Polarized electron gun beam tests in mA range

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eRHIC (Linac-Ring version)

Requires a polarized electron source with an extremely high average current (at least 5-10 mA).

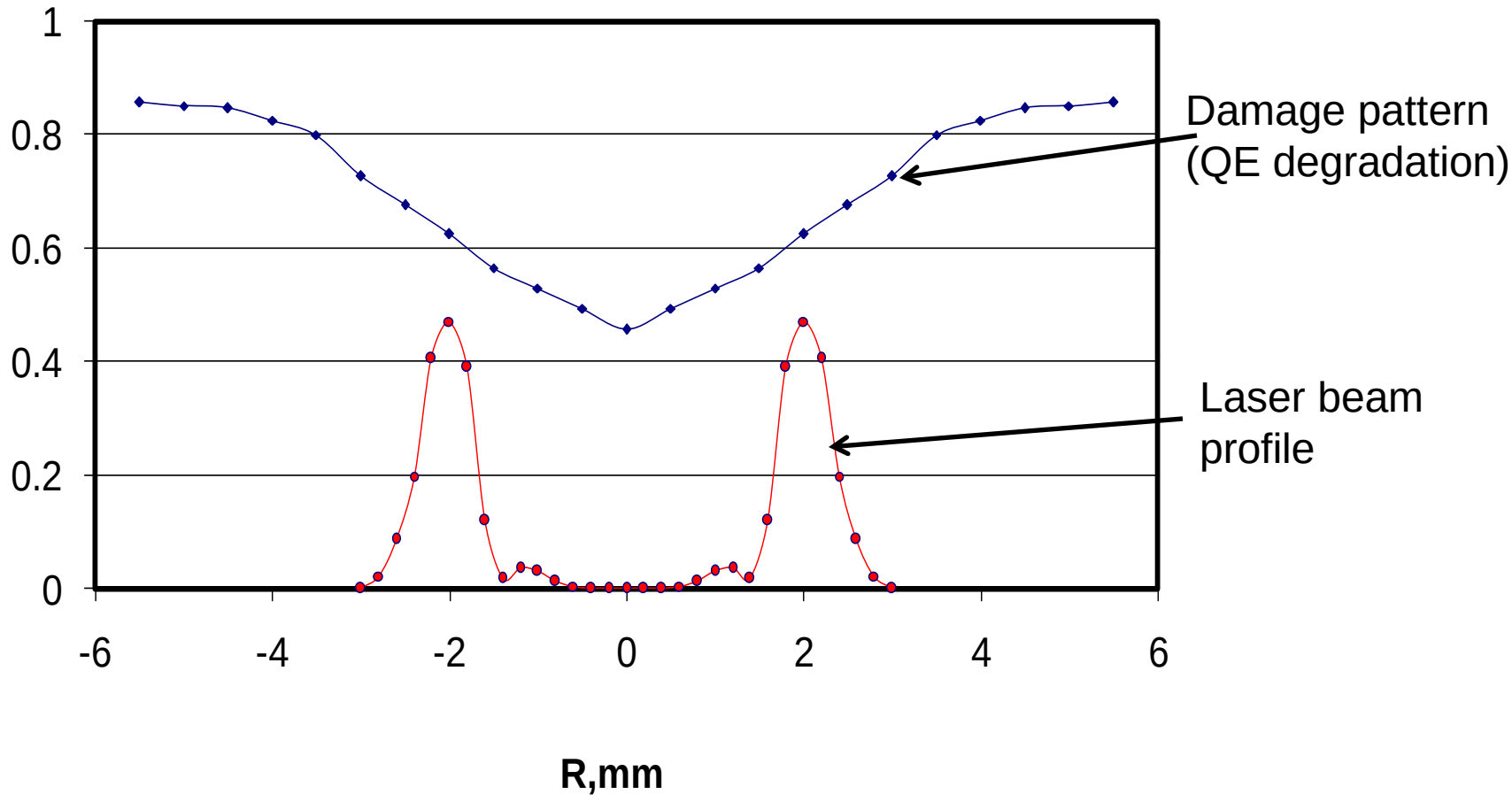
- Modern state-of-the-art guns produce ~100-200 μA
- Average current of ~ 1 mA achieved in tests at JLab and Mainz;
- Average current of up to 10 mA achieved at Mainz with very short lifetime (needs active cathode cooling)

