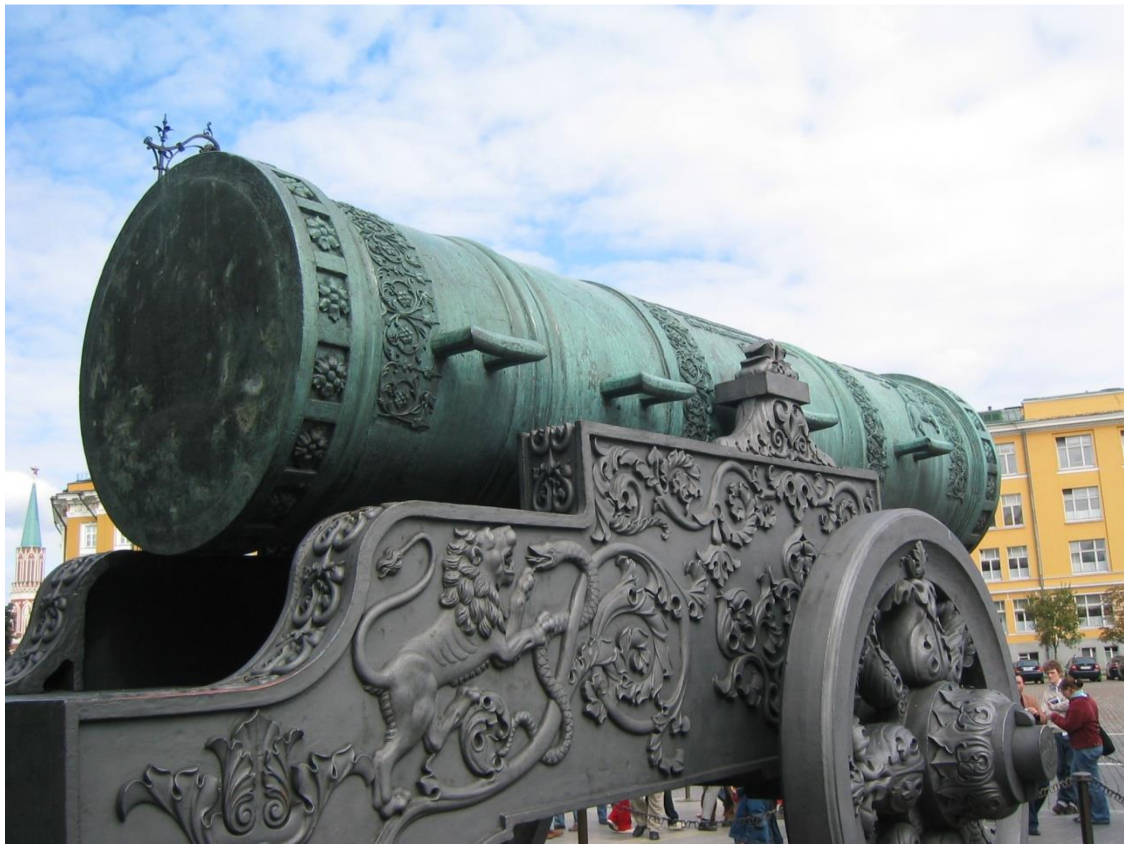
Status of high intensity polarized electron gun project at MIT-Bates



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General Information

- Polarized electron guns utilize GaAs photo cathodes.
- When polarized laser beam strikes the cathode, polarized electrons are ejected.
- Photocathodes must have atomically clean surface and they must be activated by heating to about 600°C and applying Cs and NF3 to the surface.
- UHV conditions are required in the gun. Any traces of gases (excluding hydrogen and noble gases) poison the crystal.

eRHIC (Linac-ring version)

Requires a polarized electron source with an extremely high average current (at least 10 mA).

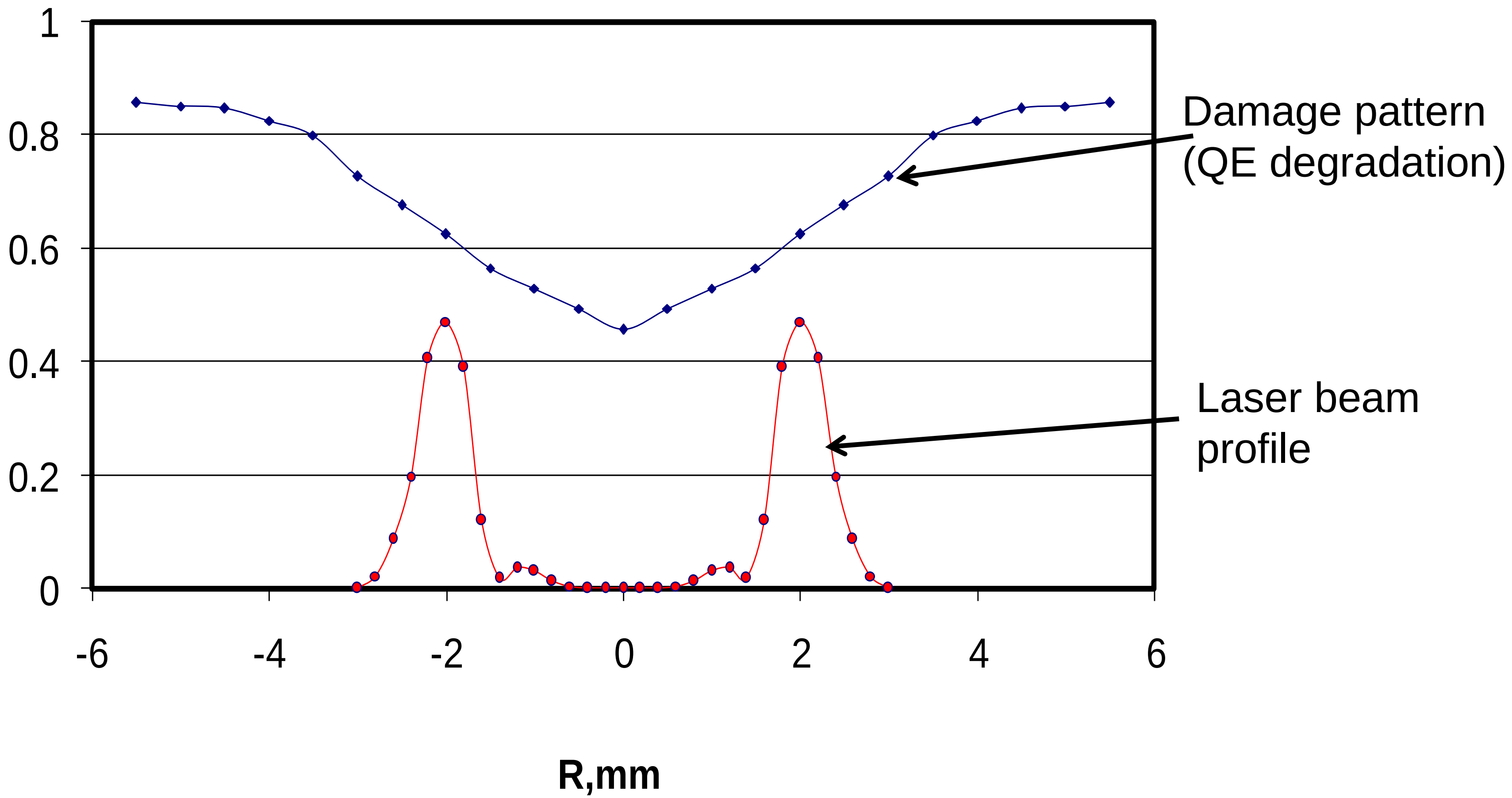
- Modern state-of-the-art guns produce ~100-200 μA
- Average current of ~ 1 mA achieved in tests at JLab and Mainz;
- Average current of up to 10 mA achieved at Mainz with very short lifetime (needs active cathode cooling)

Main problem – ion back bombardment.

Anode hole acts like a focusing lens for ions.

Ion damage is most severe at the center of the cathode.

Ion damage mostly the center of cathode (Bates results)



High Intensity Polarized Electron Gun

The principal points to achieve high average current:

• Large area cathode.

• Ions tend to damage the central area of the cathode – ring-shaped emission pattern.

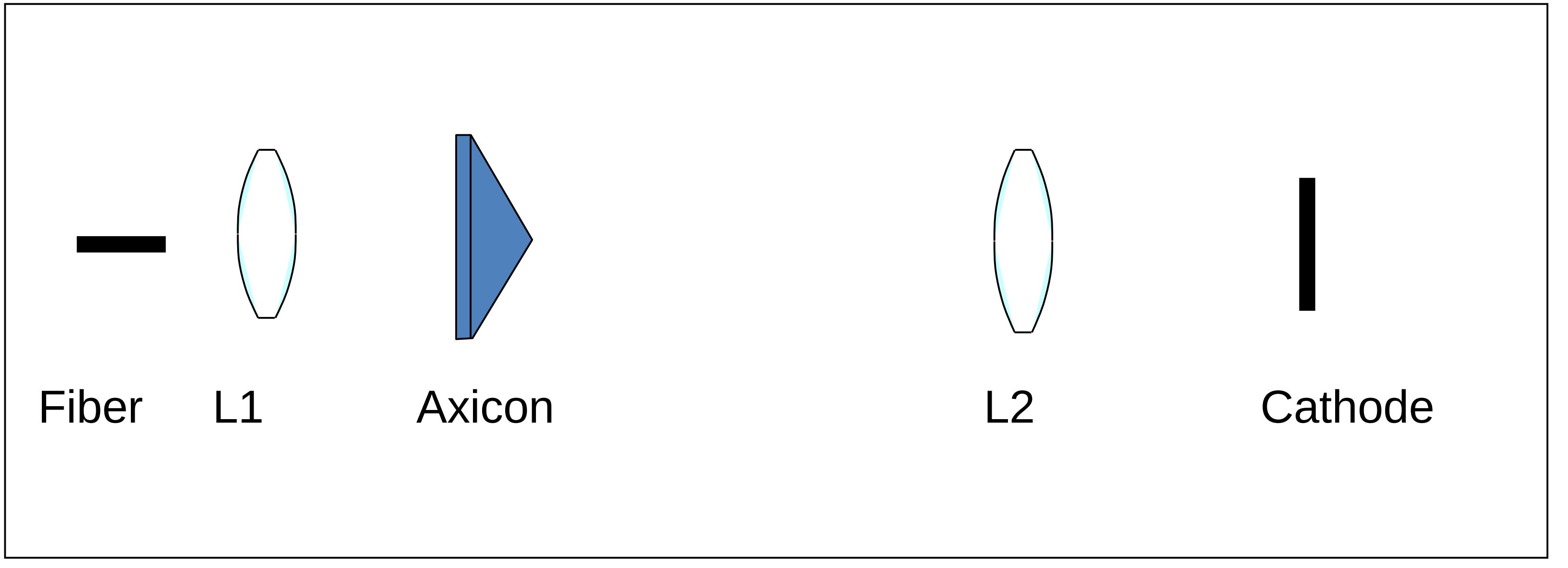
• Active cathode cooling.

