Cornell Laboratory for Accelerator-based Sciences and Education (CLASSE)

High Brightness, HVDC, Photoemission Electron Gun Development at Cornell

Charlie Sinclair

Cornell University

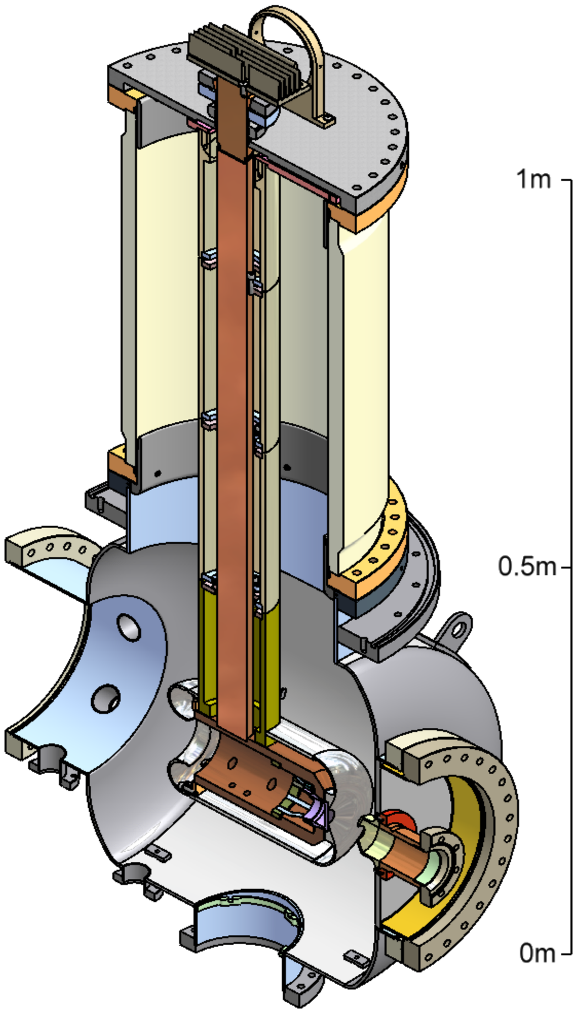
Outline

- 750 kV Gun
- 750 kV, 100mA HVPS
- GaAs Photocathode
- 20W, 520 nm, 1.3 GHz Laser
- Photocathode and Gun Development Laboratory
- Summary

HVDC Gun Performance Goals

- Operation at or above 500 kV
- Maximum voltage of 750 kV
- 100 mA average current, in a 1.3 GHz train of 77 pC bunches, 20-30 ps duration,
- $\varepsilon_n < 0.3\ \mu m$, with nominal “tophat” transverse and longitudinal profiles
- Cathode operating lifetime 100 h at 100 mA

