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

ERL 2011
the 50th ICFA Advanced Beam Dynamics Workshop
on Energy Recovery Linacs

Progress Report for the Cornell ERL Injector Prototype

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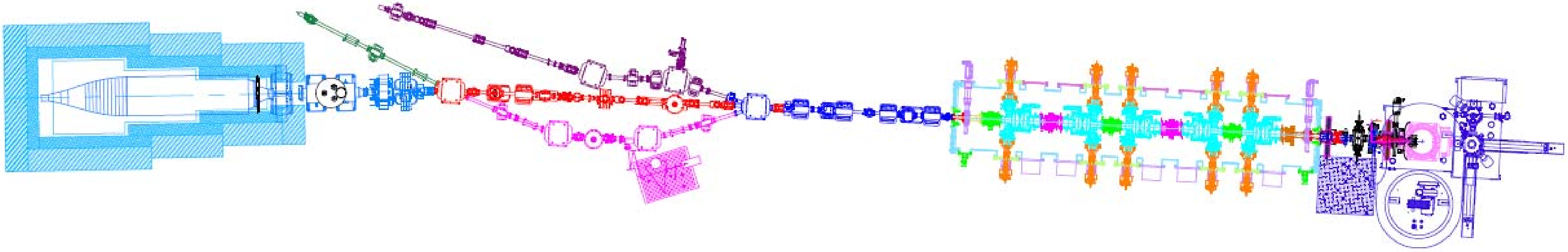
Outline

- Specifications
- DC Gun Status
- Laser (another presentation)
- Cathodes (another presentation)
- Emittance Results
- High Current Results

System Specifications

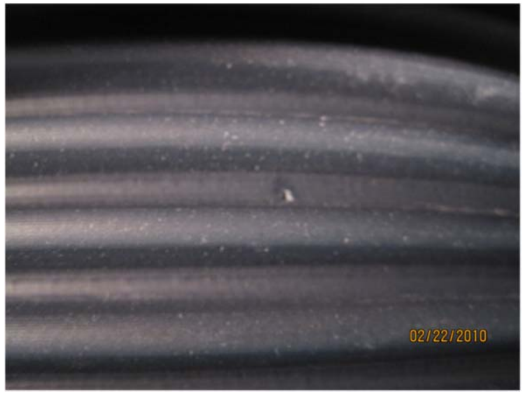
Parameter	Metric	Status	Notes
Average Current	100 mA		25 mA max (32 is the world record)
Bunch Charge	77 pC		Pulsed mode (50 MHz)
Energy	5 to 15 MeV		13 MeV max (due to cryo limits)
Laser Power	> 20 W		> 40 W at 520 nm
Laser Shaping			Adequate for now
Gun Voltage	500-600 kV		Currently operating at 350 kV
Emittance	< 2 μm (norm, rms)		Ultimate ERL goal 0.3 μm, with merger
Operational Lifetime	> 2000 C/cm^2		Long way to go