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

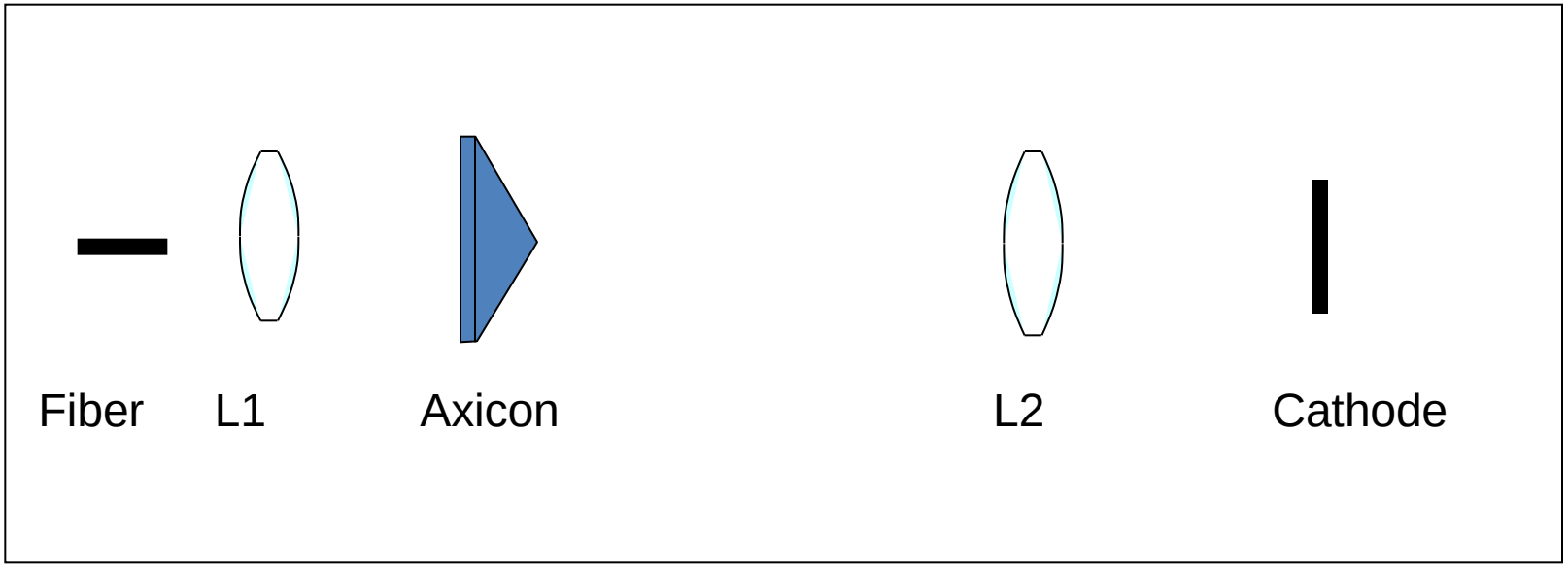
The principal points to achieve high average current:

- 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

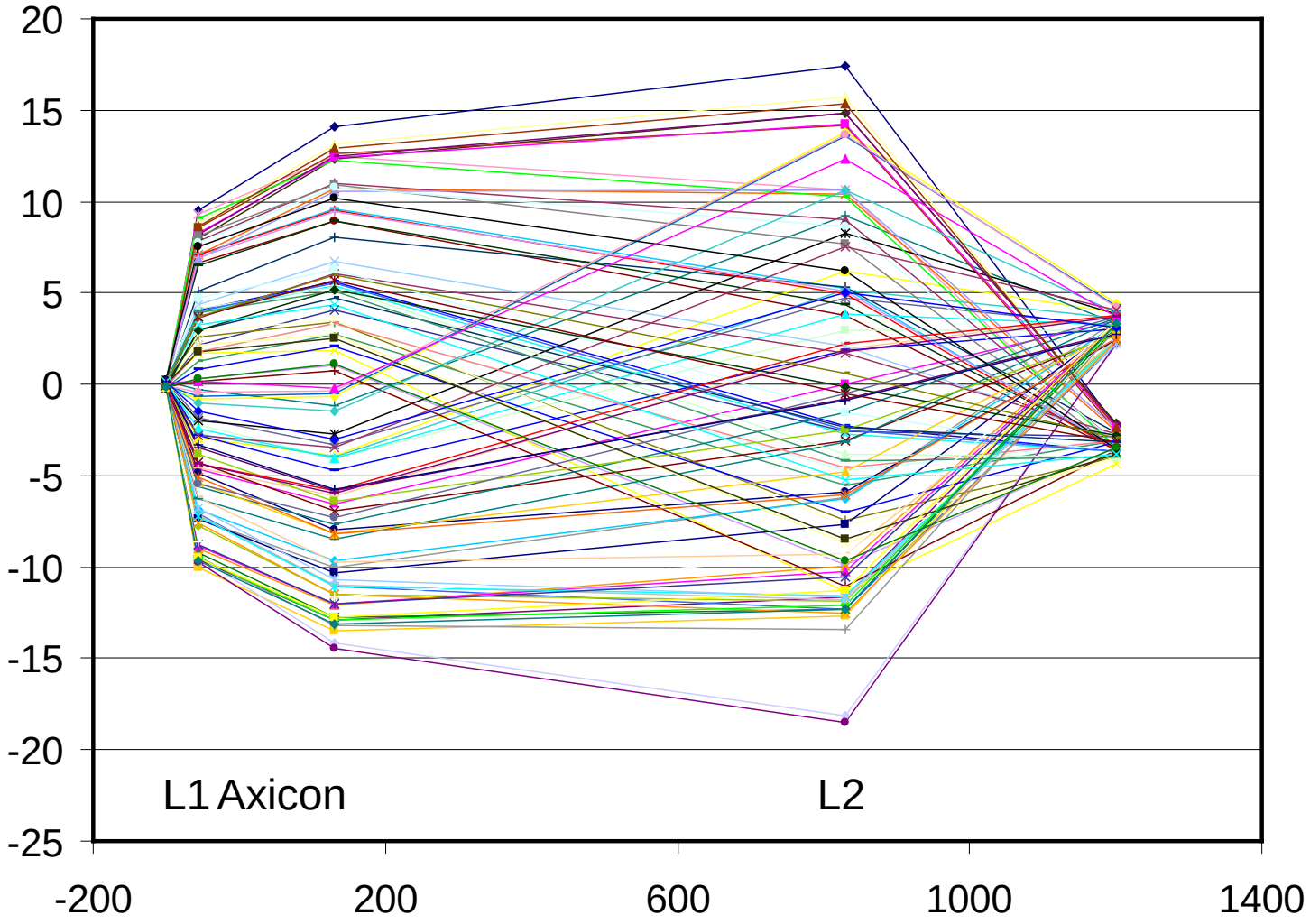
- Heat-cleaning and activation compromise vacuum condition, they should be done in a separate chamber (preparation chamber).
- It takes months to achieve good vacuum, so gun chamber and preparation chamber should never be vented. New cathodes should be loaded into the system via load lock.