750 kV Gun Details

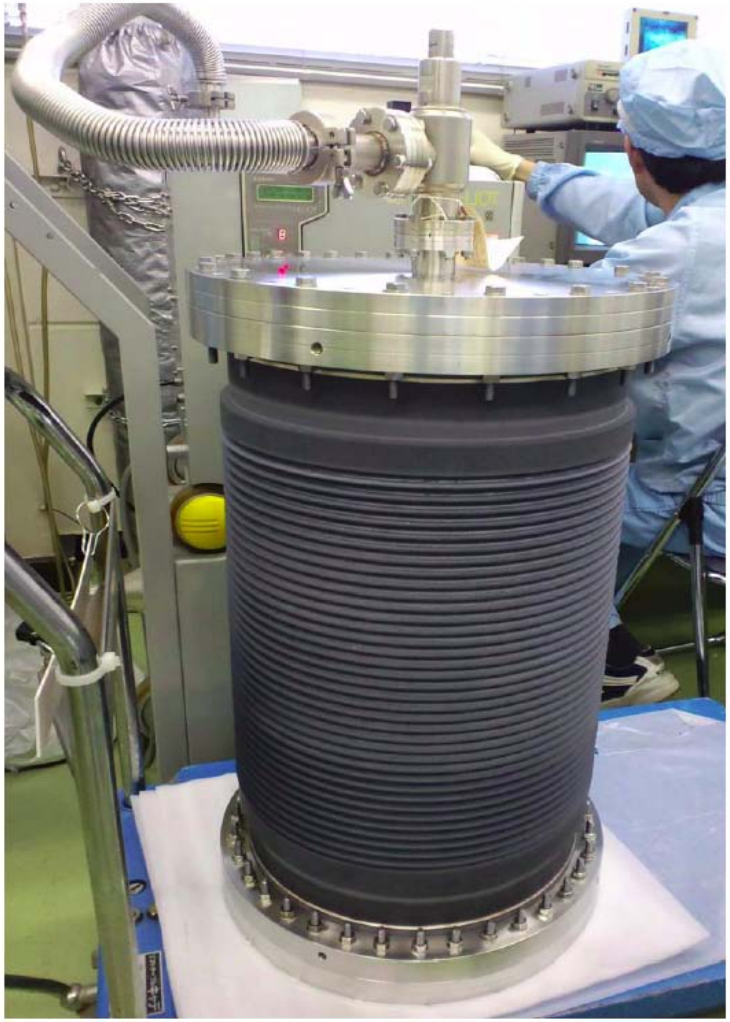


- Externally cooled Be anode
- GaAs photocathode, ~ 12 mm active diameter
- Copper cooling rod to cathode
- Ti4V6Al and 316L stainless electrodes
- Full electrode and its support assembled without touching any external surface
- Gun bakeable to 450 C in air, chamber to 900 C in vacuum
- Ceramic diameter set by 419 mm knife edge flange diameter
- Massive NEG pumping

Gun Operation to date

- First beam in September 2006
- Operated standalone for cathode and beam studies for many months
- Operation to date limited to ~ 250 kV by ceramic problems (punch through and braze failures)
- Operation for a year in full injector test
- Gun operation and cathode exchanges are trouble free and routine

Ceramic development



- Ceramic with bulk resistivity and improved braze design installed
- Measured resistivity of 6.45 x 10^{10} Ohm-cm gives 30 μA current draw at 500 kV
- Ceramic by Morgan, brazing and welding by Kyocera

Electrode Preparation and Current Gun Performance

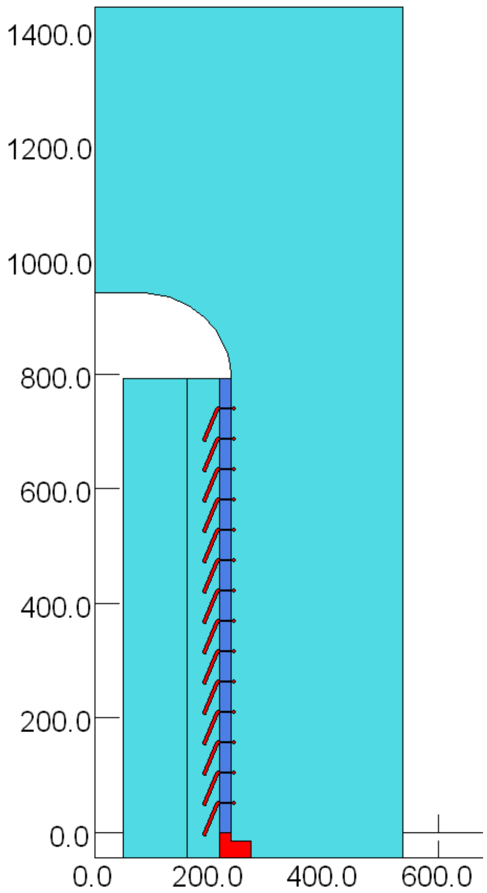
For the most recent gun assembly, with the new resistive ceramic, the full 316L electrode assembly was electro-polished, high pressure water rinsed (HPR), baked in air at 400 C for 100 hours, given a second HPR, and blown with high pressure, ultra-filtered dry nitrogen until a particulate counter registered nothing. Subsequent HV processing reached 445 kV (12.1 MV/m peak field), and had a punch through failure.

