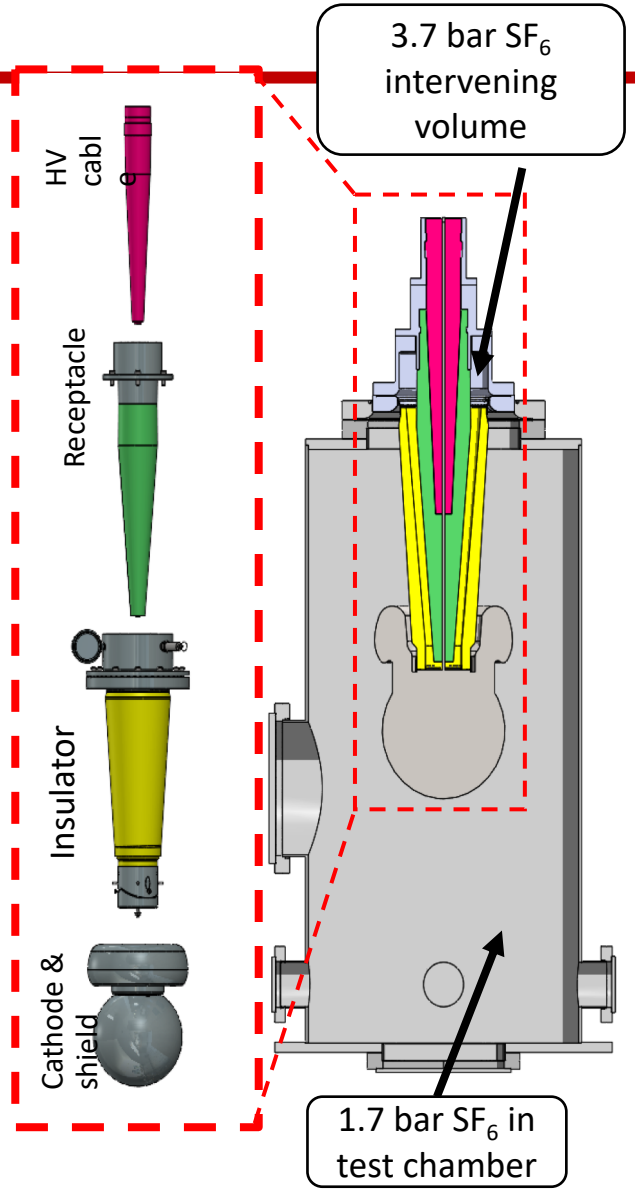
JLab 400 kV inverted insulator development compatible with commercial high voltage cable

FY 2024 tasks:

- Q1
  - Present high voltage inverted geometry insulator R&D as invited speaker at the 14th International Vacuum Electron Sources Conference: IVESC2023, Tsukuba, Japan September 25-29, 2023.
  - Meet with KEK high voltage gun team, and with Kyocera engineers to discuss design and development of insulator (Meeting arranged by Masahiro Yamamoto, KEK).
  - Perform initial insulator electrostatic design using CST FEA modeling software.
- Q2
  - Finalize insulator electrostatic design iterating with triple point junction shield electrostatic design to linearize potential along insulator while keeping the maximum electric field below 10 MV/m at 500 kV.
- Q3
  - Develop insulator engineering design iterating with electrostatic design.
- Q4
  - Finalize insulator engineering design iterating with ME designers.
  - Complete insulator engineering drawing package required to start manufacturing inquiries with potential suppliers (Kyocera in Japan, and MPF in US).

