2$$

V (kV)	j_0 (A/cm^2)
140	14
200	23
350	53

for 3 cm cathode/anode gap

Increase Gun Voltage

Historically, Labs have had difficulty operating DC high voltage guns above field gradient ~ 5 MV/m and bias voltage ~ 100kV (at least polarized guns).

That said, it would be beneficial to build an ILC gun with higher field gradient and bias voltage to...

- Address current density limitation due to Child’s Law
- Reduce space-charge-induced emittance growth, maintain smaller transverse beam profile and short bunchlength
- Reduce problems associated with surface charge limit (i.e., QE reduction at high laser power)
- Prolong Operating Lifetime?

Must Eliminate Field Emission

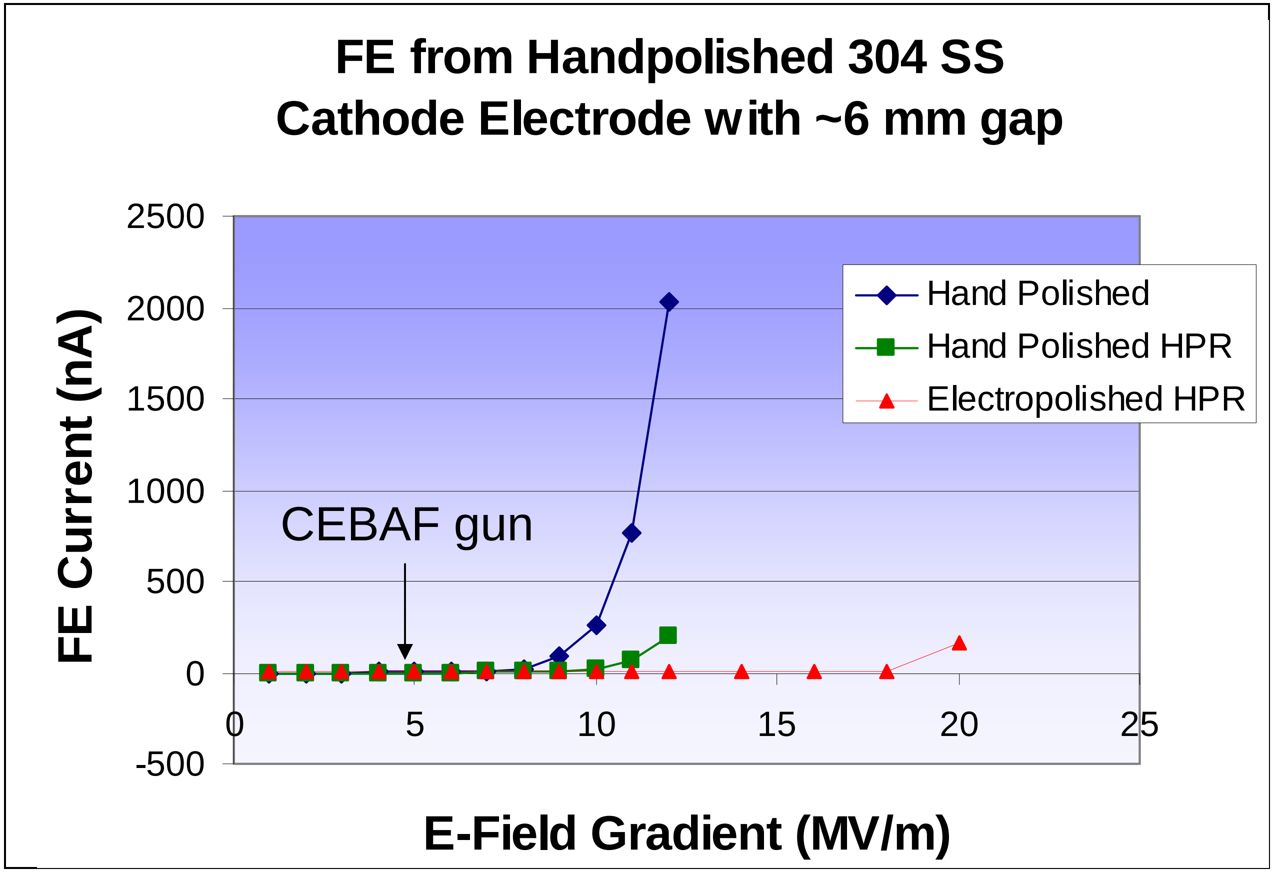
- Investigate field emission properties of Stainless Steel and single crystal Niobium
- Investigate field emission properties of diamond paste polished, electropolished, and chemically etched surfaces for each material
- Investigate effect of HPR of cathode and anode
- Open HV chamber under “clean room like” conditions (portable hood)
- Working closely with SRF group

Must Eliminate Field Emission

Investigate the SRF-cavity technique "high pressure rinsing"