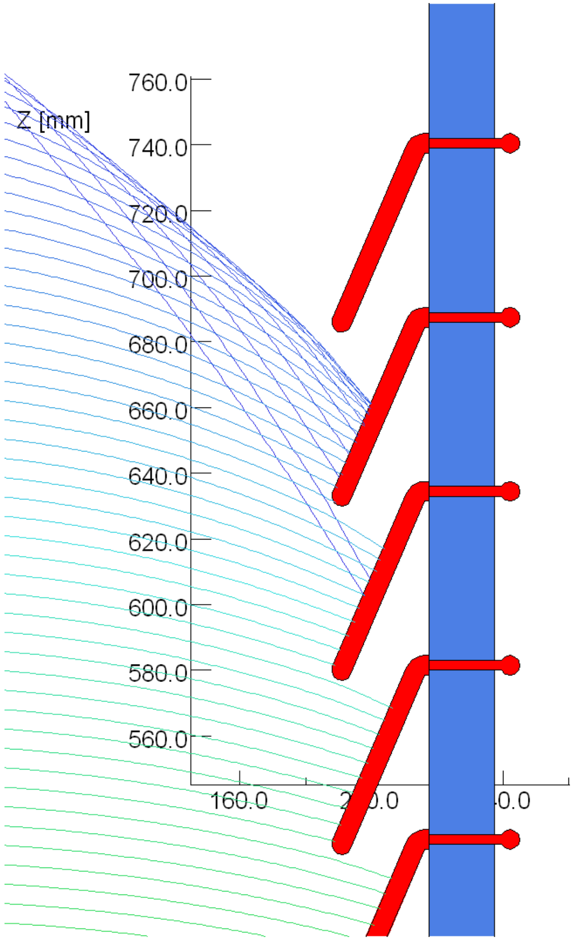
The Next Ceramic

- A resistive ceramic does NOT prevent punch through failures
- To eliminate punch through, it is necessary to prevent electrons from depositing energy in the ceramic – i.e. to stop them
- This requires metallic shielding of the ceramic inner surface – and thus a segmented ceramic design
- Shield rings need high thermal conductivity and high hardness

Segmented Ceramic

750 kV
terminal





Segmented Ceramic Design

- Built on 22 inch wire seal flanges, the larger inner diameter allows reduction of the field on the electrode support tube to <12 MV/m at 750 kV
- Copper (or CuBe) shield rings required for good thermal conductivity and hardness
- May fabricate in two sections, to allow a three-electrode gun design in the future.
- Detailed design nearing completion

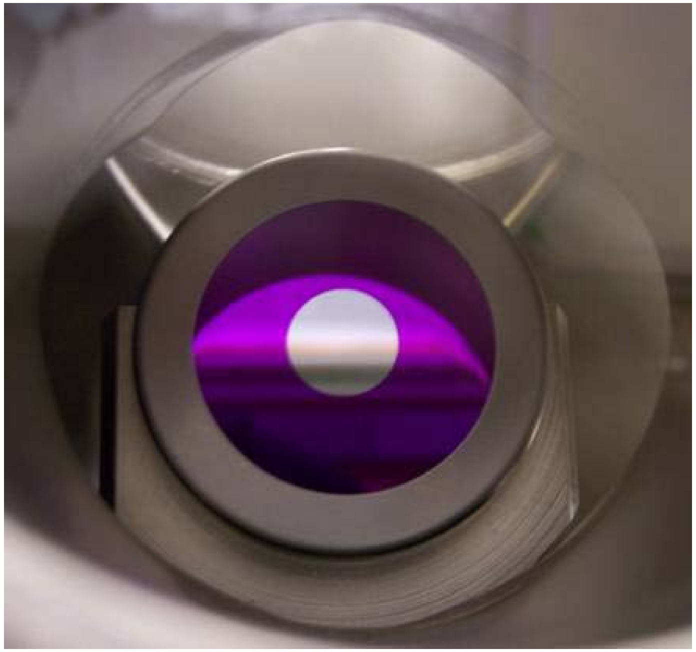
750 kV, 100 mA HVPS

- Insulating core transformer technology
- 62 circuit boards, each delivering 100 mA at 12.5 kV, stacked in series – 24 pf total capacitance
- Pressurized SF_6 insulation
- External high power, high frequency (~ 100 kHz) drive and control circuitry

HVPS issues

- Original controls unstable during operation at reduced voltage and/or current. A fixed load resistor drawing ~ 2 mA improved stability.
- Returned to Kaiser Systems for re-work – redesigned circuit boards, control circuitry, and high power driver are being installed.
- Currently operating at 30 mA, full voltage, with greatly improved stability.
- Additional 600 kV, 100 mA supply on order, to support cathode and gun test lab operation.