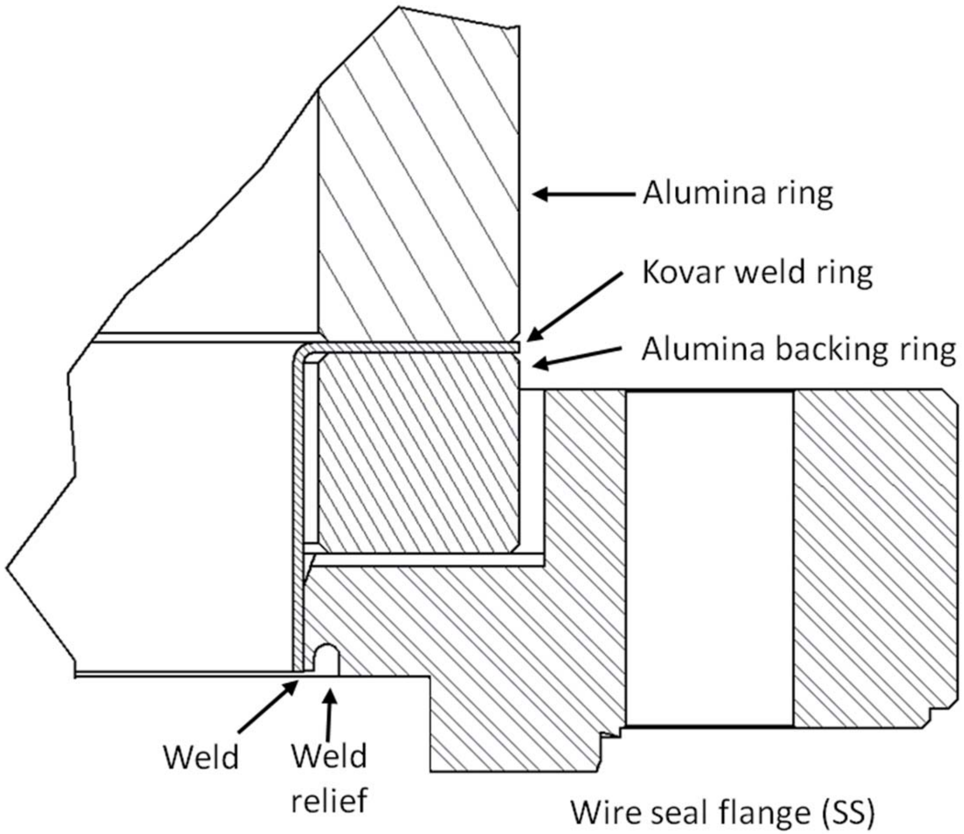
DC Gun and High Voltage

- We have all had problems with insulator braze joint reliability and with insulator punch-thru around 450 kV
- We believe the braze joint problem has been solved (see next page).
- With the assumption that having a slightly conductive insulator material will bleed away field emitted electrons that reach the insulator, we procured an insulator made with AL970CD.