Recent tests at JLab with shaped electrodes

Work of M. Chetsova, K. Surles-Law



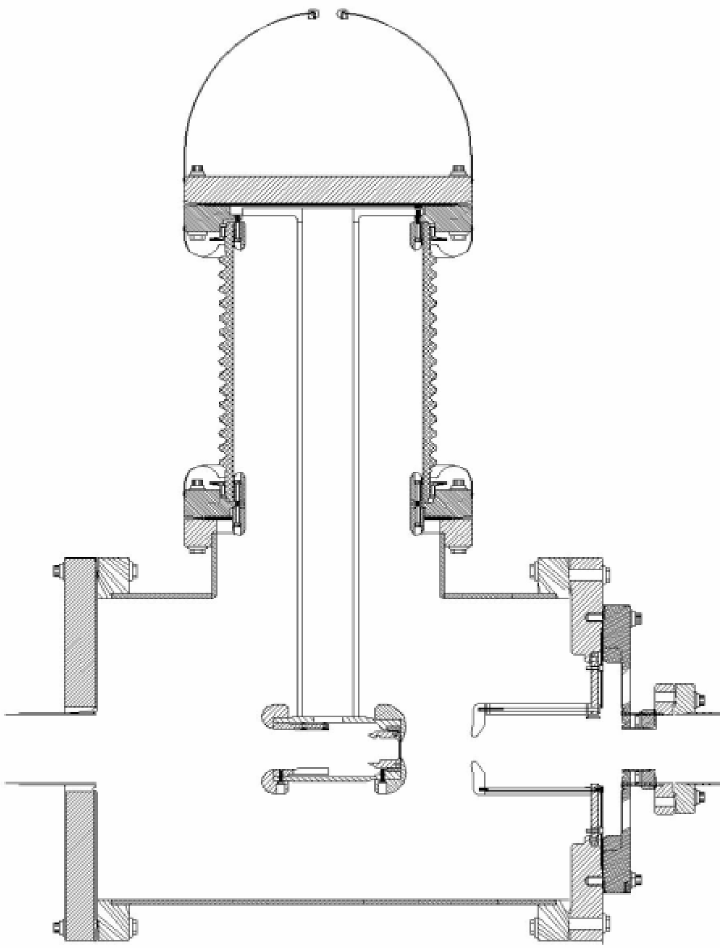
Conclusion

- R&D program to push gun voltage > 120kV to reduce ill effects related to space and surface charge limitations. Empirically determine the reasonable maximum bias voltage for trouble-free operation. Develop an inverted ceramic insulator design.
- The key to obtaining the desired high voltage is to eliminate field emission. At Jefferson lab the Center for Injectors and Sources is in a unique position to address the issue of field emission using the same principles and systems used by the SRF group.

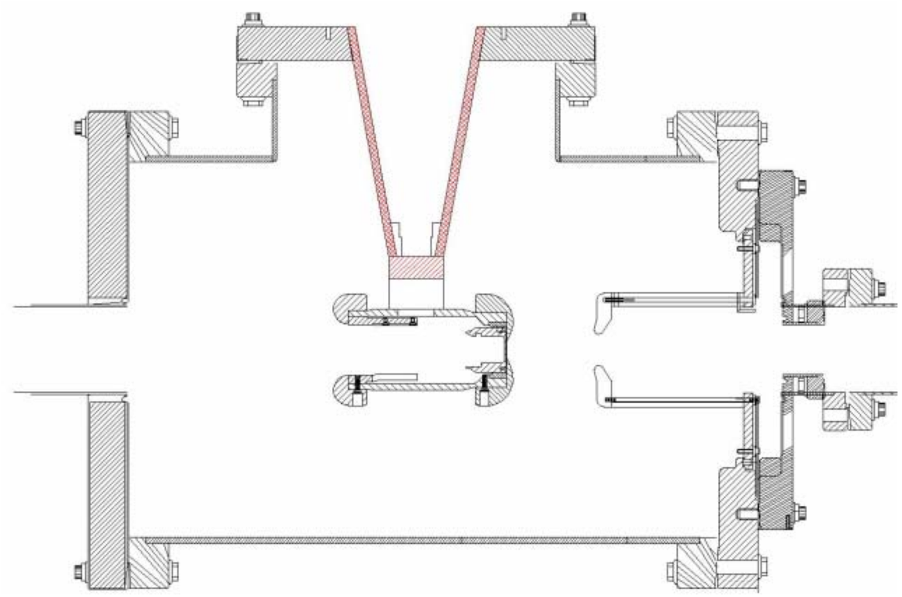
Source Parameter Comparison

Parameter	CEBAF	JLab/FEL	JLab 100mA FEL	ILC
Number electrons/microbunch	8.3×10^5	8.3×10^8	8.3×10^8	3×10^{10}
Number of microbunches	CW	CW	CW	3000
Width of microbunch	35 ps	35 ps	35 ps	~ 1 ns
Time between microbunches	0.667 ns	13 ns	1.3 ns	337 ns
Microbunch rep rate	1497 MHz	75 MHz	750 MHz	3 MHz
Width of macropulse	-	-	-	1 ms
Macropulse repetition rate	-	-	-	5 Hz
Charge per micropulse	0.13 pC	0.133 nC	0.133 nC	4.8 nC
Charge per macropulse	-	-	-	14420 nC
Average current from gun	200uA	10mA	100mA	72 uA
Average current in macropulse	-	-	-	0.0144 A
Duty Factor: beam ON/beam OFF (during macropulse for pulsed machines)	5×10^{-2}	2.6×10^{-3}	2.6×10^{-2}	3×10^{-3}
Peak current of micropulse	3.8 mA	3.8 A	3.8 A	4.8 A
Current density (for spot size below)	1.9 A/cm^2	19 A/cm^2	19 A/cm^2	6 A/cm^2
Laser Spot Size	0.05 cm	0.5 cm	0.5 cm	1 cm