• Very small beam losses could be allowed near the gun ($<10^{-6}$). A lot of simulations performed with a proven code.

Additional requirements

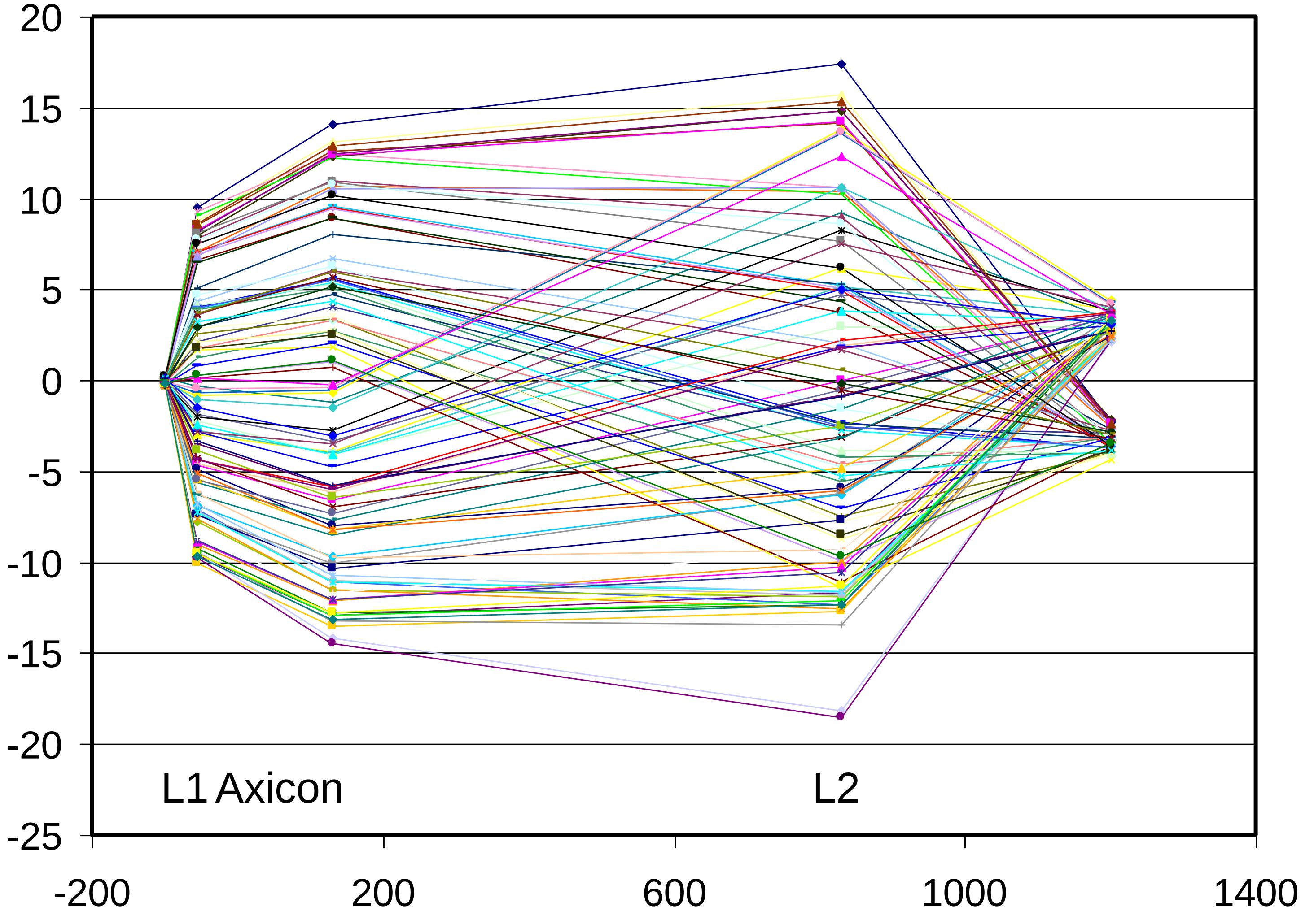
- Heat-cleaning and activation compromise vacuum condition, they should be done in a separate chamber (preparation chamber).
- It takes months to achieve good vacuum, so gun chamber and preparation chamber should never be vented. New cathodes should be loaded into the system via load lock.

Ring-shaped Laser Beam

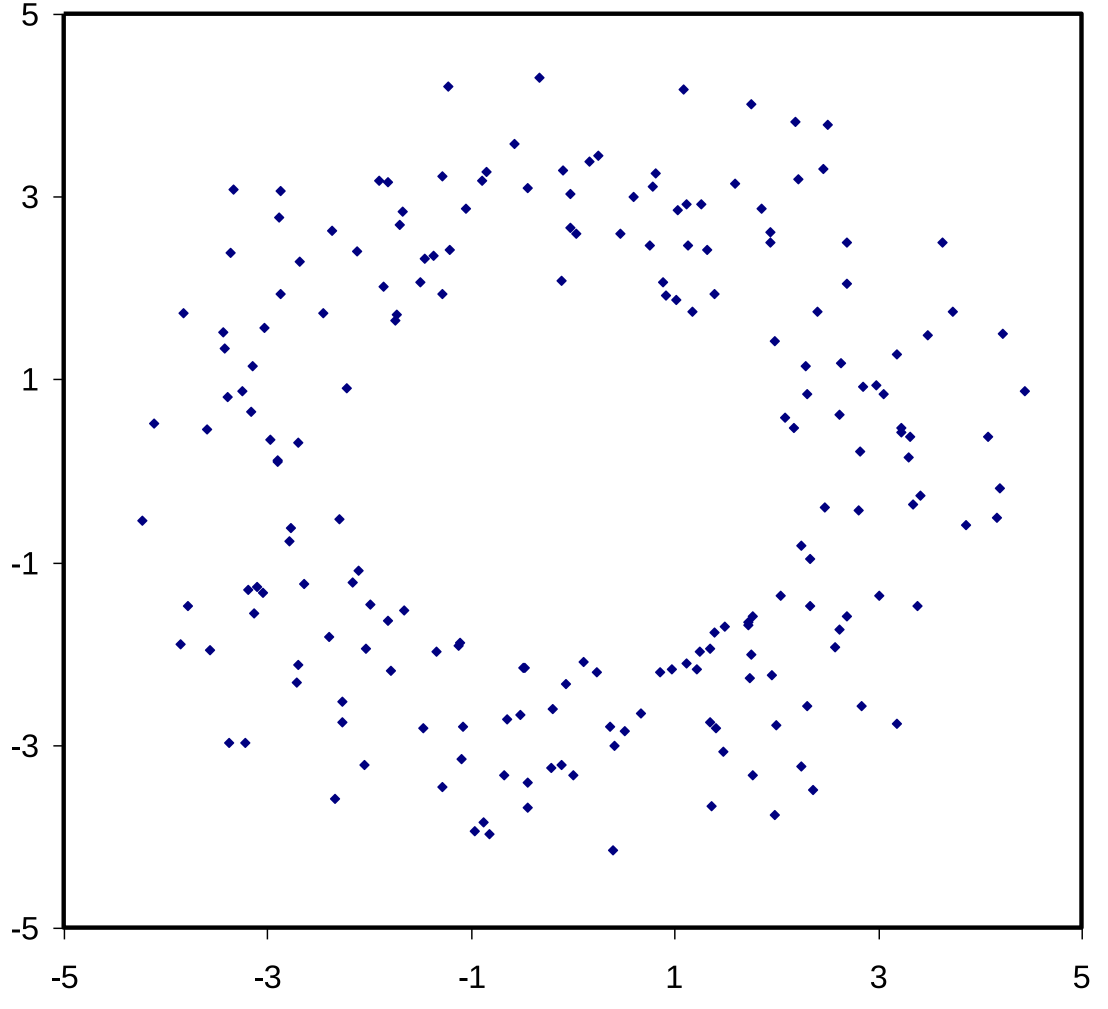


Axicon (conical lens) in combination with a converging lens (L2) produces ring-shaped beam in the focal plane of L2. Lens L1 reduces the laser beam divergence (25° from the fiber). Without axicon, very small beam spot will be produced. QE could be mapped by moving the L2