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



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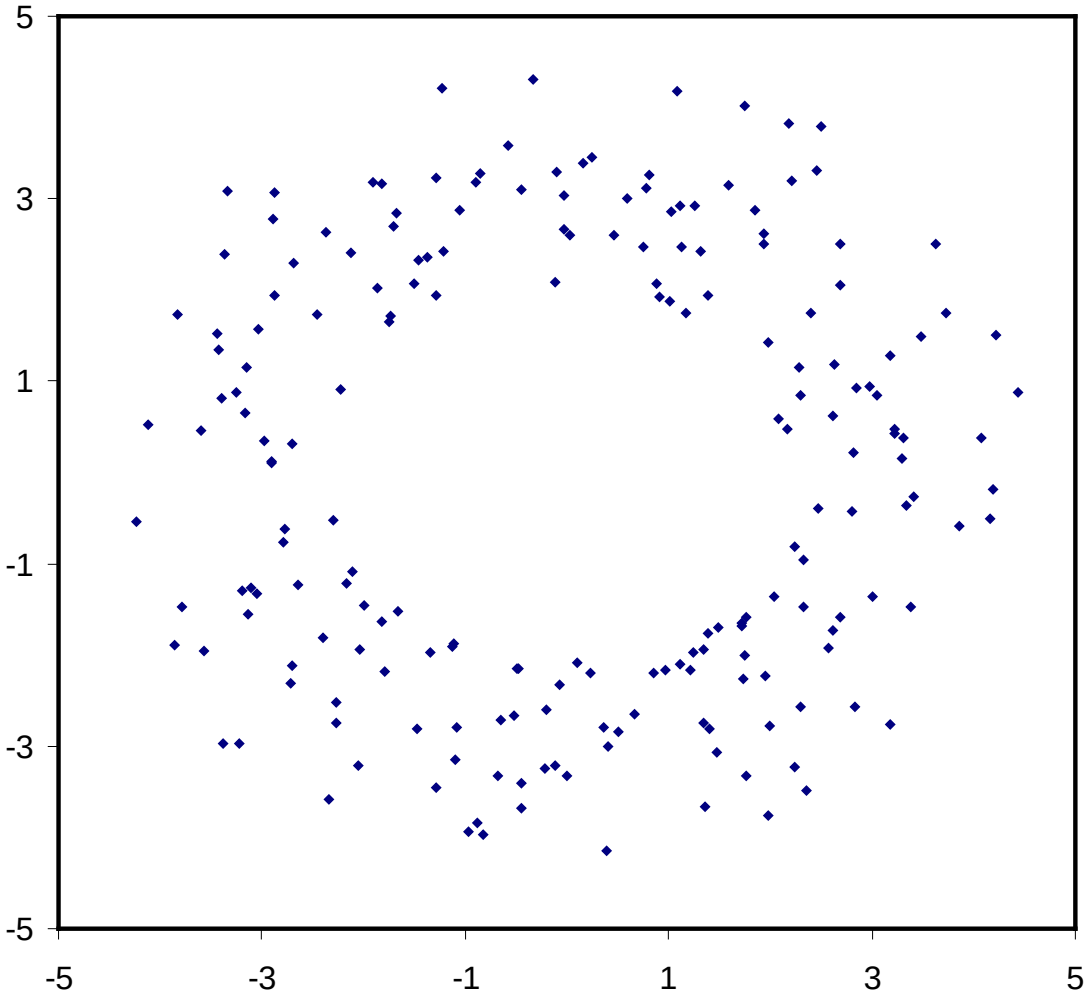
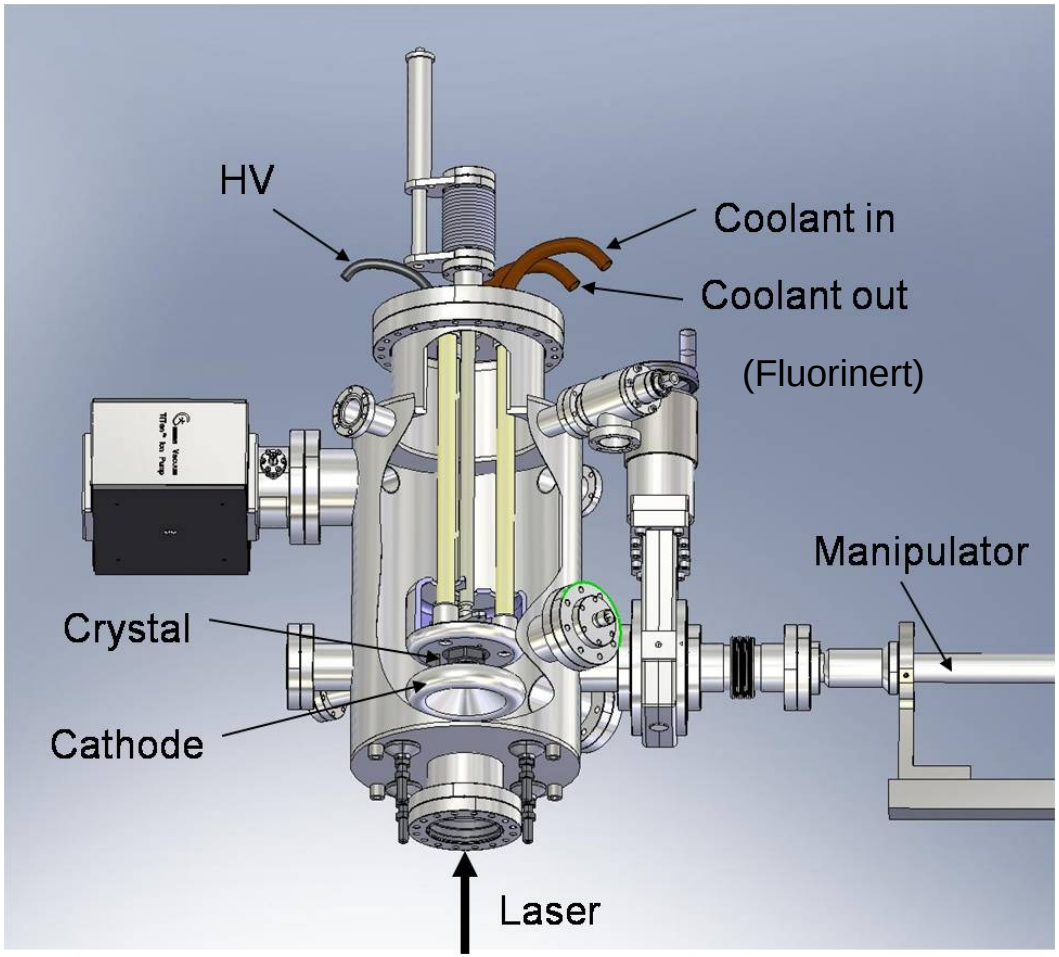
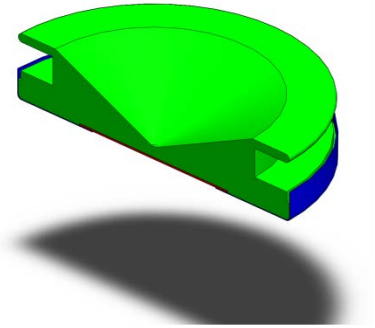