Inverted Gun Geometry

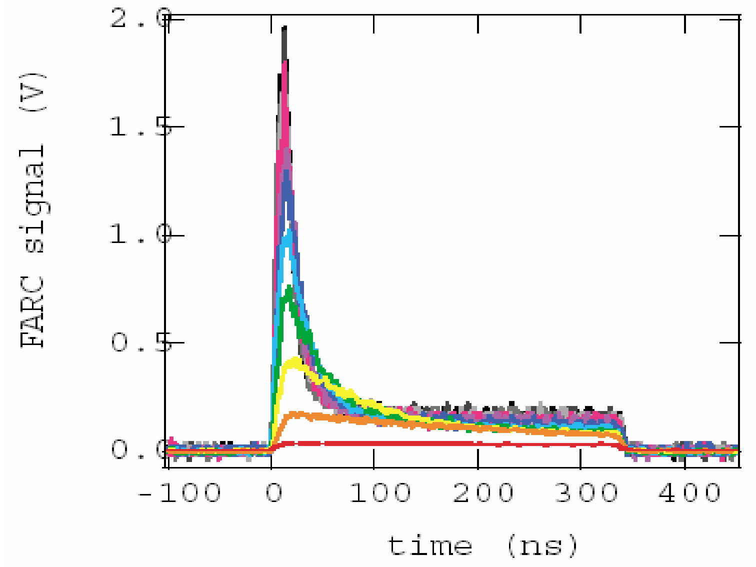


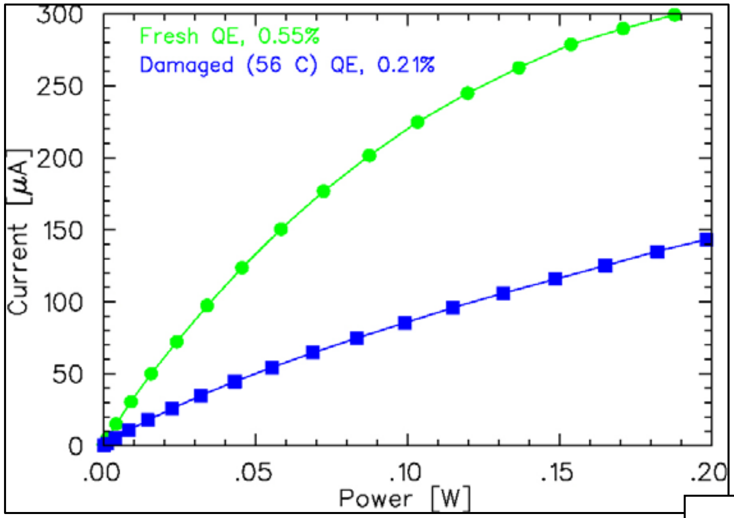
- Medical x-ray technology
- Ceramic not exposed to FE
- Compact



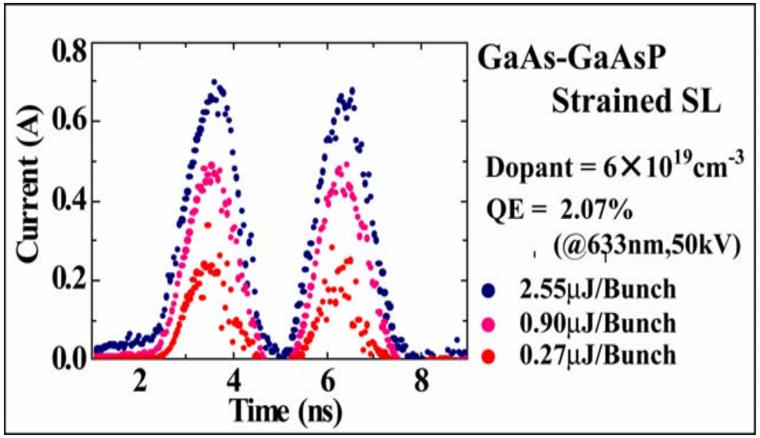
Surface Charge Limit

QE reduction at high laser power





Nagoya



Peak to peak spacing 2.8ns, bunchwidth 0.7ns, Charge: 1nC/bunch

Heavily doped surface: viable solution?

5.5 A/cm2 measured @ SLAC for 780 nm, 75 ns pulse

9.7 A/cm2 @ Nagoya for 780 nm, 30 ps

ILC current density comparable to these values…something to worry about

Slide info courtesy Takashi Maruyama, SLAC