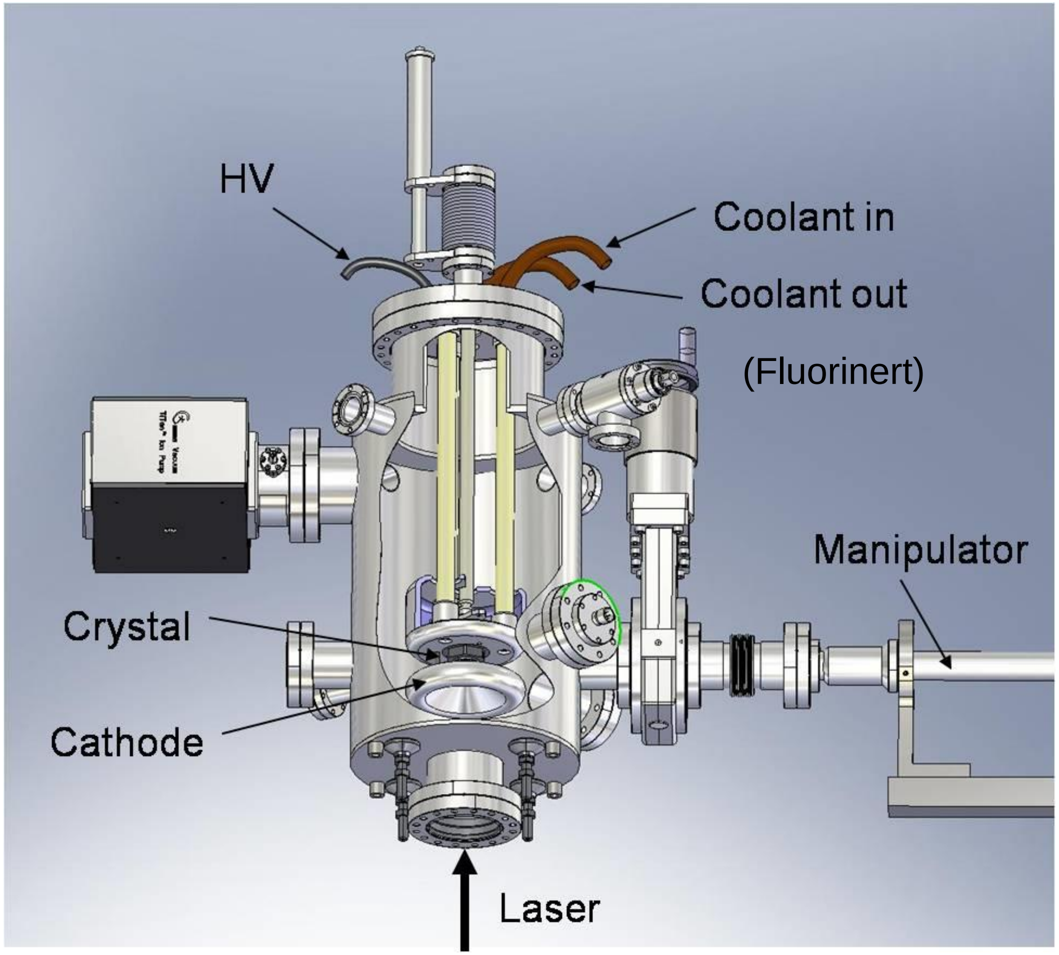
Axicon-based System Simulations

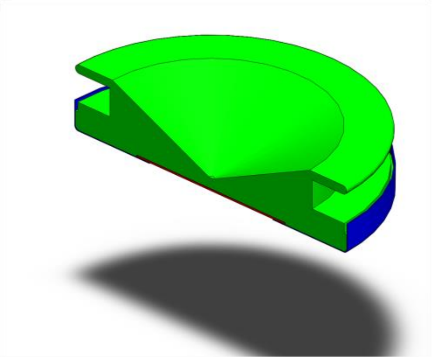


Axicon-based System Simulations



Cathode cooling



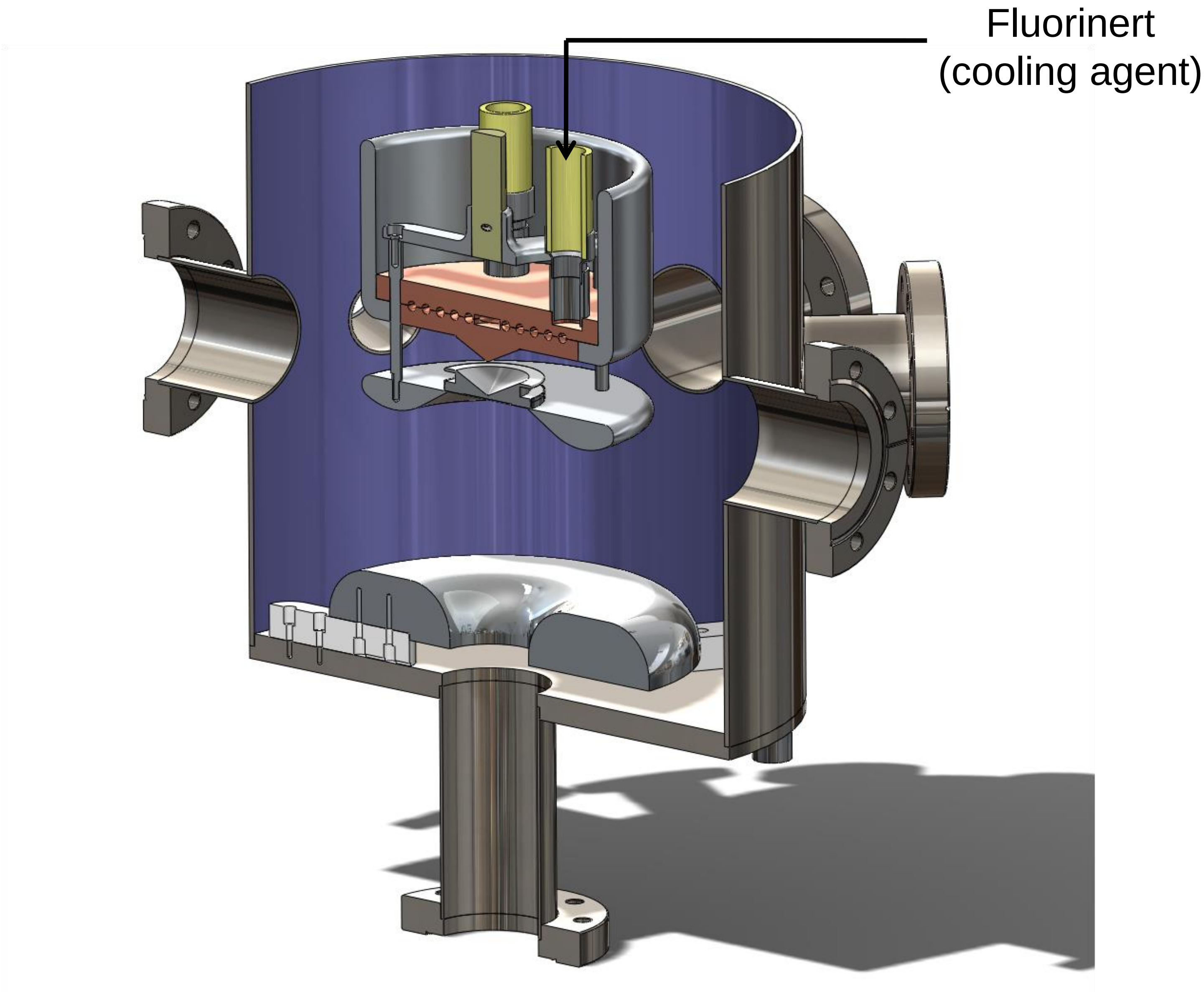


Cathode puck (Moly)