Cathode cooling



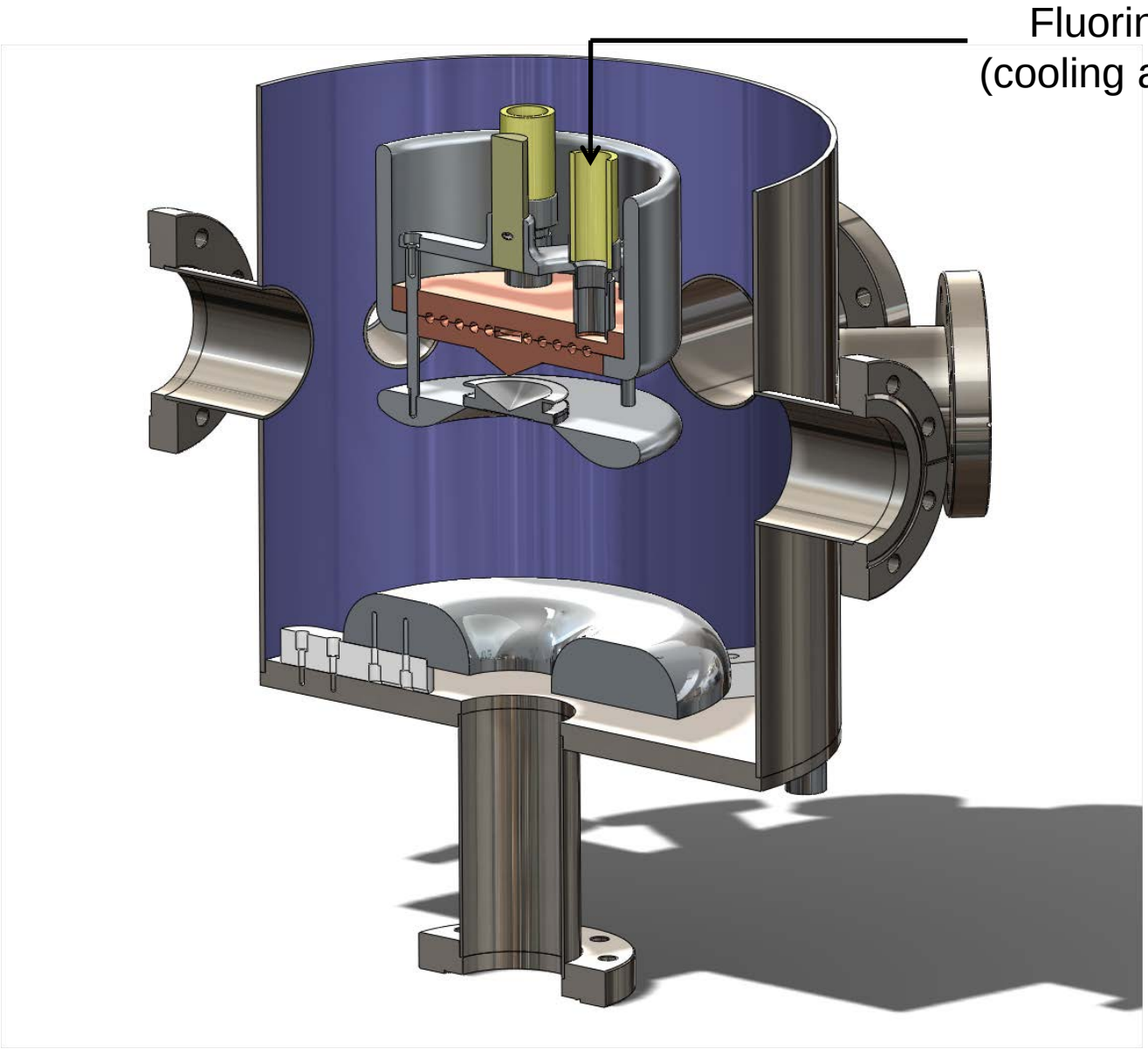


Cathode puck (Moly)