Photocathode Performance

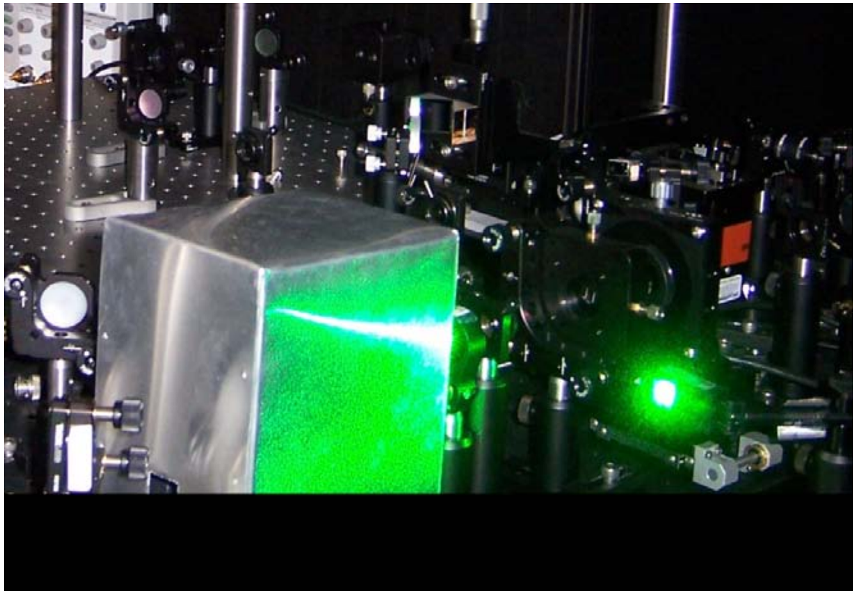


GaAs wafer, anodized at large radius, indium soldered to Mo Puck

- Cathodes to date have been GaAs, cleaned by atomic hydrogen and heating, and activated with Cs and NF_3
- Initial QEs of 12-15% at 520 nm, with lifetime limited only by ion back bombardment
- Cathode changes, every several weeks, take about ½ hour, with no dropped pucks
- Maximum current to date 20 mA DC in test lab, 8 mA with 1.3 GHz RF structure

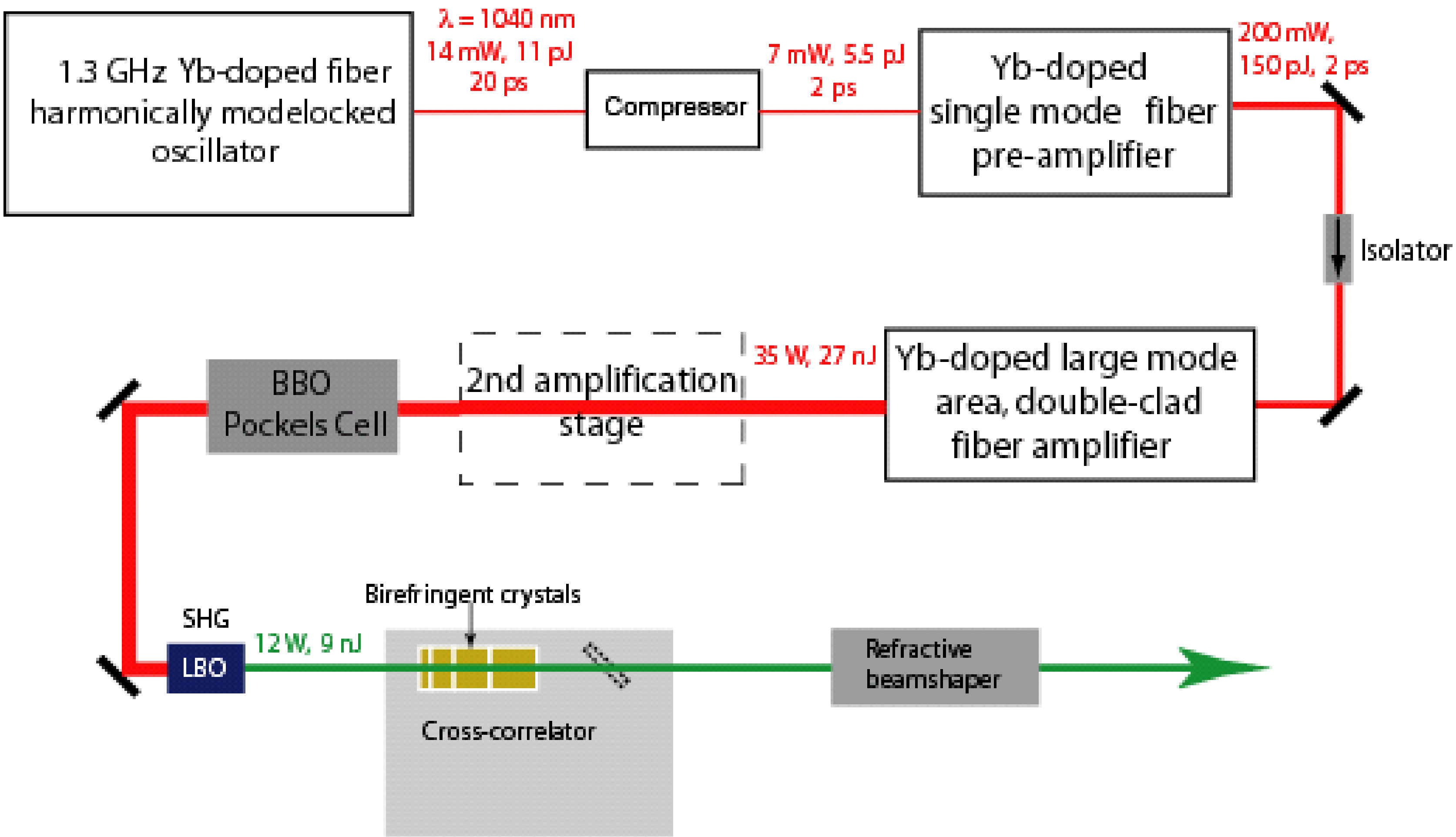
Photocathode cleaning, preparation and transport