- Unfortunately, had a punch-thru at 450kV, so it appears to be no better than plain alumina
- Now, can run beam at 350kV, and probably higher with further processing

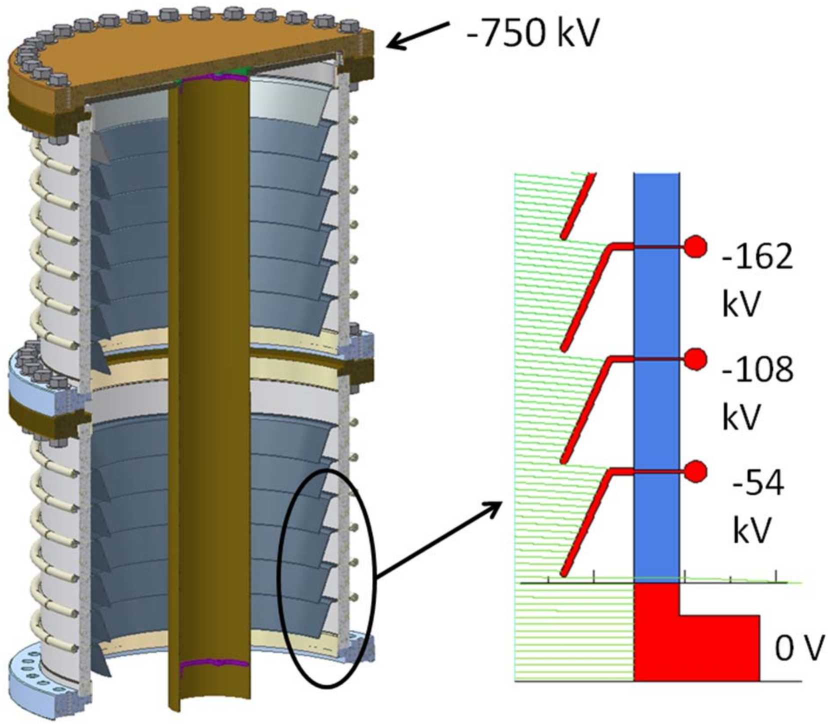


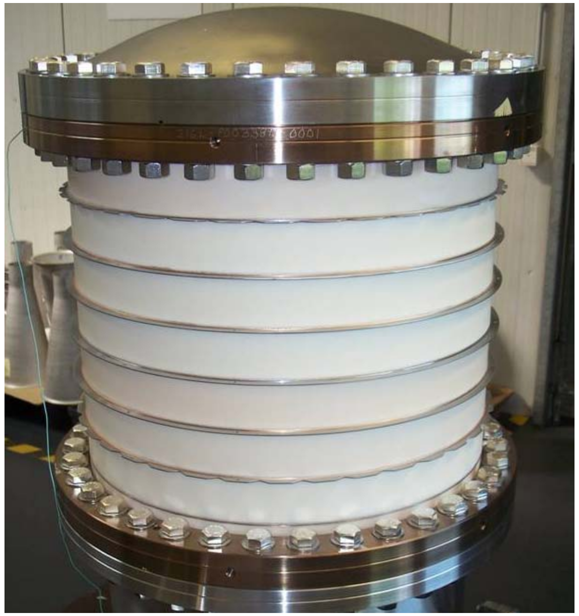
Braze Joint



New braze design for large insulators, first implemented by Kyocera.
Has performed great so far!