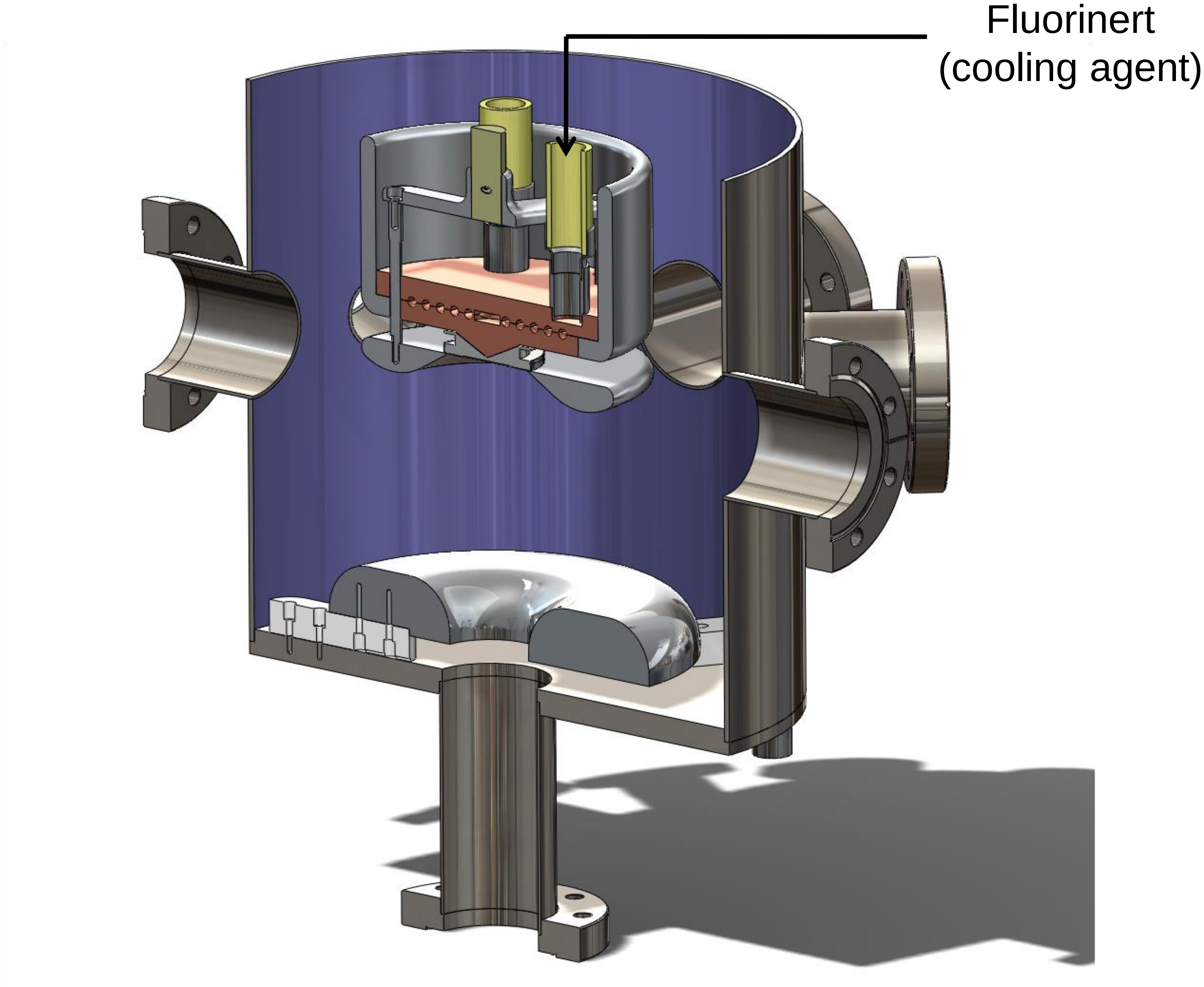
Heat exchanger

Up to 40 W of laser power

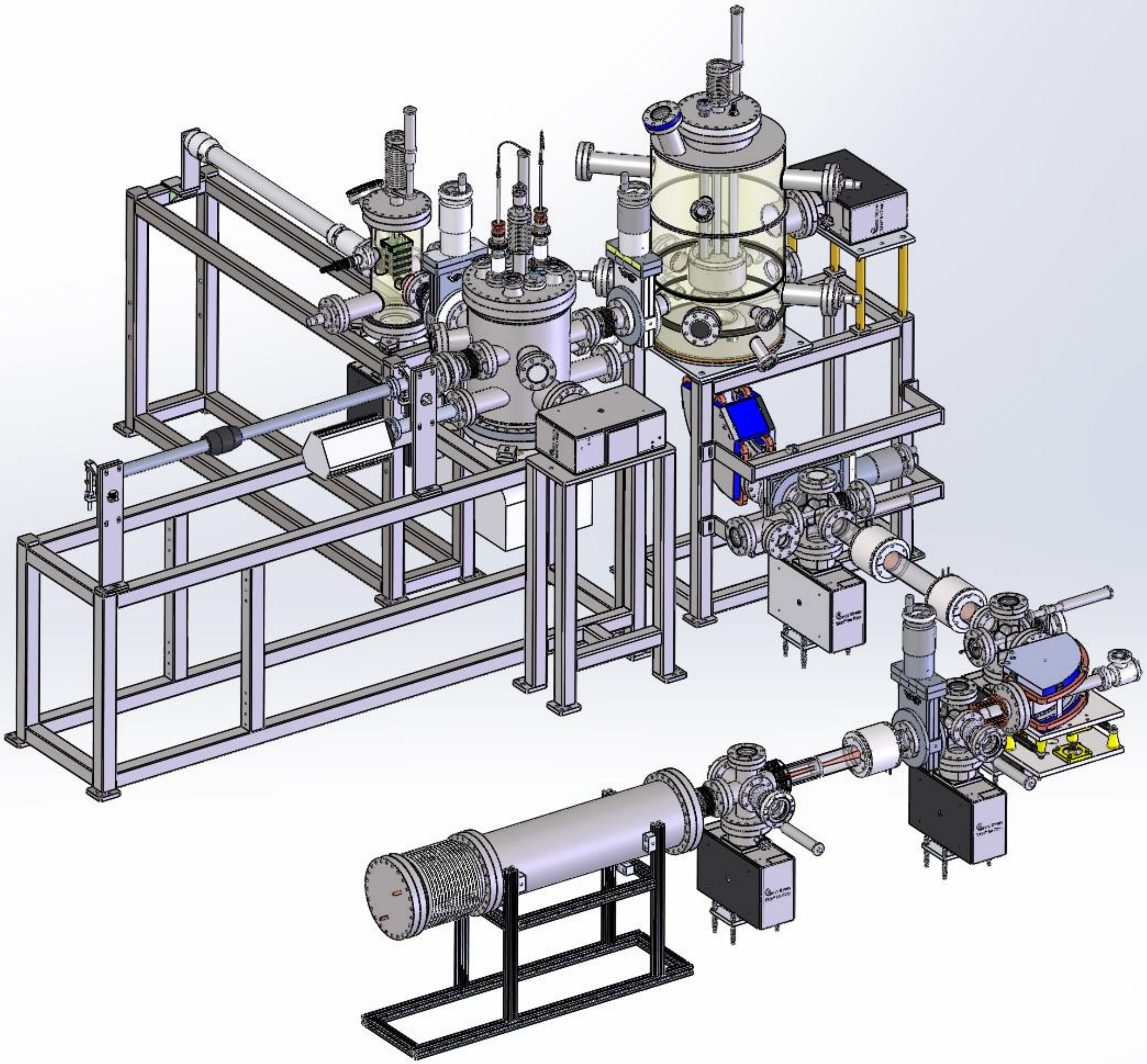
Cathode – anode assembly



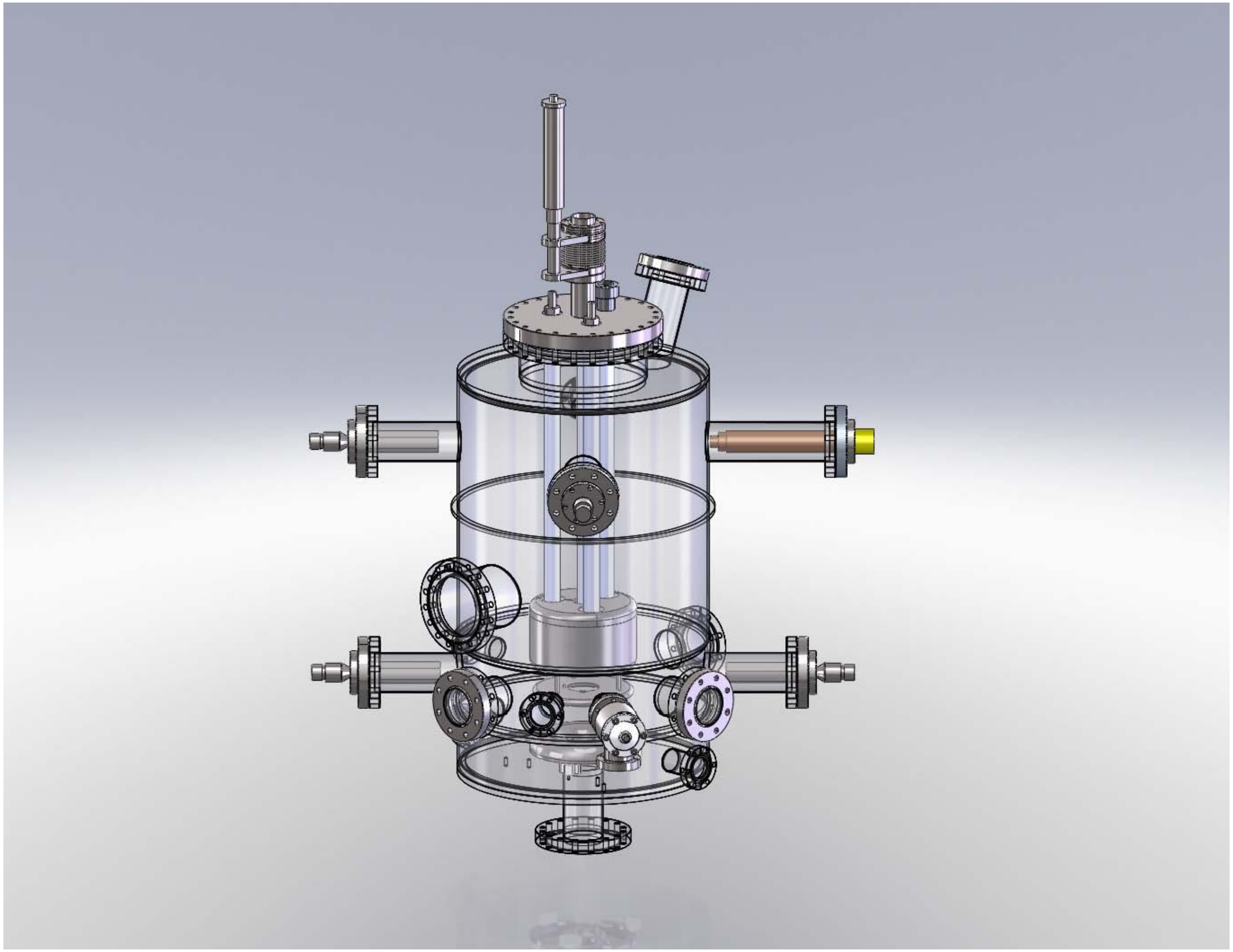
Cathode – anode assembly



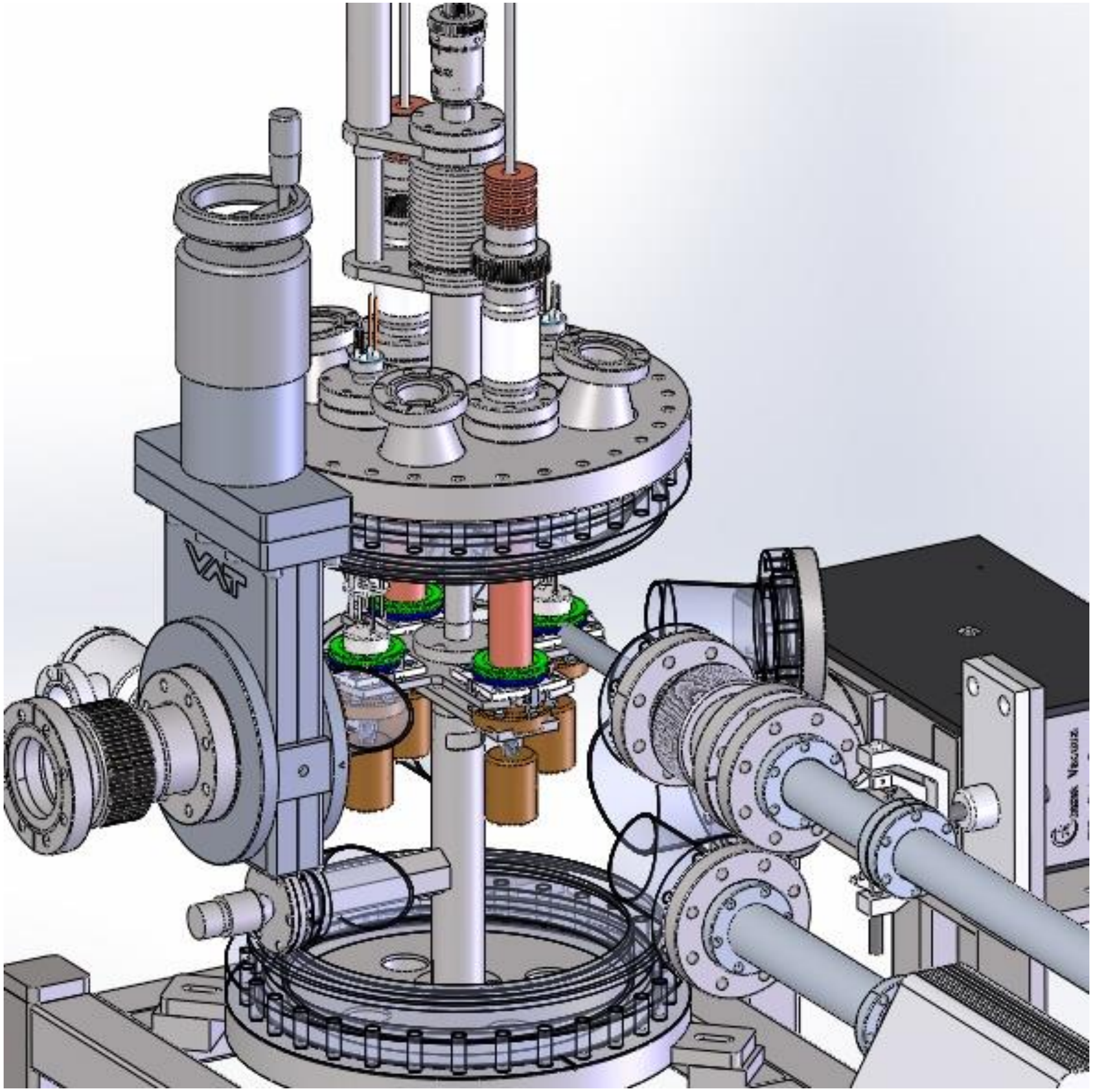
Gun + beam line



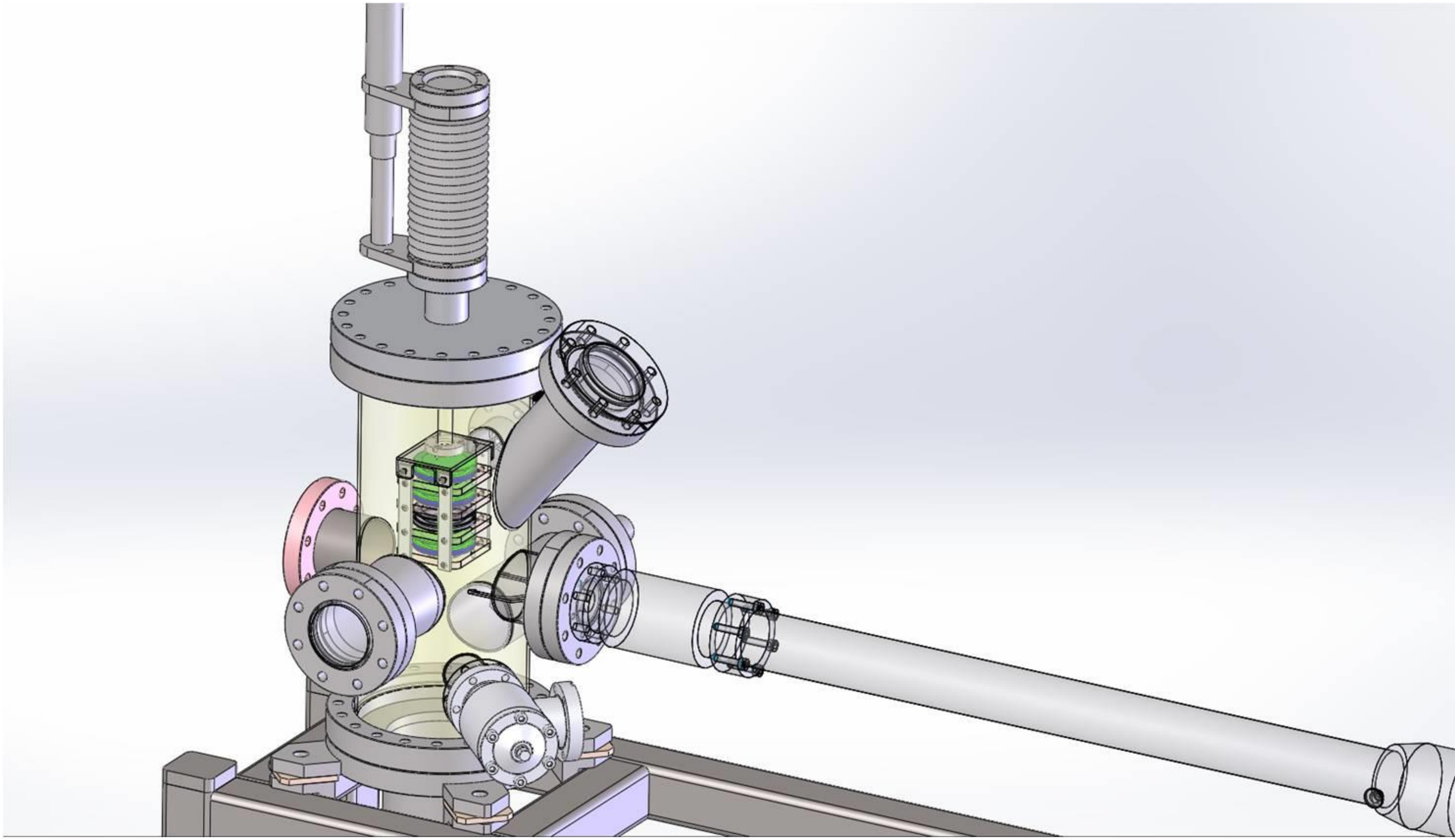
Gun chamber

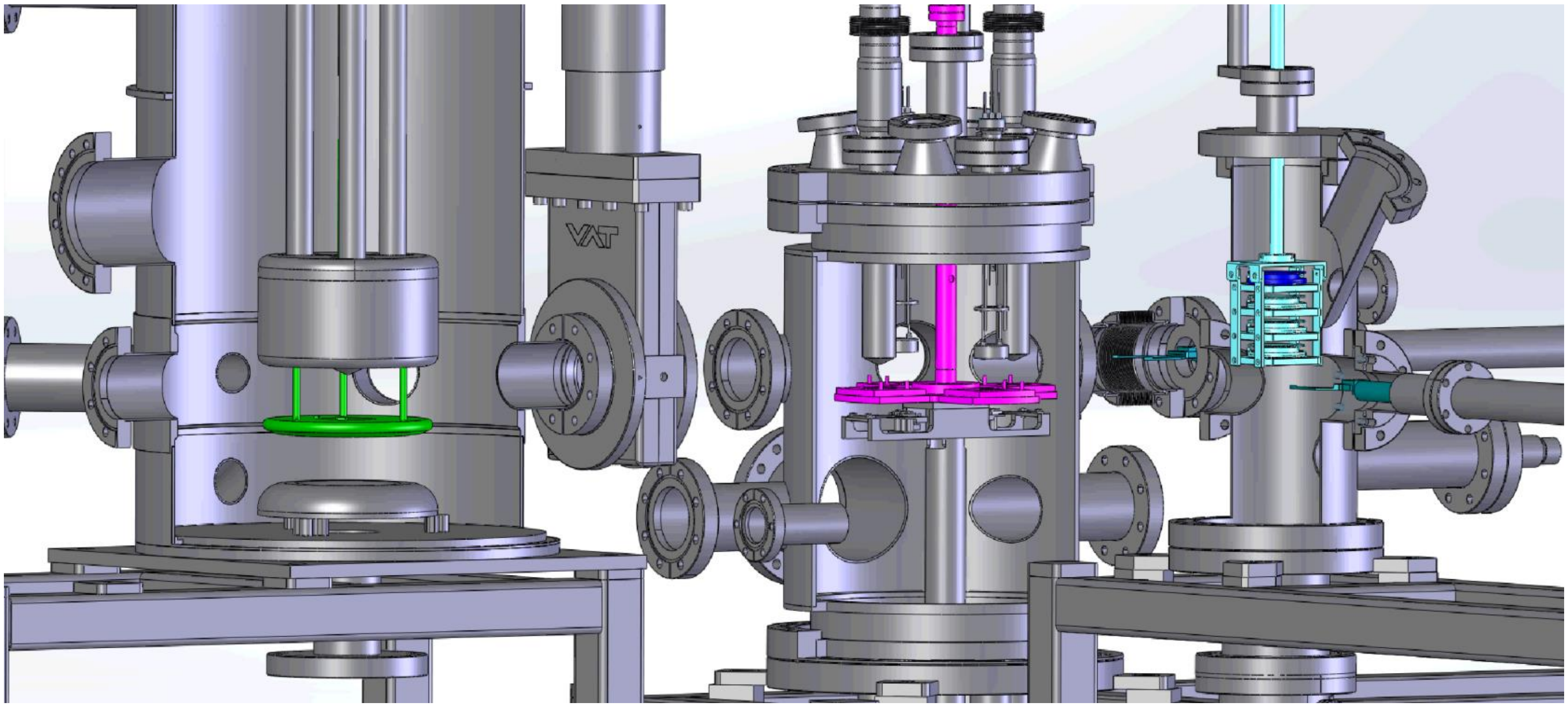


Preparation chamber

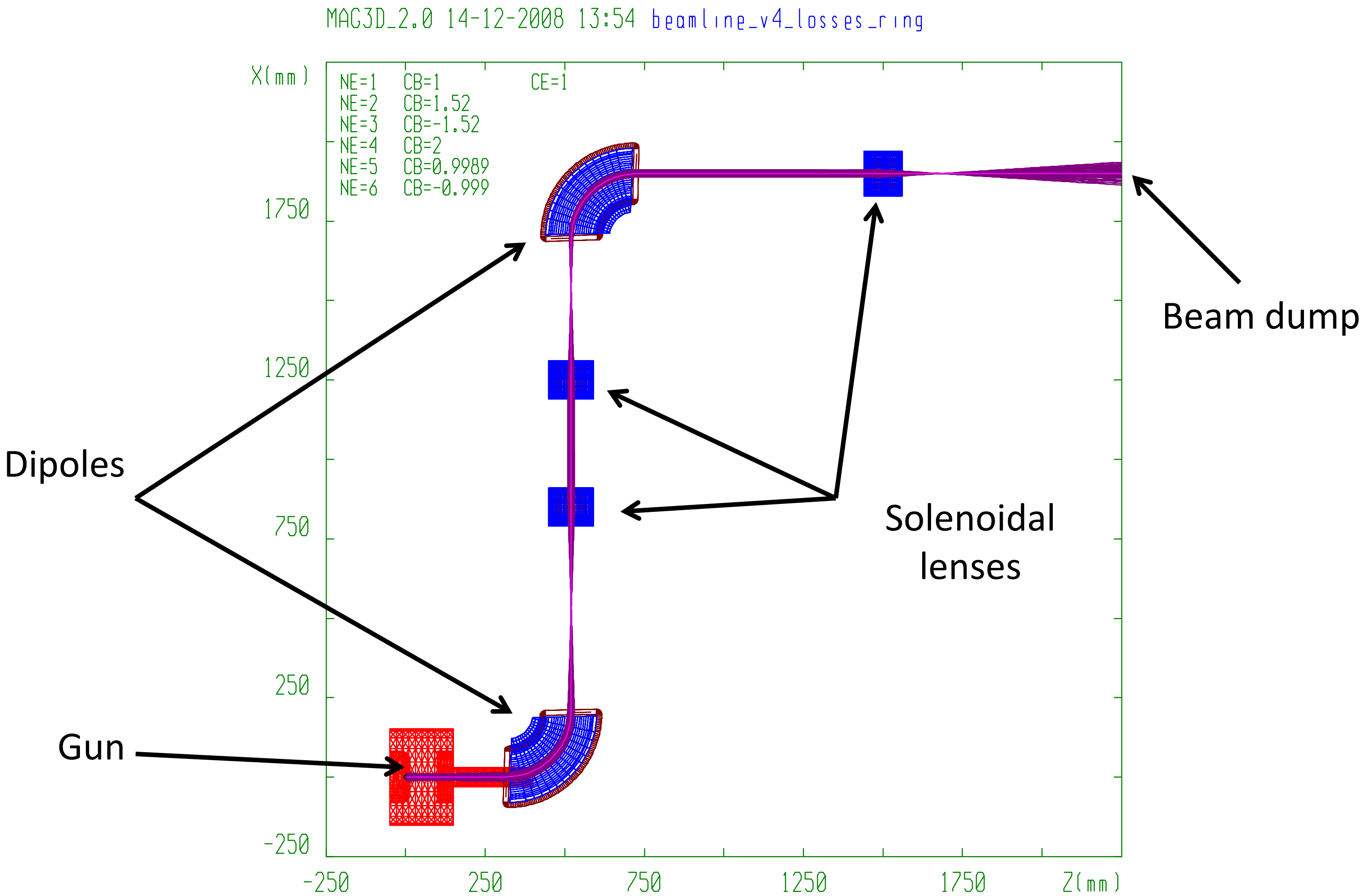


Load lock

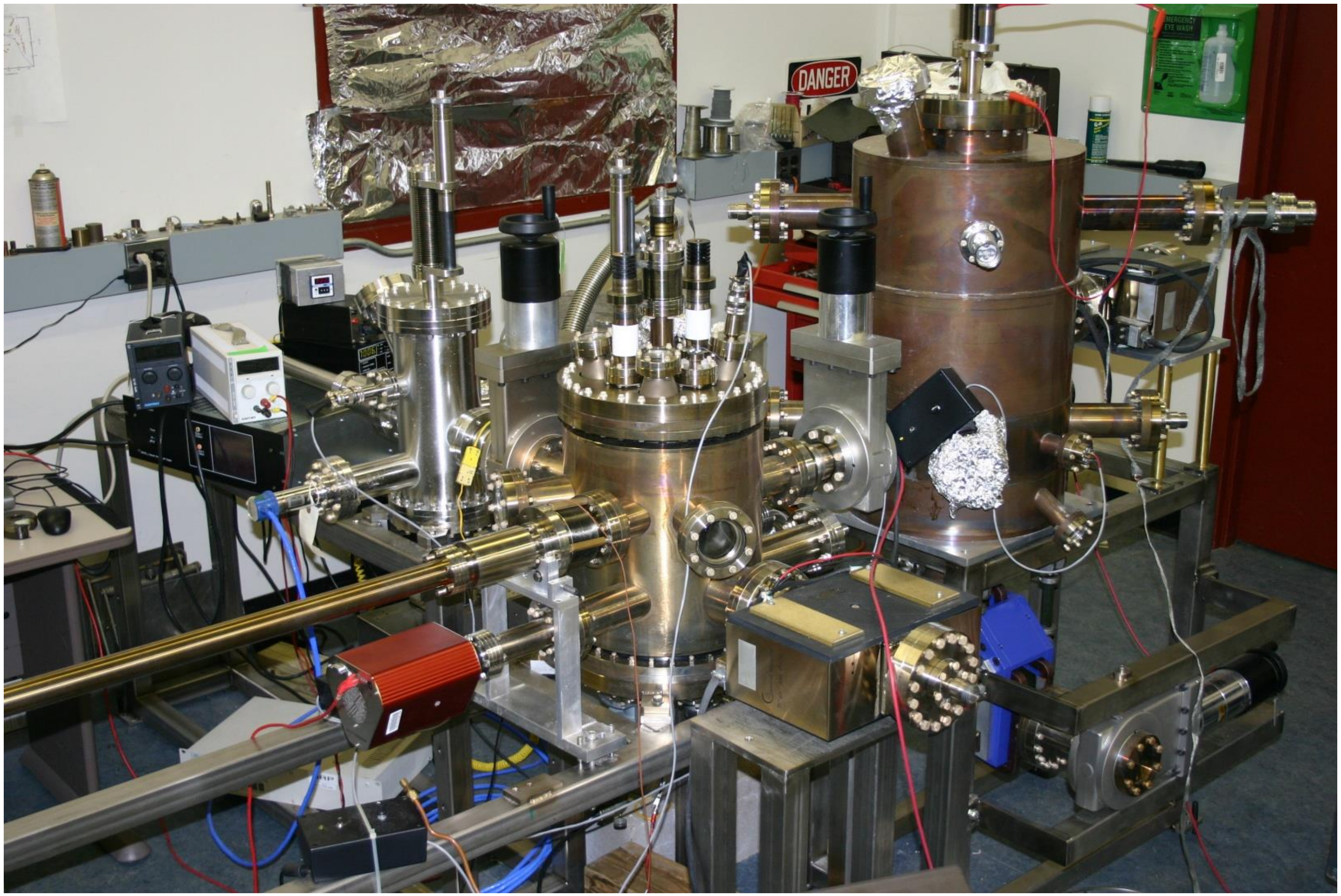



VAT

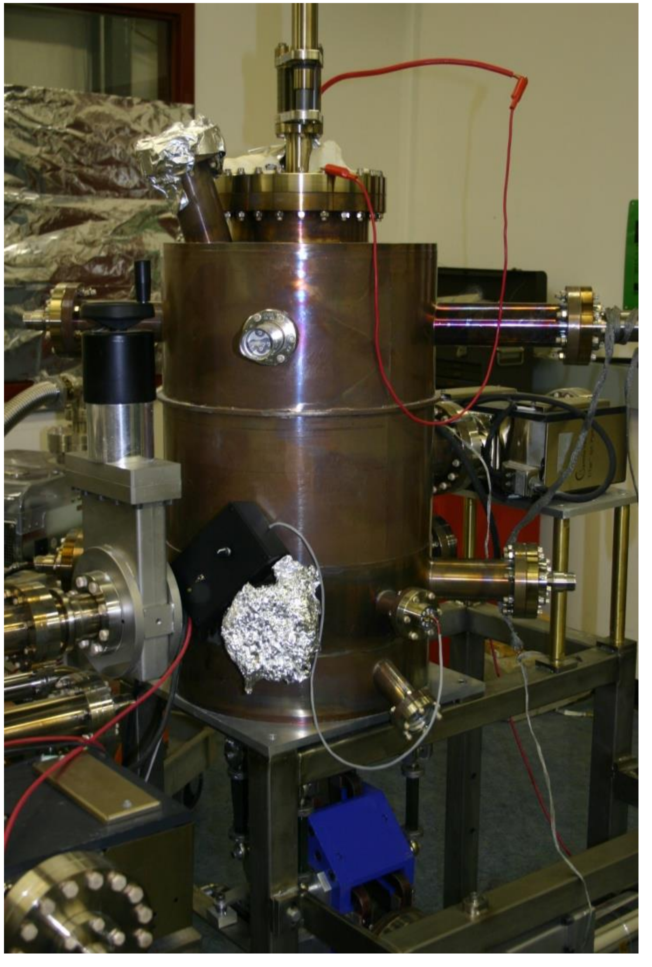
Beam line. Pipe aperture ~±34 mm.



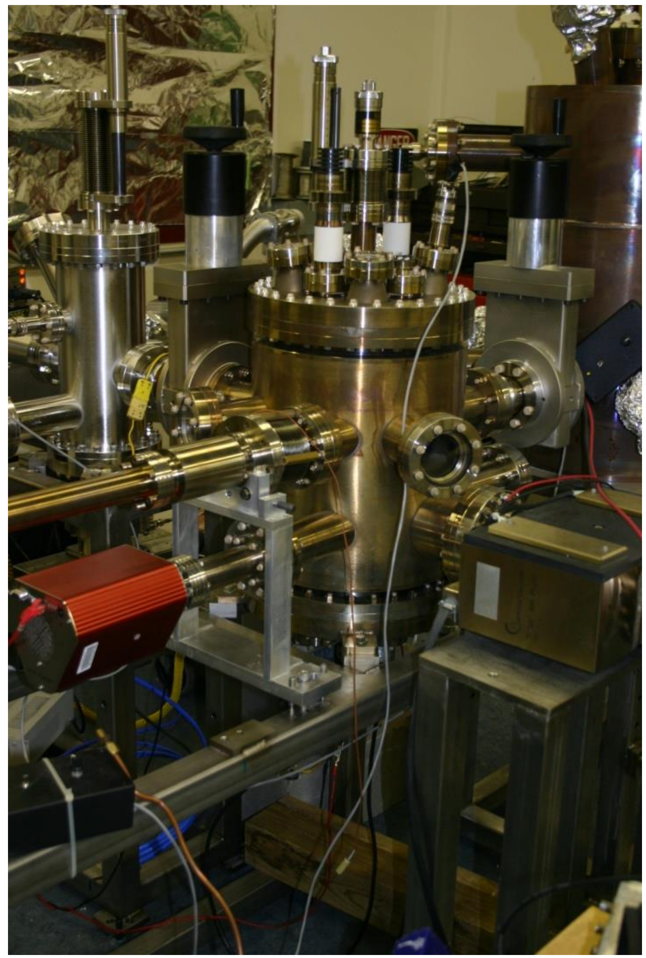
Gun + beam line



Gun chamber