High Power 1.3 GHz Laser

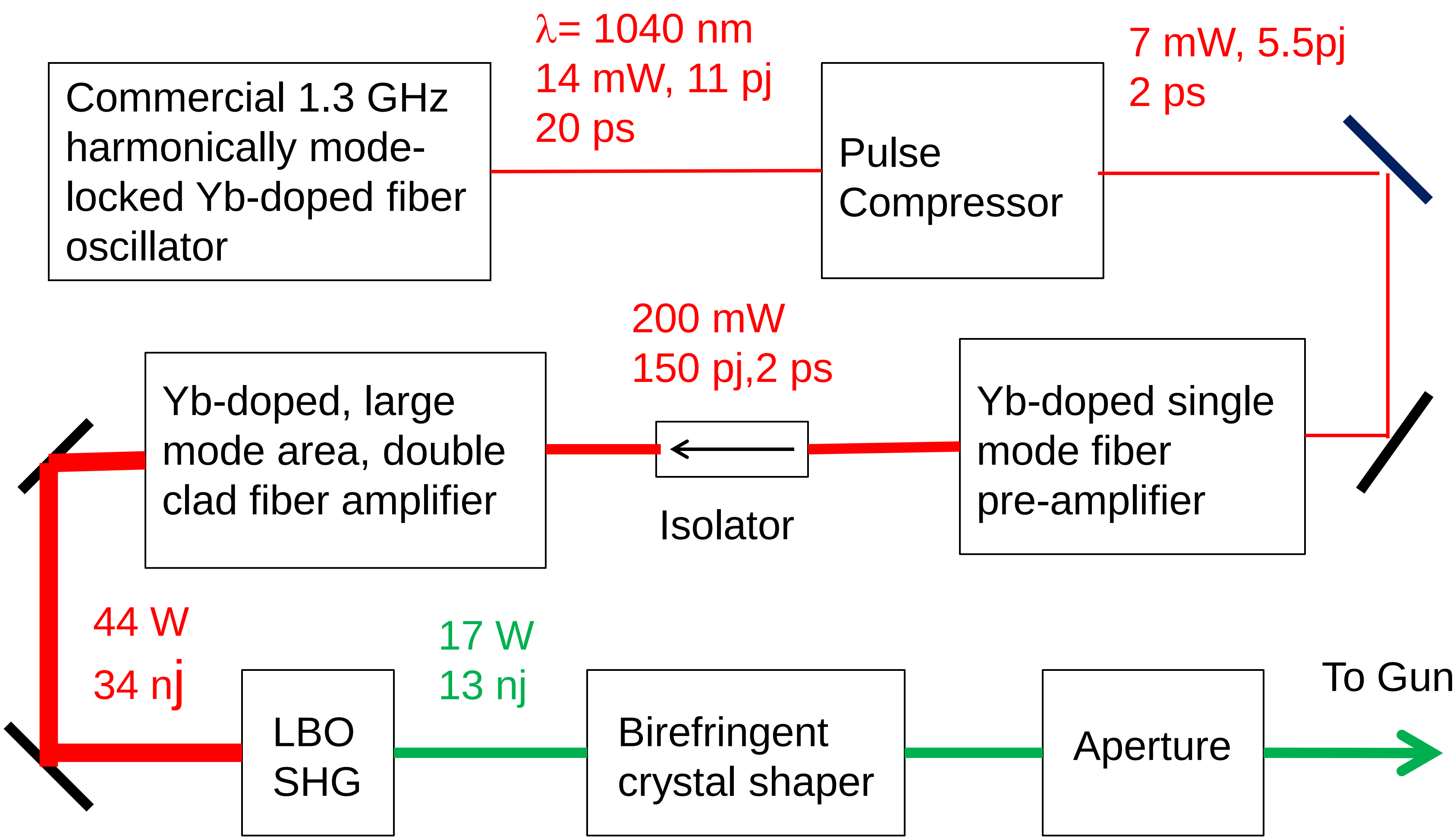


- Operated for ~ 5 hours at 20 W green, and for very extended times at 15 W green
- Measured 53% transmission from laser output to gun entrance window