Segmented Insulator

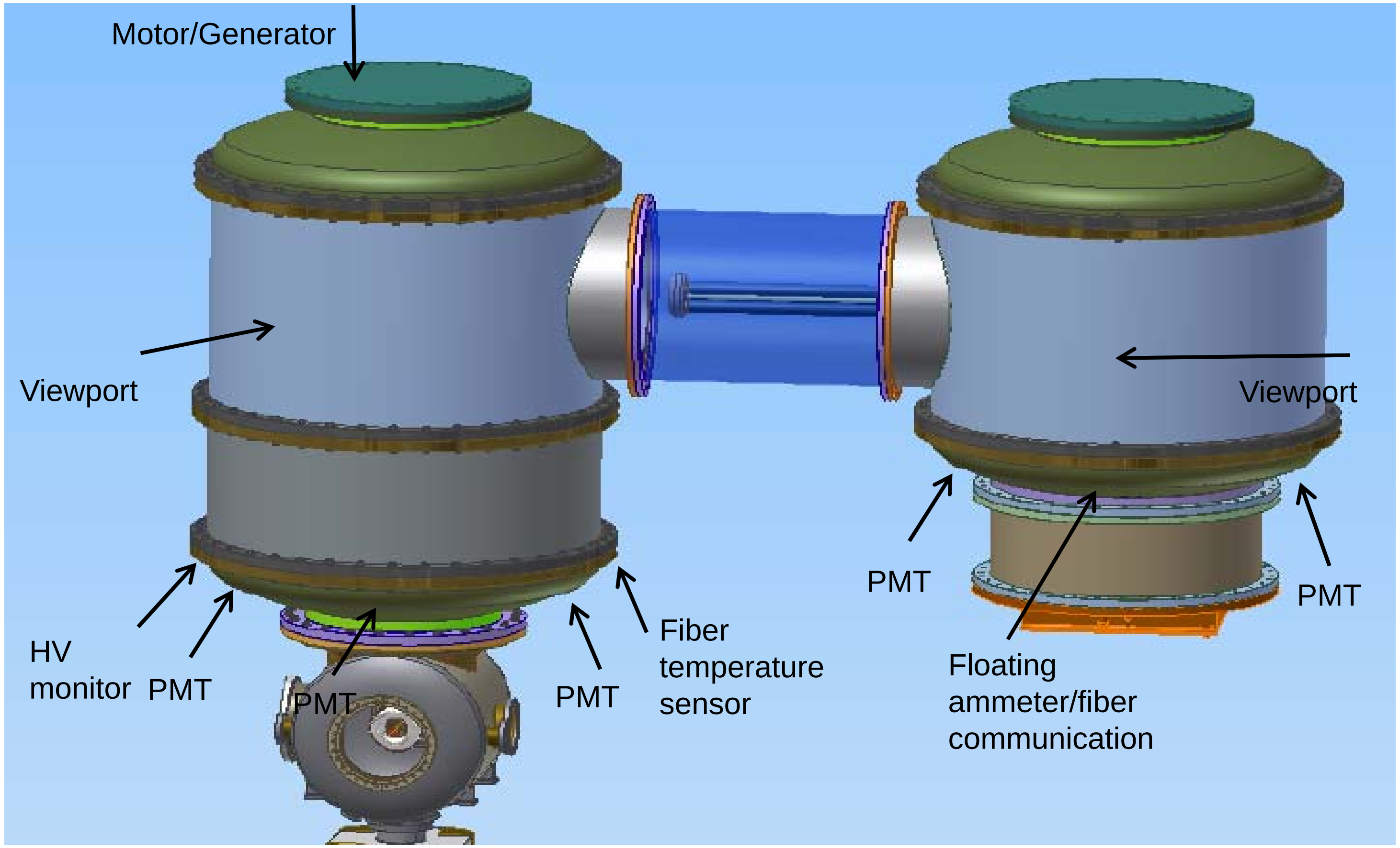




We designed a segmented insulator with intermediate guard rings to catch any field emitted electrons before they reach the insulator material.