Prep. chamber



Vacuum features of the chambers

Gun chamber:

- 100 l/s Ion pump with 400 l/s NEG and 4 additional 400 l/s NEGs.
- The chamber walls are thin (~ 3 mm) to reduce outgassing.
- The chamber and most of the parts have been prebaked to 400°C before the final assembly.
- Bake-out at 250°C after the final assembly.
- Vacuum better than $1 \cdot 10^{-11}$ (all Hydrogen) (limited by RGA outgassing)

Prep. chamber:

- 100 l/s Ion pump with 400 l/s NEG and 2 additional 400 l/s NEGs.
- Vacuum better than $1 \cdot 10^{-11}$ (all Hydrogen)

BUDGET

FY	From BNL	From DOE	Actual cost
07-09	$444 K		$444 K
10-11	$150 K	$586 K	$736 K
12-13		$388 K	$388 K
14-15		$500 K	$500 K
16		$130 K	$54 K
Total	$594 K	$1604K	$2122 K

The funds were used for equipment, manufacturing and salaries

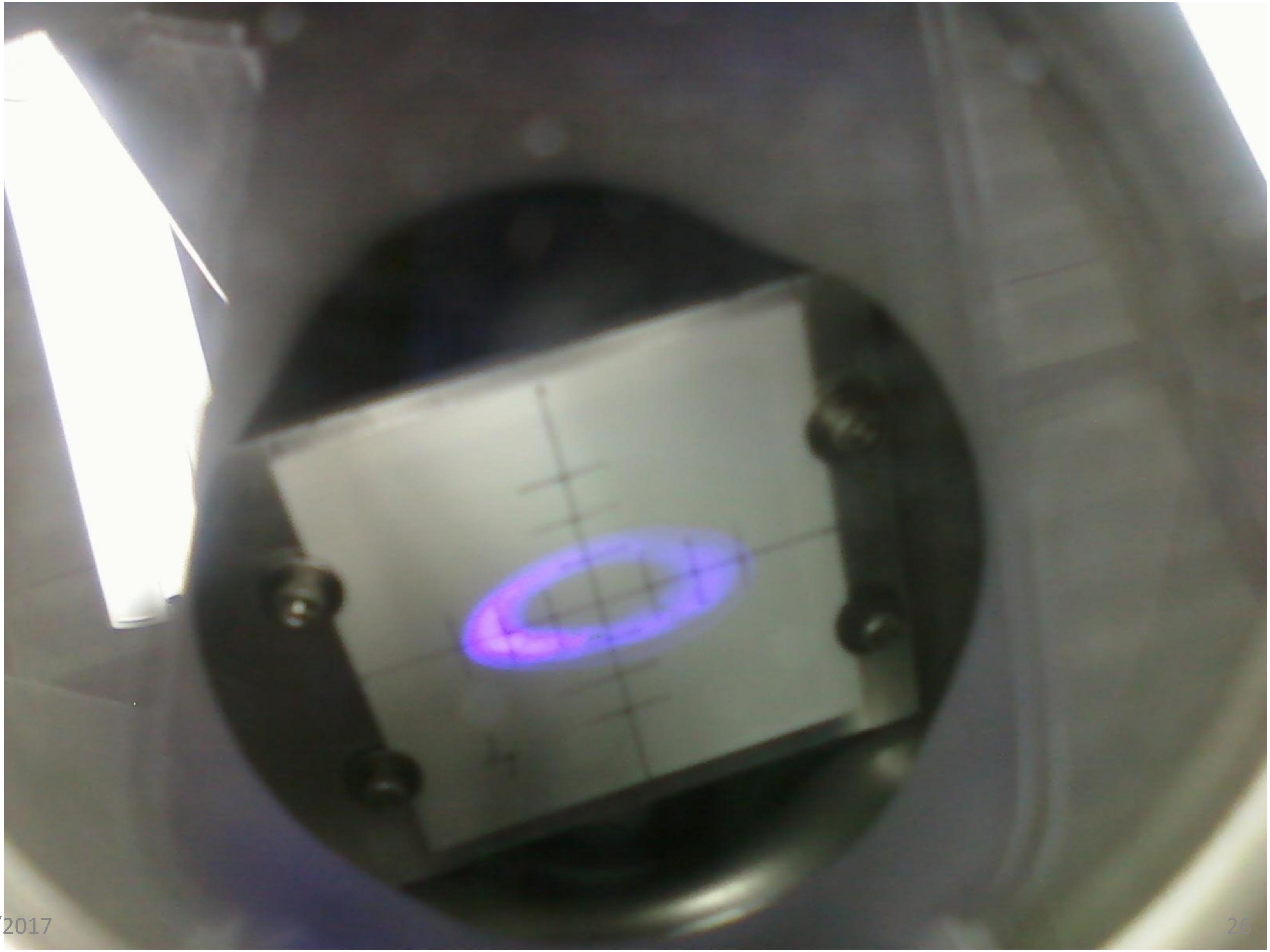
PROJECT PROGRESS

- FY 2007-2009 - preliminary simulations and tests. Beam simulations through the gun and entire beam line. Emphasis – no beam losses near the gun. Tests of active cooling. HV tests.
- FY 2010-2011 – gun chamber and preparation chamber built and assembled. Load lock and beam line designed, and manufacturing began.
- FY 2012-2013 – load lock built and assembled. Beam line and unbiased beam dump built.
- FY 2014-2015 – beam line and beam dump completed. First beam tests.
- FY 2016 – beam tests.

PROJECT PROGRESS

- Gun chamber, preparation chamber, load lock manufacturing and assembly – not a glitch. Excellent vacuum conditions. Reliable cathode transfer between chambers (good illumination and observation conditions). Very high QE (~2% at λ=805 nm) has been achieved. However, the dark lifetime of the cathode in the gun is short (less than 100 hours).
- Beam line assembly – successful. Beam tuning through the beam line – the shape of the beam in full agreement with simulations.
- Beam tests – real problem. The lifetime is much shorter than in old generation guns even at low current.