Original High Power Laser Design



ACTUAL 1.3 GHz Green Laser



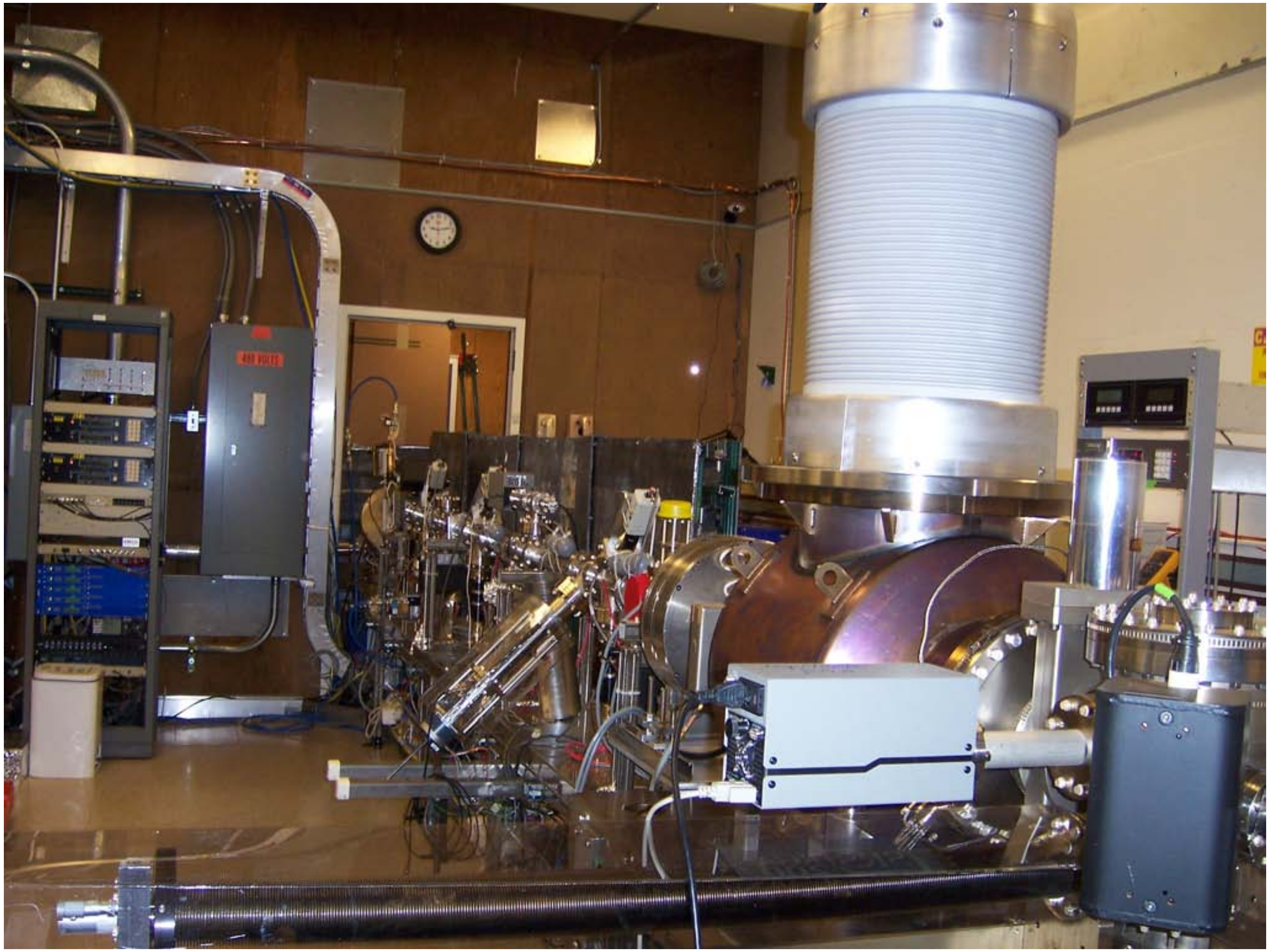
High Power Laser, continued

- Fiber burning problem fixed by cooling gain fiber. This should allow doubling the IR pump power, giving ~ 40 W green
- Use the original 50 MHz laser with the BBO Pockels Cell for full bunch charge beam measurements at low duty factor
- Elimination of thermal and mechanical noise sources underway