JLab Higher voltage insulator R&D status

- In August 2023, JLab demonstrated 500 kV DC test on a large conical insulator with a test electrode immersed in SF_6
- The insulator made in 2010 does not fit commercial cable
- A custom cable termination using a modified commercial receptacle and SF_6 intervening layer was utilized to connect the insulator to the high voltage power supply
- KEK hosted a meeting on September 28th with Kyocera representatives to explore developing a more compact 500 kV inverted insulator 500 kV for next ILC gun

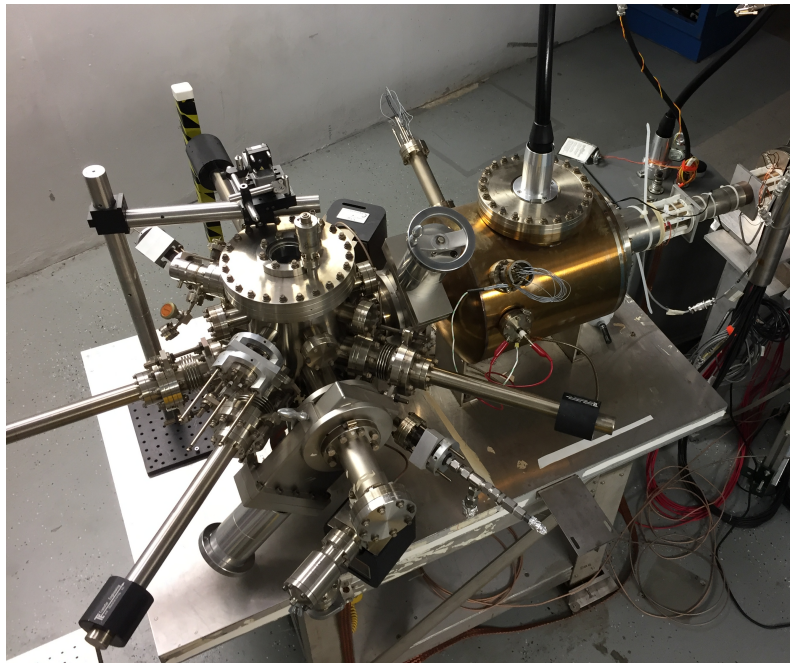


Model: G. Palacios-Serrano, JLab

Jefferson Lab

JLab built two 200 kV prototype guns with commercial inverted insulators for ILC in 2010

- One off the prototypes has delivered since then high polarization high current beam for the JLab nuclear physics program at the Continuous Electron beam Accelerator Facility (CEBAF) operating at 130-180 kV:
- Strained Superlattice GaAs/GaAsP, polarization >85% (measured at Mott polarimeter)
- Good QE > 1% @ 780 nm after activation
- Lifetime about 200 C (s4D ~ 1mm) with intensity < 200 uA
- CW rep. rate >250 MHz => bunch charge < 1 pC



Develop higher voltage gun

- ILC source parameters from TDR 2013 impose more stringent requirements on electron source
  - Bunch charge 4.8 nC compared to <1 pC in CEBAF
  - New electron gun design for higher operating voltage with no measurable field emission is needed to meet the new requirements while maintaining ~ 100 uA avg. current, beam polarization and photocathode lifetime
- The photogun would be designed to meet the following performance requirements
  - Beam polarization > 85 %
  - Beam current > 1 mA CW
  - Charge lifetime > 1000 Coulombs
- **Technical objectives**
  - **Higher voltage > 350 kV**
  - **Larger laser spot size**
  - **No field emission**
  - **XHV ~ 10^{-12} Torr**
  - **Good beam optics**

Parameter	Symbol	Value	Units
Electrons per bunch (at gun exit)	N_-	3×10^{10}	Number
Electrons per bunch (at DR injection)	N_-	2×10^{10}	Number
Number of bunches	n_b	1312	Number
Bunch repetition rate	f_b	1.8	MHz
Bunch train repetition rate	f_{rep}	5 (10)	Hz
FW Bunch length at source	Δt	1	ns
Peak current in bunch at source	I_{avg}	3.2	A
Energy stability	σ_E/E	<5	% rms
Polarization	P_e	80 (min)	%
Photocathode Quantum Efficiency	QE	0.5	%
Drive laser wavelength	λ	790±20 (tunable)	nm
Single bunch laser energy	u_b	5	μJ

Child's Law: $j_0 = \left(2.33\times10^{-6}\right)V_0^{3/2}/d^2$

Assume d=3 cm cathode/anode gap

V (kV)	j_0 (A/cm^2)
100	7
140	14
200	23
350	53

Factor 2 in charge
Factor ½ in pulse
Factor 0.7 in size