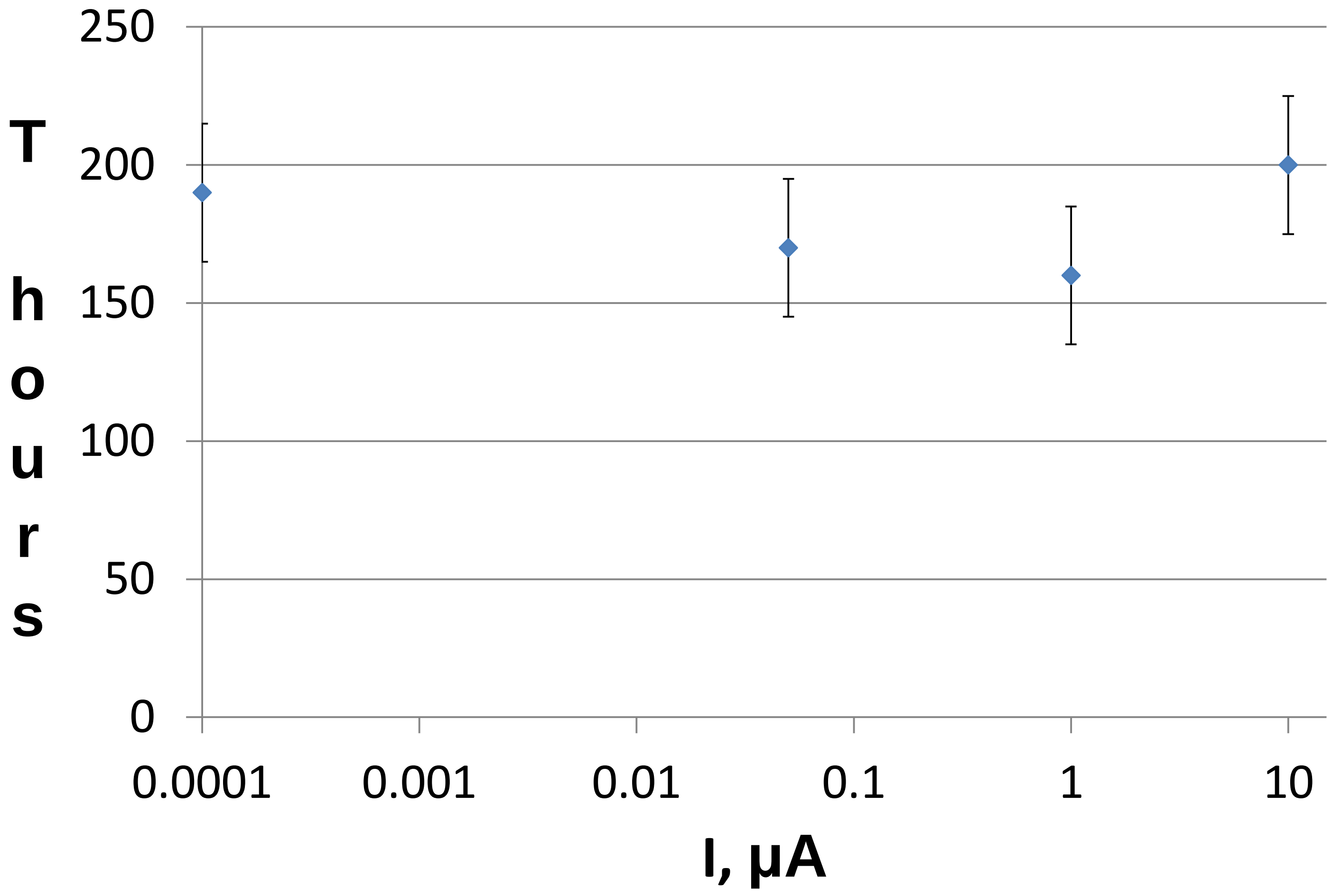
Beam on BeO target



SECOND TRY

- Most likely the problem is a fluorinert leak into the gun chamber. The molecules are very compact and penetrate through very narrow cracks, they are too heavy to be detected with RGA, and they are chemically active.
- The gun was vented and the problem addressed. Preparation chamber was vented as well to fix minor problems. Reassembly and re-bake.
- Several incidents with vacuum leaks delayed the progress.
- This gun is a prototype. It took several tries to address all the bugs. Any modification or accident are very costly (require re-bake). Any bake-out is a risk and a heavy load on equipment.
- We operate on a very tight budget.
- We gained invaluable experience in building reliable system.

Lifetime measurements

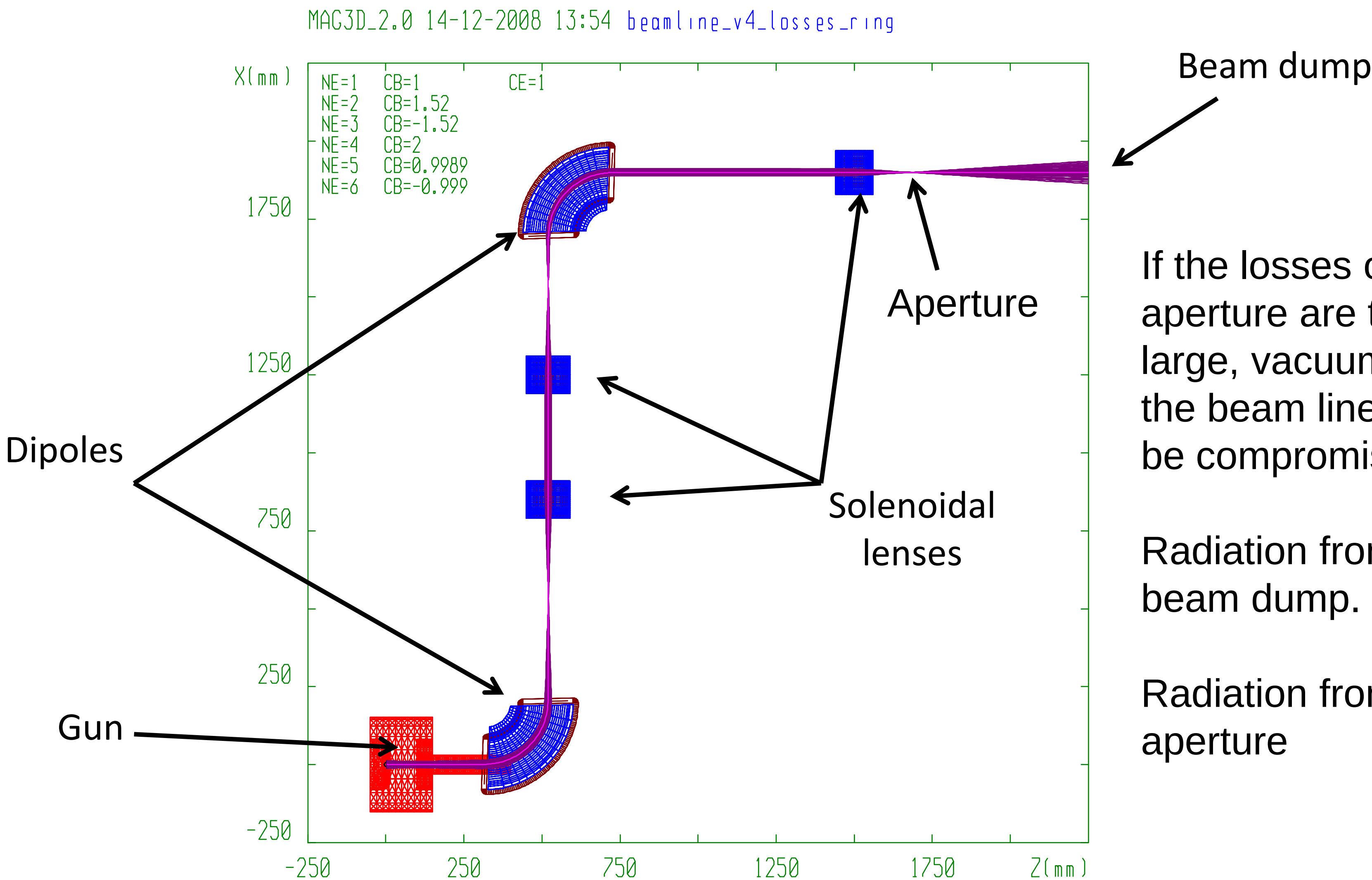


Lifetime doesn’t depend on the current – no significant ion back bombardment at this level !

CURRENT STATUS

- We believe that we made a lot of progress with the gun.
- Good vacuum conditions achieved in the gun and activation chambers.
- Very reliable cathode transfer between chambers in vacuum.
- High QE in every activation (~2% at λ=805 nm).
- Active cooling allows to deliver up to 40 W of laser power on the cathode.
- The beam tuned through the beam line and the size and the shape of the beam is in full agreement with simulations.
- The lifetime of the crystal does not depend on the current up to 10 μA.
- Several equipment breakages delayed the beam tests. We found that our NEGs in the preparation chamber are saturated due to multiple activations. The re-bake of the chamber was required. We also lost our laser, laser chiller and several more pieces of equipment.
- Currently, everything is restored and we resumed the beam tests.

Possible Concerns:



If the losses on the aperture are too large, vacuum in the beam line could be compromised.

Radiation from the beam dump.

Radiation from the aperture

PLANS FOR THE FUTURE

- At this stage we plan to continue improving the vacuum conditions in the gun and beam line and demonstrate high intensity polarized electron beam with good life time.
- After the high intensity CW beam is demonstrated, we plan to run pulsed beam and investigate the life time of the beam with high peak current (up to several A). The goal is to measure the life time dependence on the peak current with constant average current. We anticipate that for very high peak current the gun geometry needs to be modified (shortening the cathode-anode gap).
- We welcome to develop a stronger collaboration with BNL, JLab and Cornell.