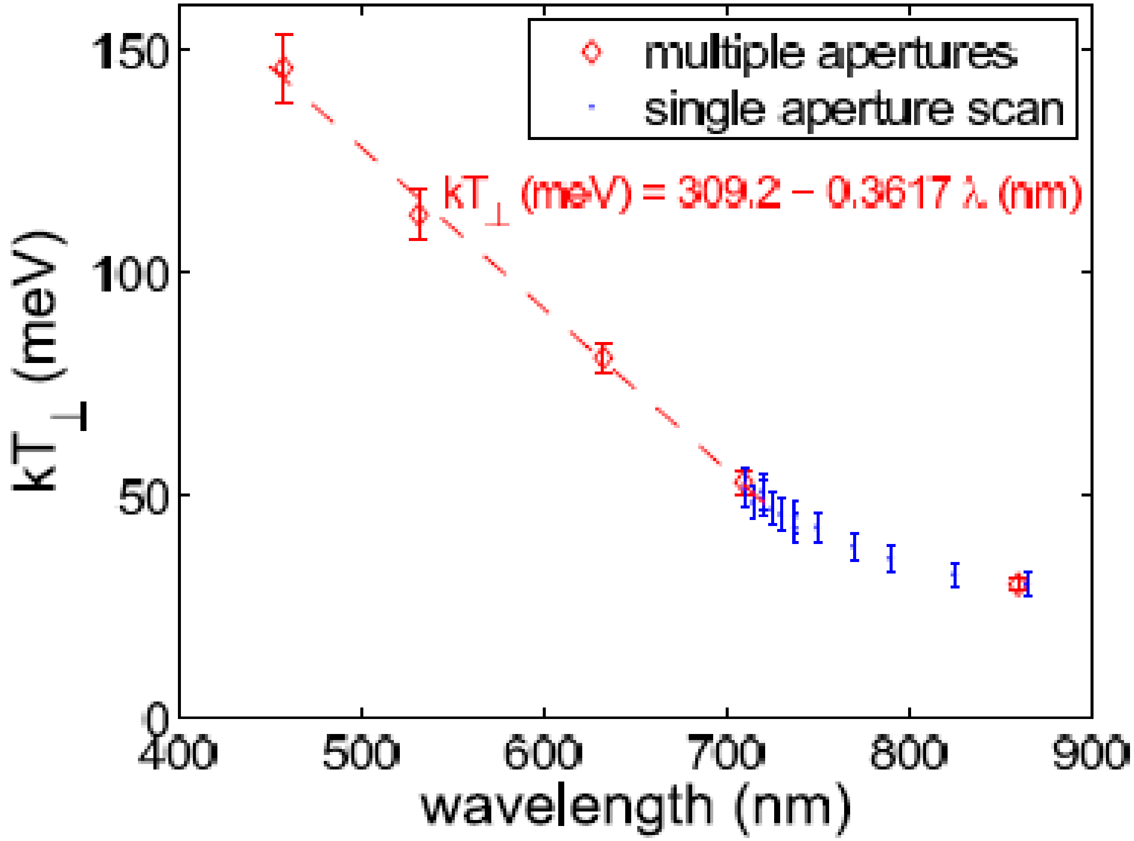
Gun and Cathode Development Lab

- Restoring original Gun test lab capabilities, with gun operation to 600 kV, 100 mA
- Photocathode physicist hired
- Surface analysis equipment in hand (Auger, LEED….)
- Constructing system to measure cathode transverse and longitudinal energy
- Adding 300 kV field emission test stand