Heat exchanger

Up to 40 W of laser power

Cathode – anode assembly



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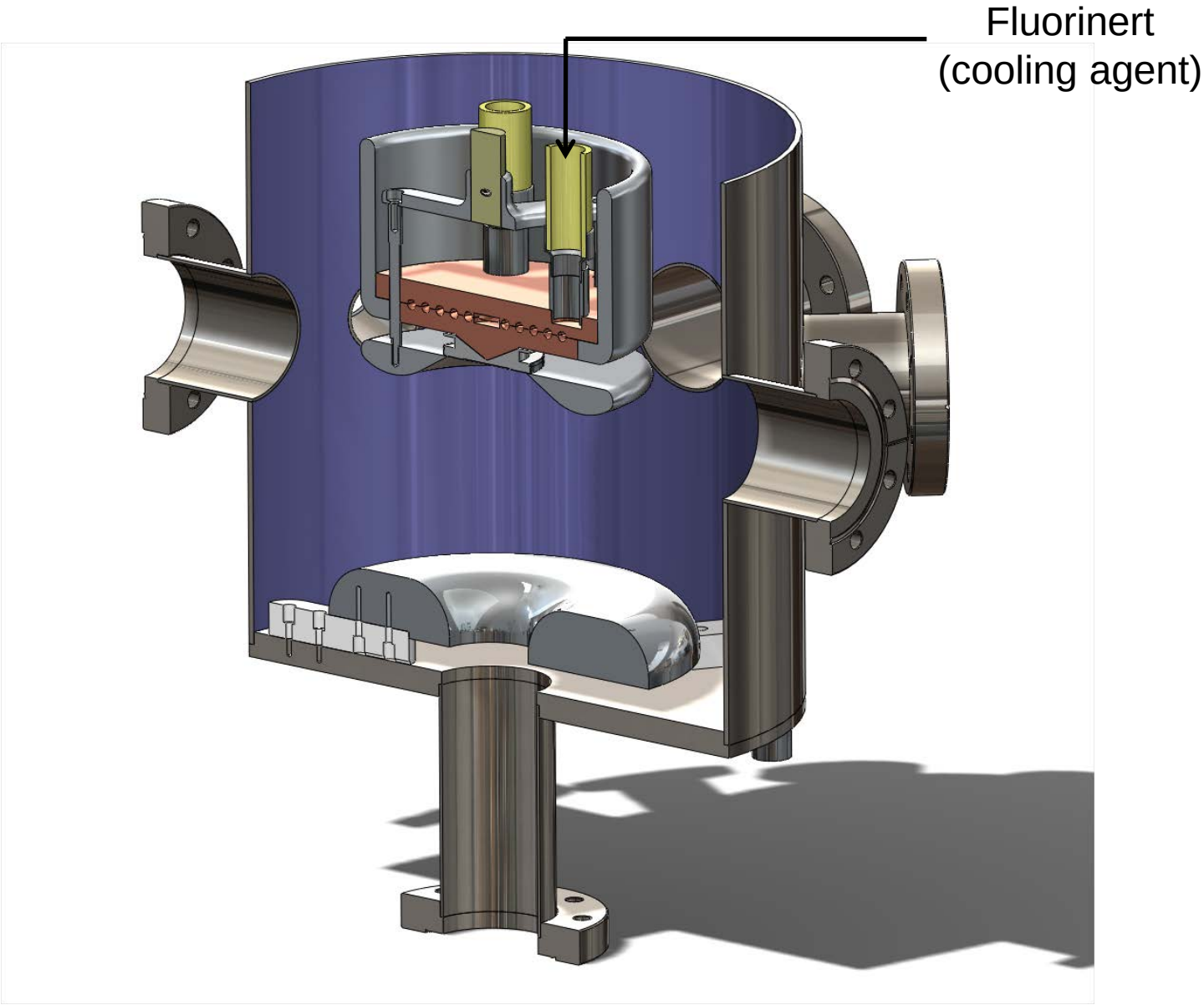
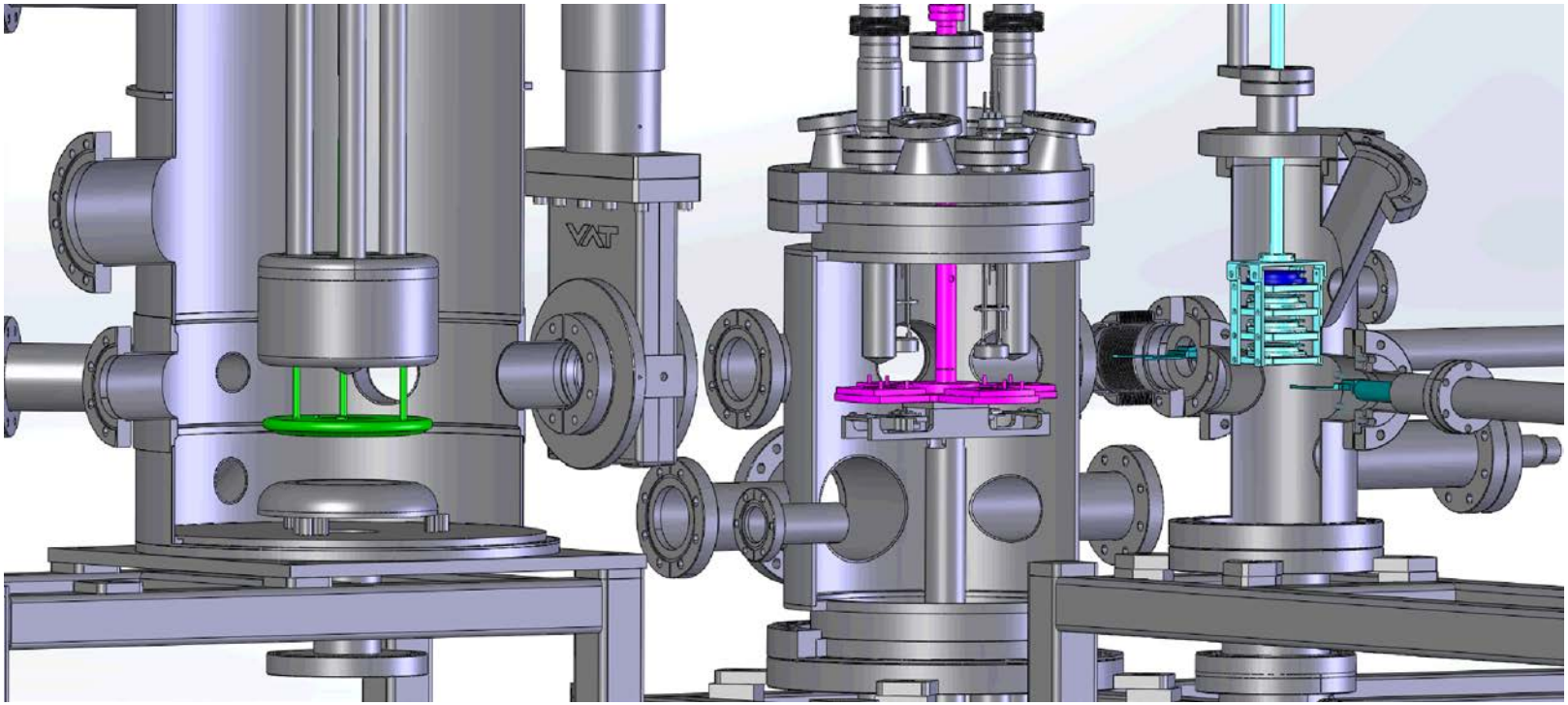