New insulator delivered recently, and is undergoing vacuum testing.

SF_6 tank



A new SF_6 tank has been designed and is being manufactured. HV test with the entire system early next year

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Emittance

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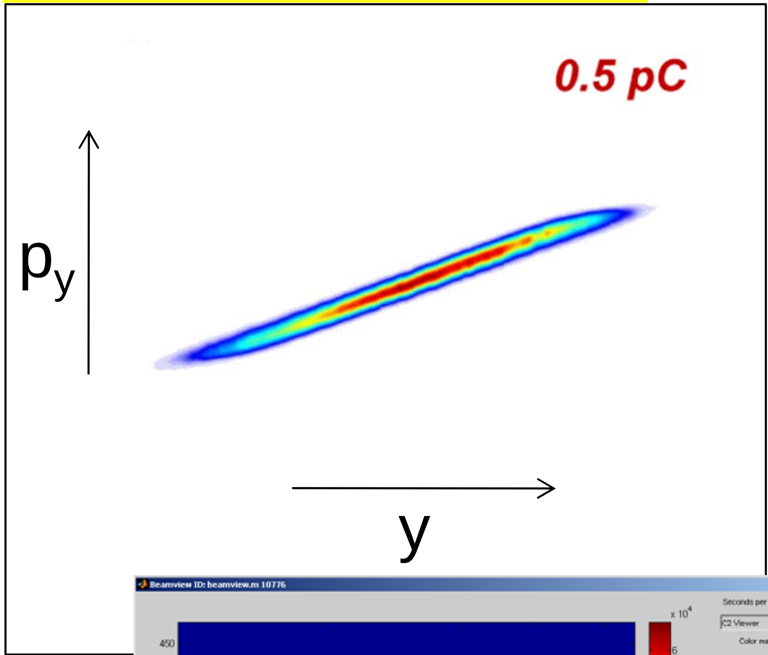
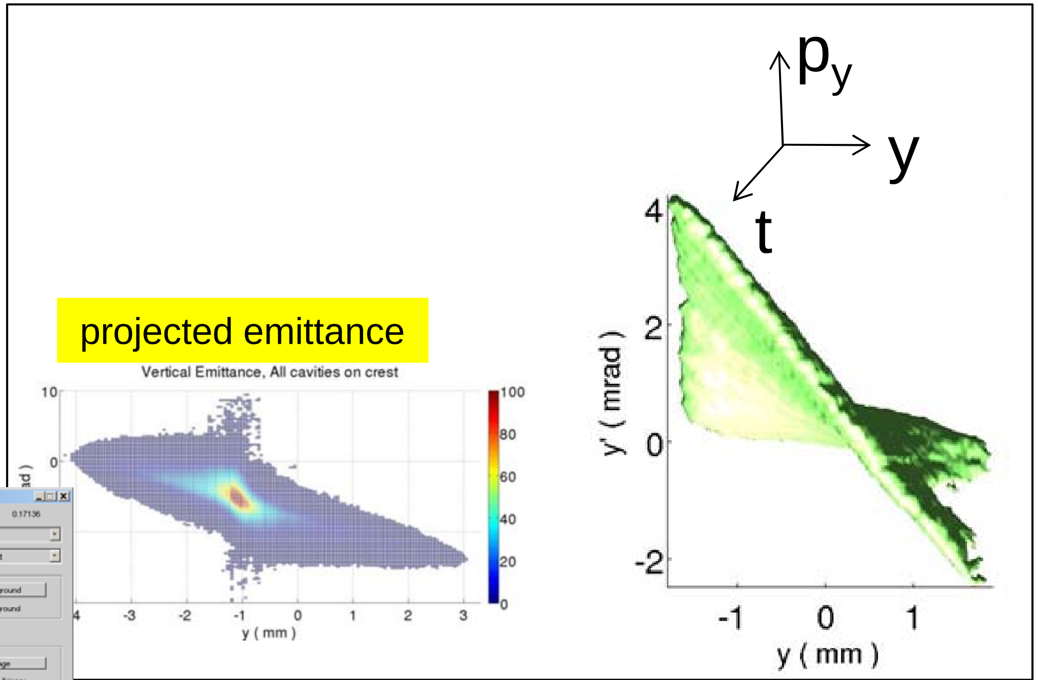
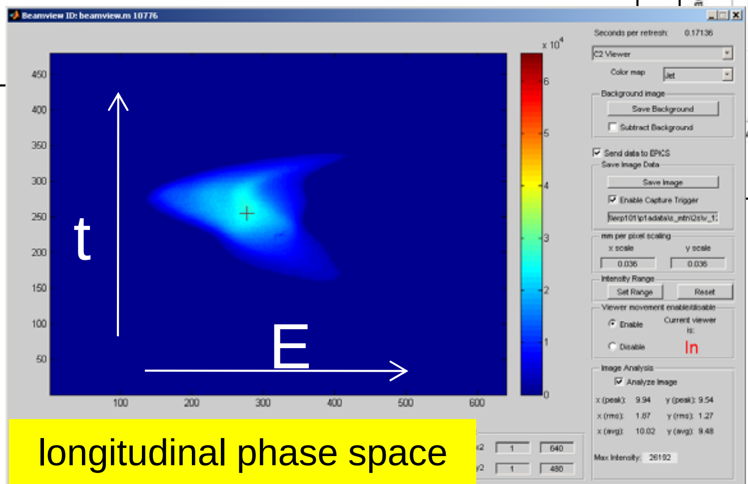
transverse phase space (animation)