Gun Development Lab Beamline



Measured GaAs Thermal Emittance vs. Wavelength



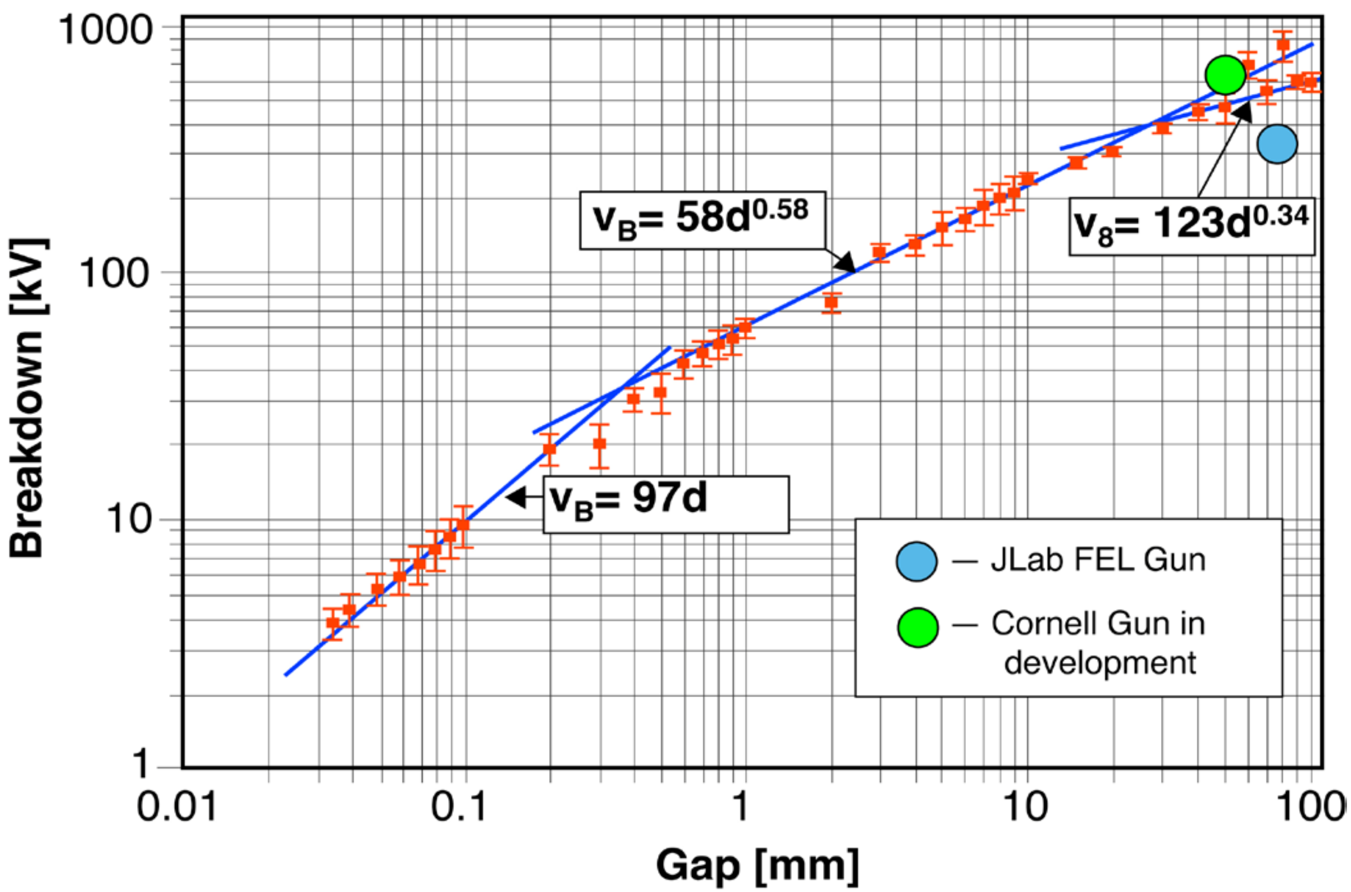
GaAs Temporal Response vs. Wavelength

Wavelength (nm)		Gun Voltage (kV)		Temporal Response (ps)
860		200		76 +/- 26
		250		69 +/- 22
785		200		11.5 +/- 1.2
		250		9.3 +/- 1.1
710		200		5.8 +/- 0.5
		250		5.2 +/- 0.5
520		250		< 1
460		250		<0.14

HVDC Gun Challenges

- Eliminating or mitigating the effects of field emission is the **greatest** challenge
  - Inverted gun design?
  - Process with heavy gas (krypton)?
  - Conductive glass or dielectric coatings?
  - Three electrode design?
- Reduce cathode thermal emittance, so a lower field gives the same brightness?

HV Holdoff Voltage vs. Gap



From Paul G. Slade

Laser Challenges

- Transverse shaping
- More longitudinal shaping crystals
- Coatings cannot take high CW power
- Generating full charge bunches at very low duty factor, without “ghost” pulses
- Eliminate thermal, mechanical and electrical noise sources

Summary

- Field Emission remains the predominant problem for HVDC photoemission electron guns
- Cathode, laser, HVPS and vacuum issues are challenging but solvable for a 100 mA average current source
- Well equipped cathode characterization and gun development laboratory being assembled

Summary, cont'd

- New gun design, incorporating a large segmented insulator and vacuum improvements, is underway
- Beam operation with full injector will resume this month, at reduced voltage (ca. 350-375 kV)