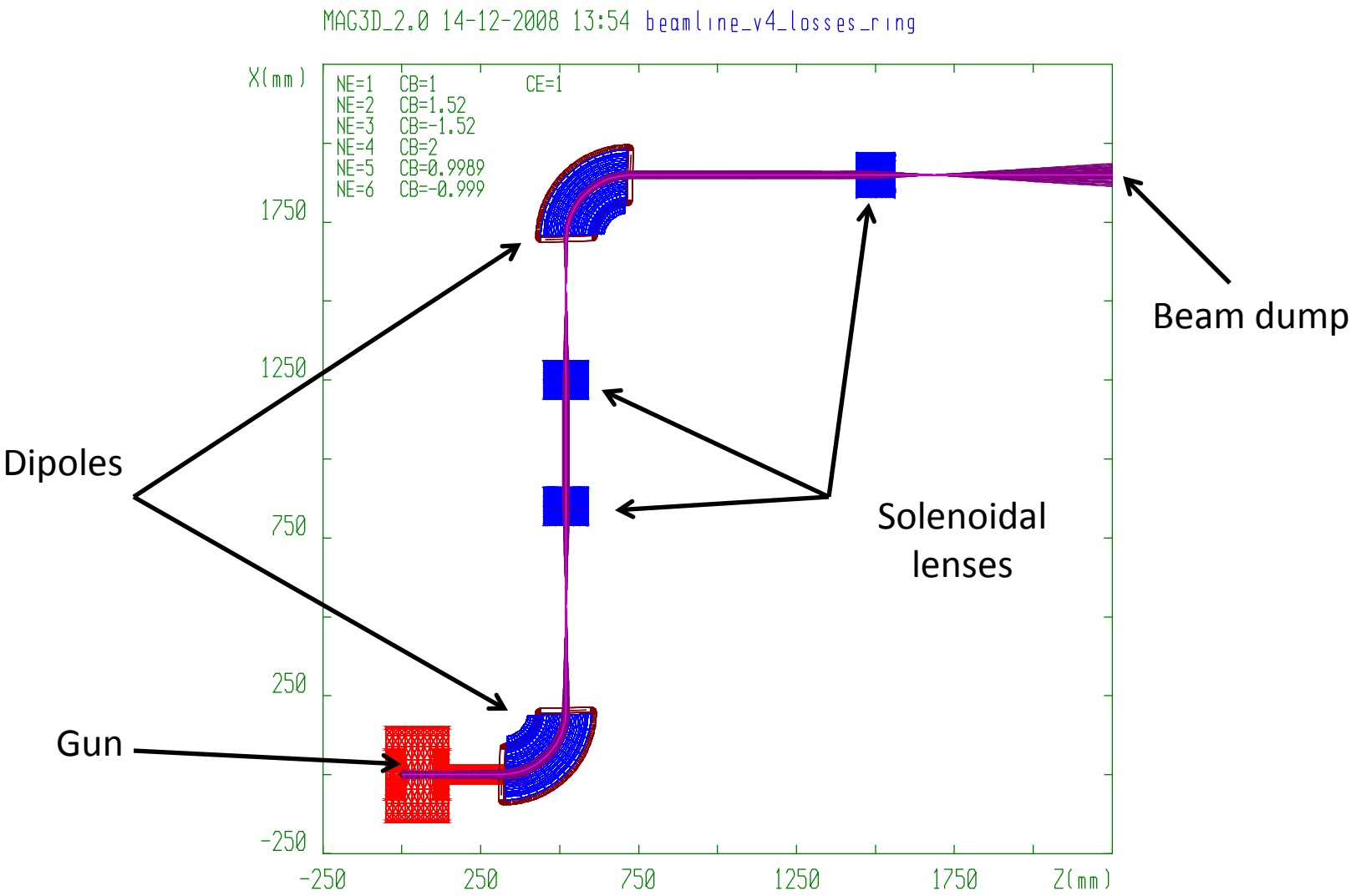
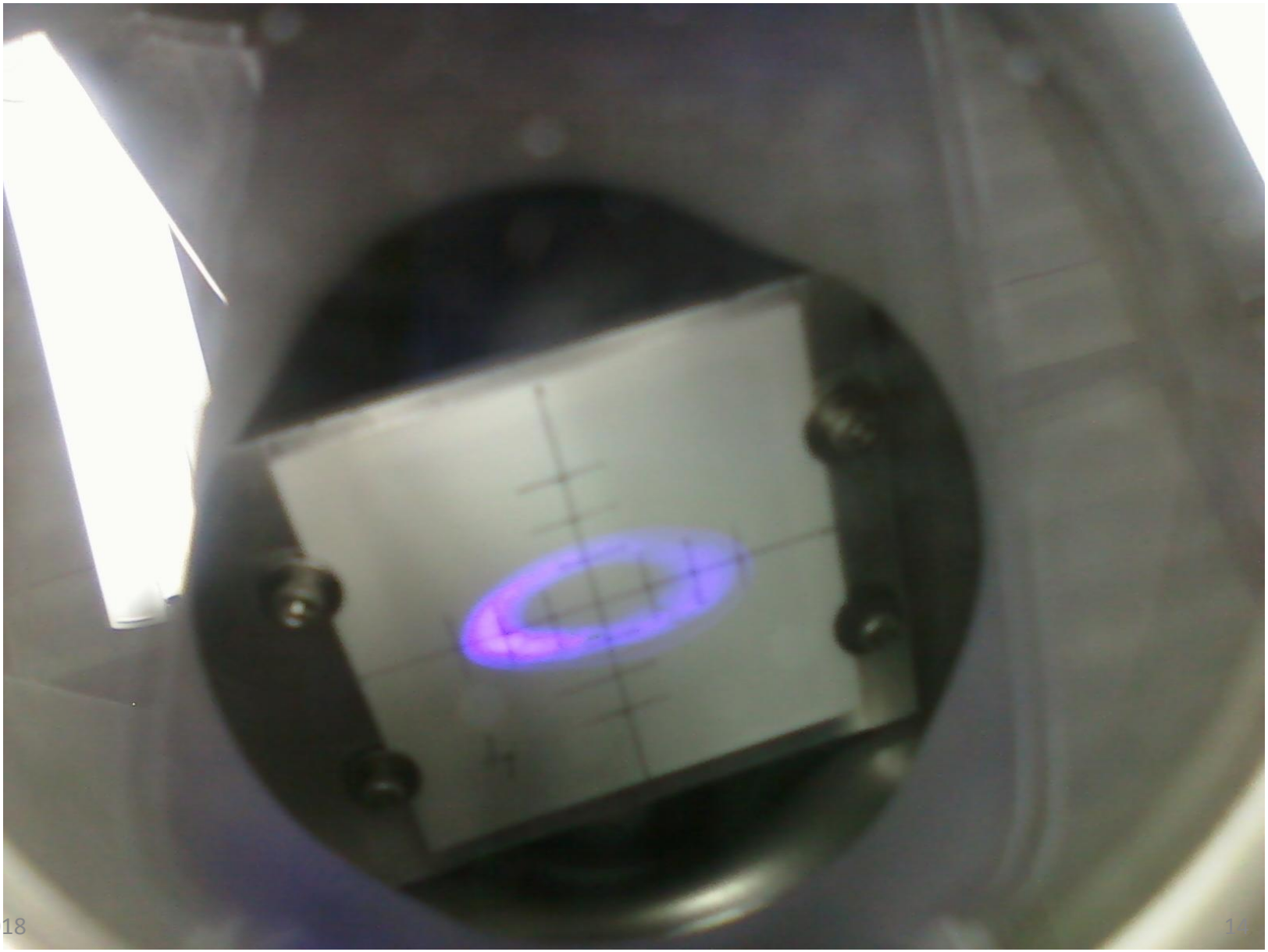