slice emittance with resolution of few 0.1ps

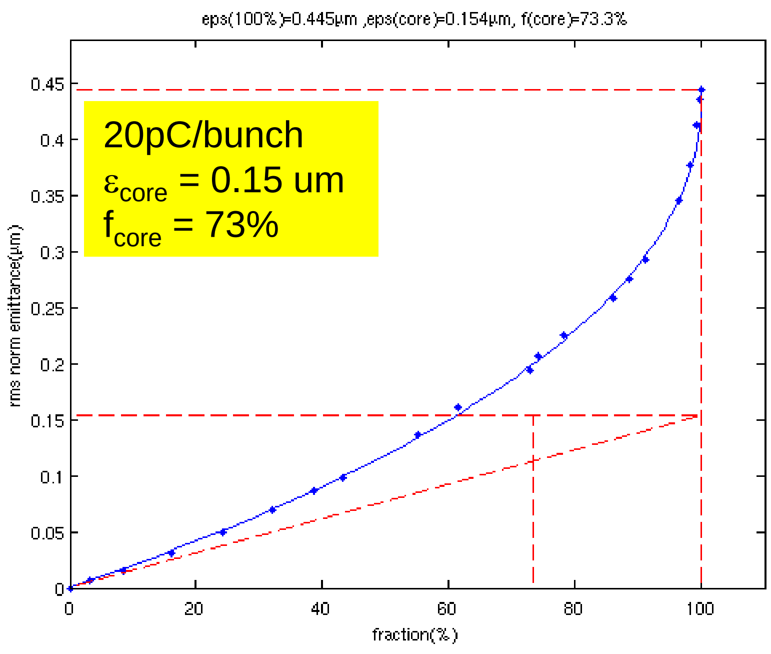


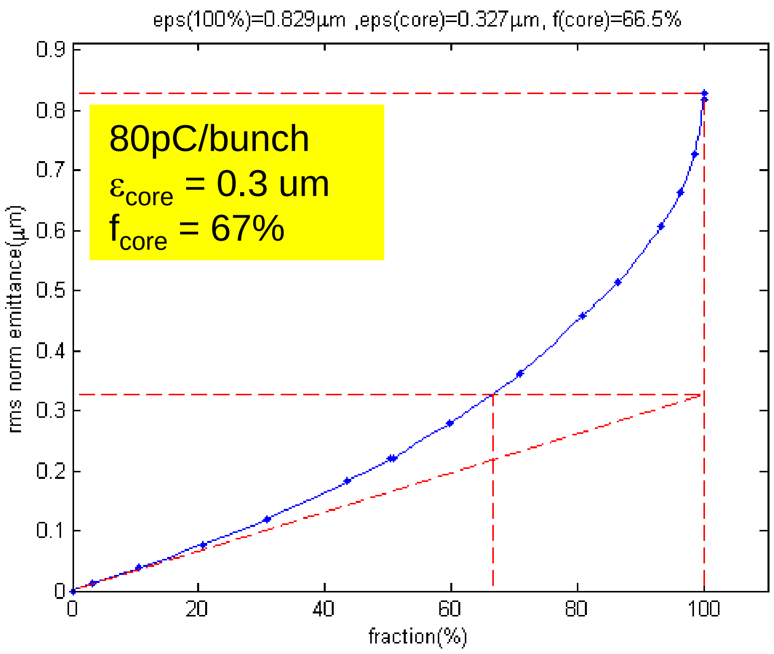


longitudinal phase space

Understanding Emittance Data

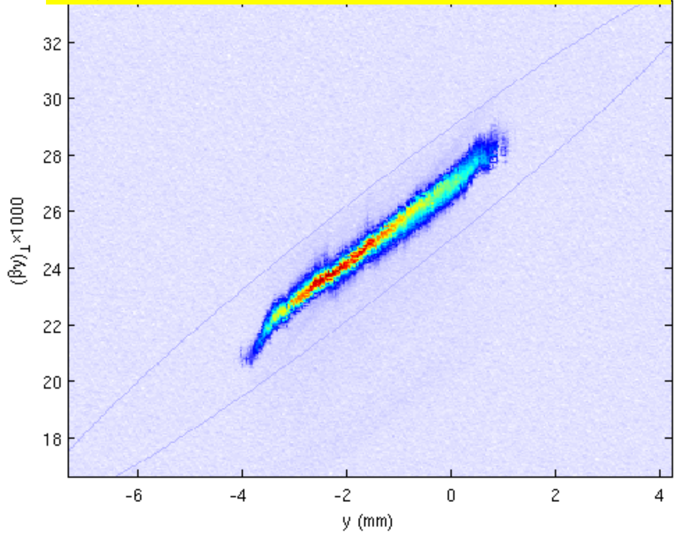
- Single RMS emittance definition is inadequate for linacs
  - Beams are not Gaussian
  - Various groups report 95% emittance or 90% emittance (or don't specify what exactly they report)
- The right approach
  - Measure the entire phase space, then obtain emittance of the beam vs. fraction (0 to 100%)



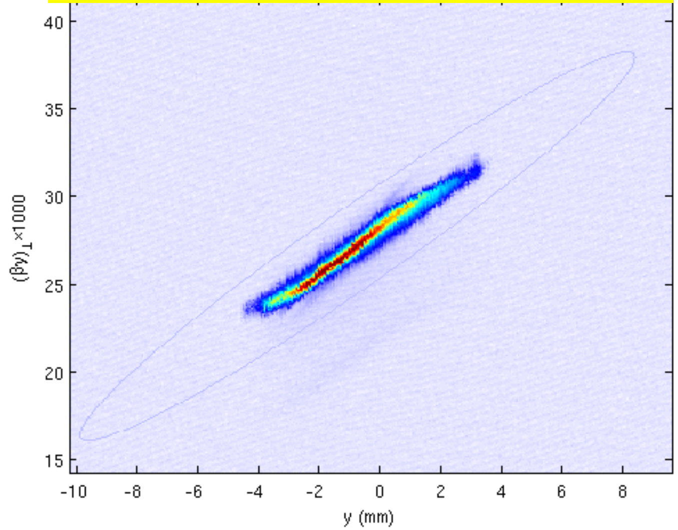


Emittance

ε_{ny}(100%) = 0.4 um @ 20pC/bunch



ε_{ny}(100%) = 0.8 um @ 80pC/bunch

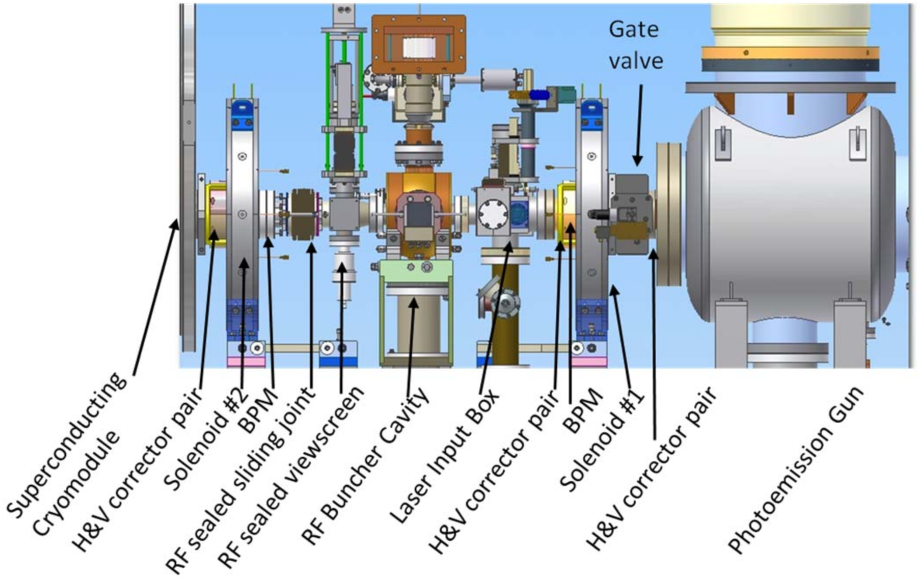


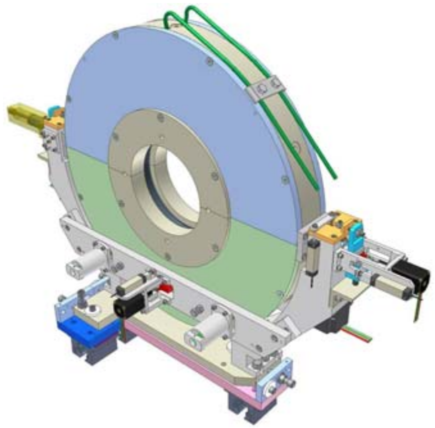
Keys to the result

- Beam-based alignment (took us several months)
- Working diagnostics!!
- Fight jitter and instabilities in the injector (laser, RF)

- x2 thermal emittance! x1.3 simulated emittance
- correct scaling with bunch charge

Beam-based alignment





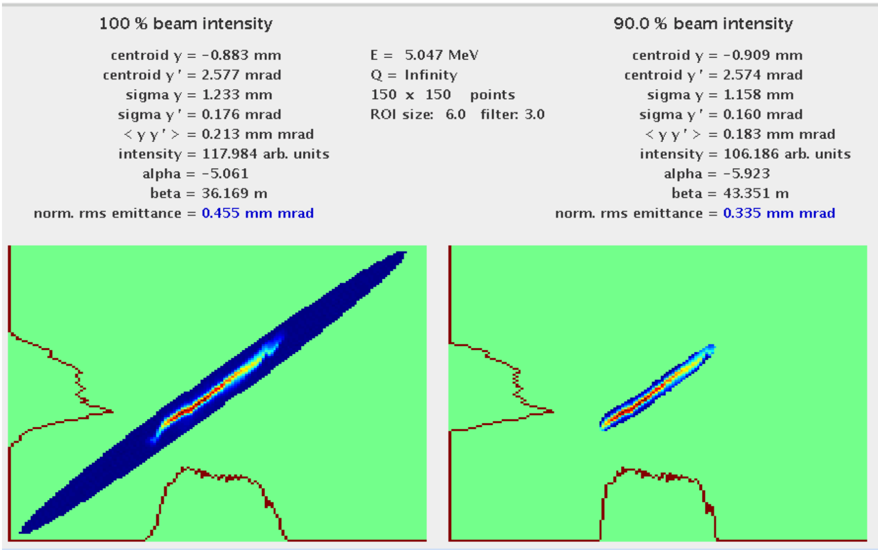
Had to retrofit remote control of the solenoids

Aligning the magnetic and electrical centers of all elements to the beam axis is crucial for obtaining low emittance and minimizing aberrations.

All element from the gun to the exit of the second RF cavity are aligned to < 100 um, and most to < 20 um.

Laser Off-center

Good news: running 5 mm off-center on the photocathode gives the same emittance (20pC/bunch) due to intrinsically low geometric aberrations in the DC gun



This is very important, as we know that we cannot run with the laser at the center of the cathode due to cathode damage issues.

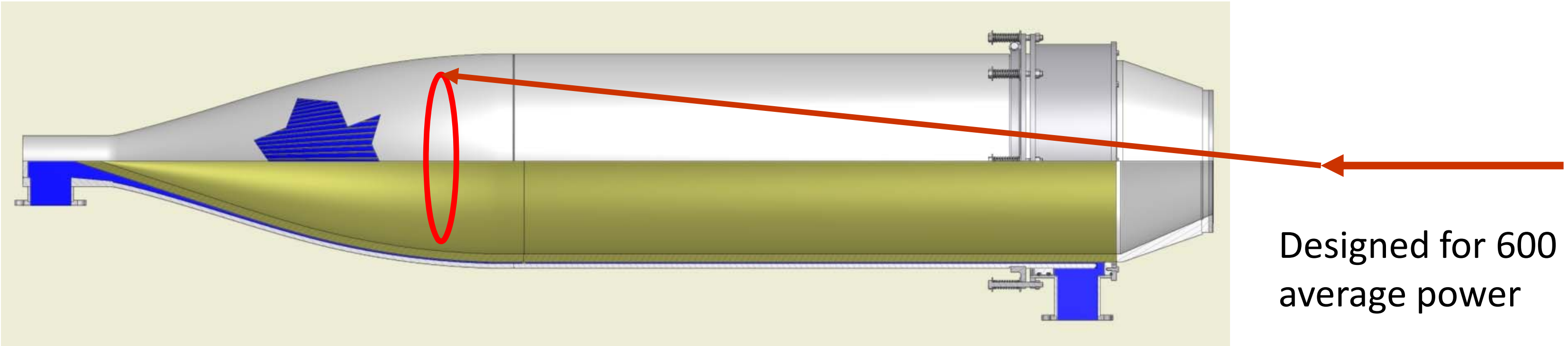
High Current

We have operated as high as 25 mA (at 5 MeV) to date using GaAs, and 20 mA for 8 hours using a CsK_2Sb cathode.

Note: the world record is 32 mA (25% d.f.) at Boeing during their FEL project.

Let's look at some of the issues that have kept us from going higher than this to date

High Power Beam Dump



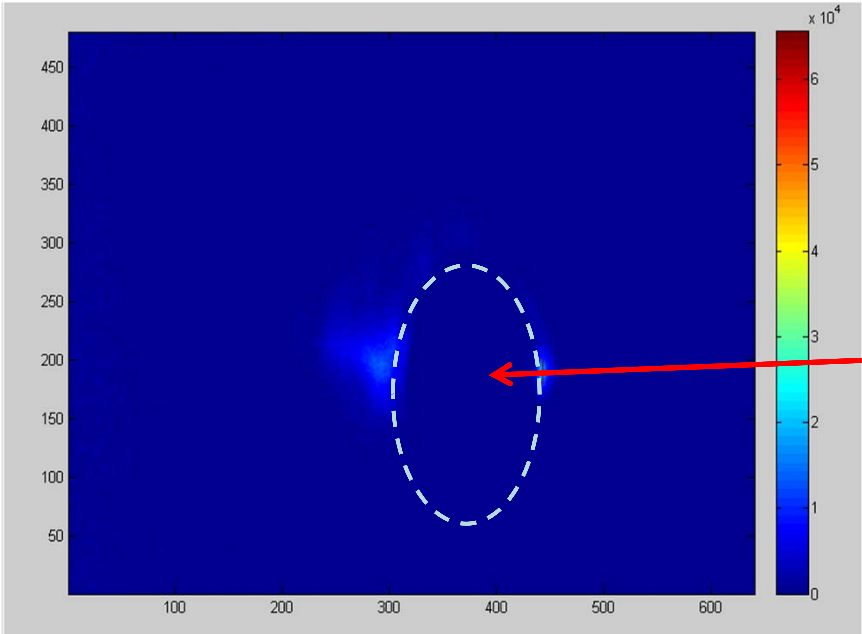
Designed for 600 kW average power

We burned a hole in the aluminum dump at 25 mA. This was due to the incorrect setup of the raster/defocusing system, and one shorted magnet.

We repaired it and are about to re-install it on the beamline.

Halo

We use a viewer with a 10 mm hole in the middle to visualize beam halo



Halo is bad – causes excessive radiation, poor cathode lifetime, increased vacuum . . . We think most of our halo comes from a less than perfect laser mirror before the cathode (in vacuum)

Prospects for higher current

- We expect to be able to reach the 30-40 mA range with all of the improvements made to date in the near future.

- So far, we have been forced into non-ideal optics settings to squeeze the halo through the beampipe to reduce radiation. If our new laser mirror works, this should improve.

- Better halo diagnostics may be needed for other halo problems. Will be following progress at other labs with similar challenges (Jlab, KEK)

- Shielding improvements, better cathodes, more laser power -> higher current!

- We typically experience new RF problems for each big jump in current, and will deal with them as we learn more.

Prospects are good for increasing our average current operation – we will push hard to get > 50 mA in the next 6 months.

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