VAT

Beam line. Pipe aperture ~±34 mm.



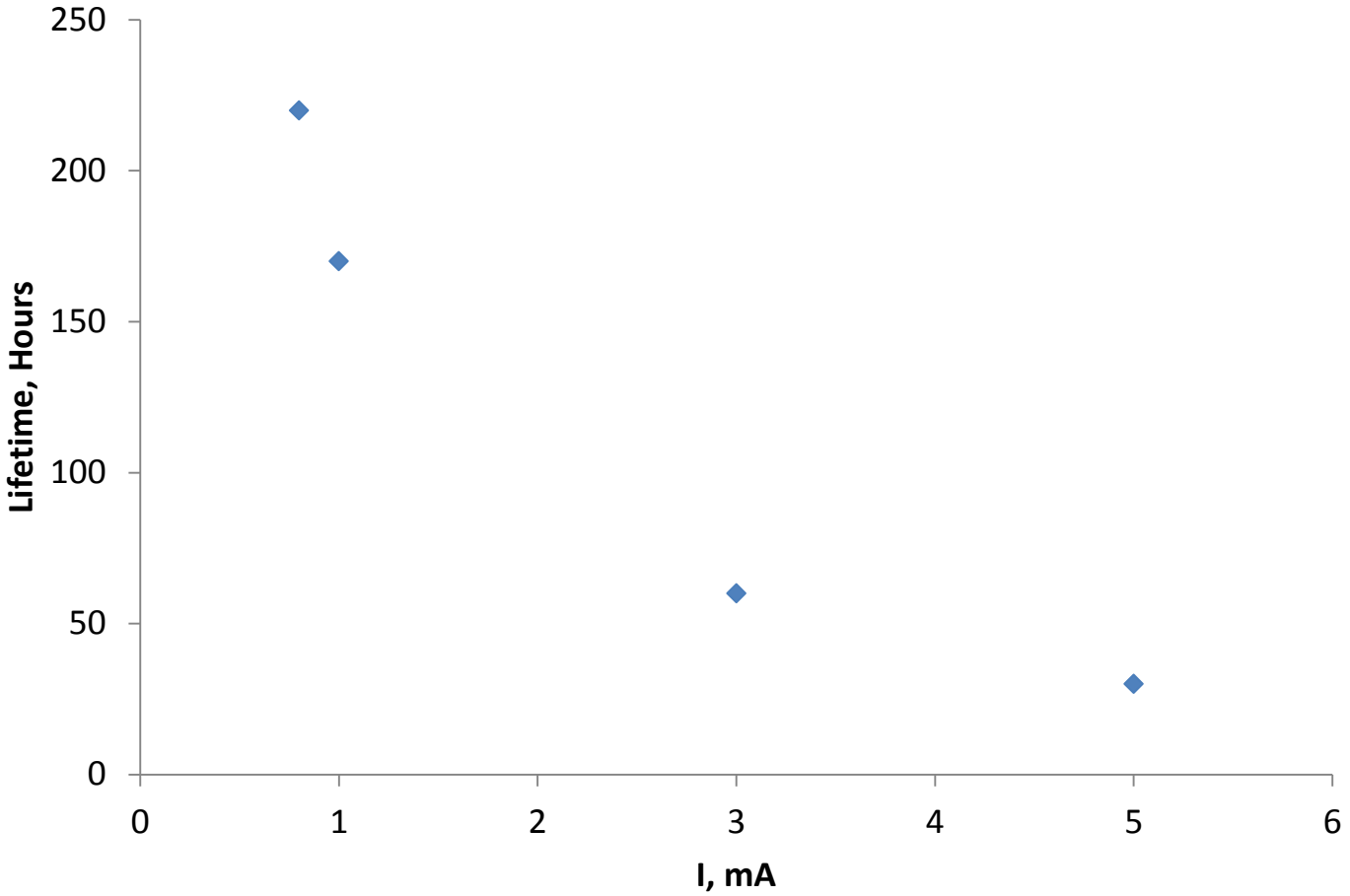
Beam on BeO target



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 are in full agreement with simulations.
- Several equipment breakages delayed the beam tests.
- First beam tests have been conducted.

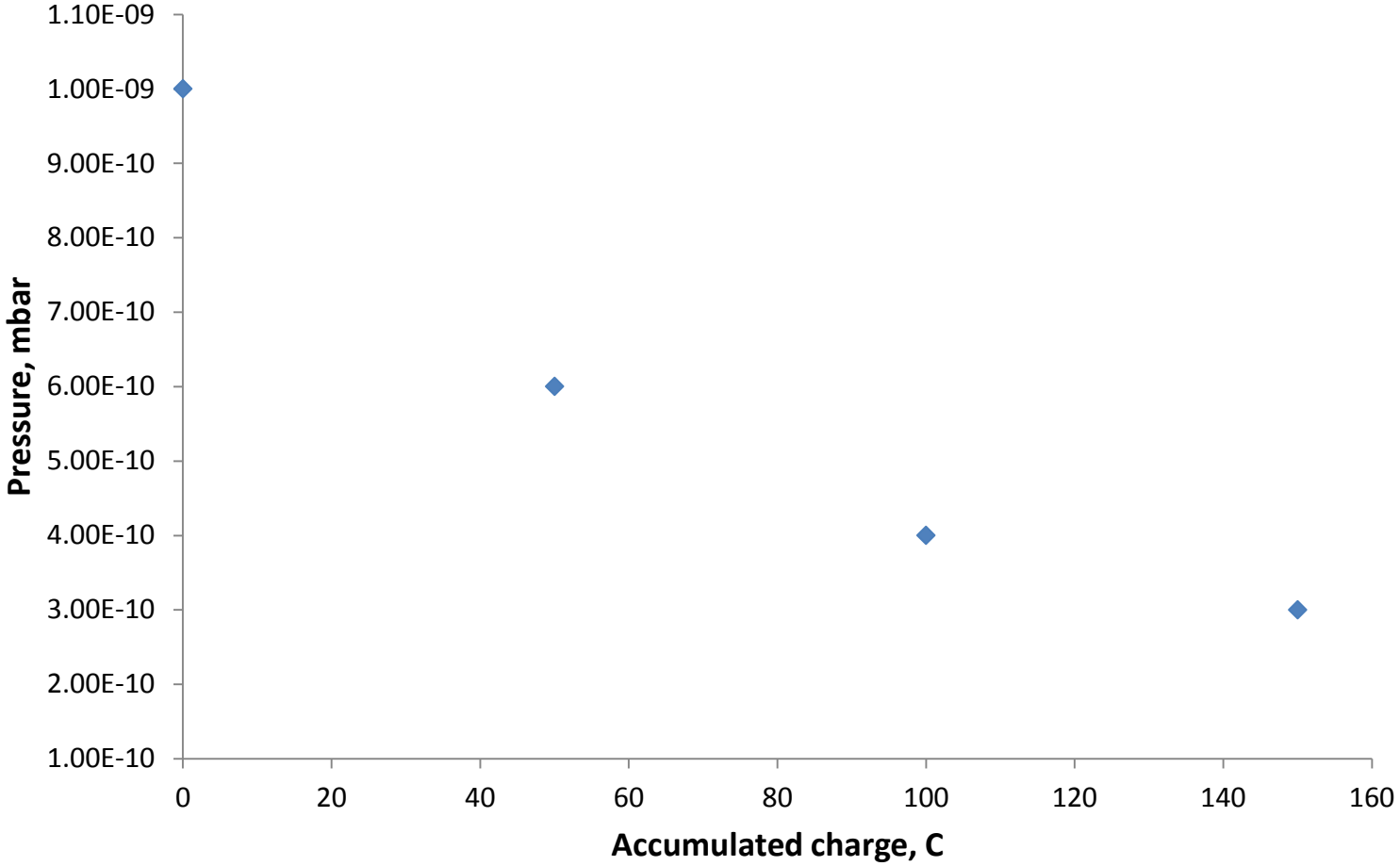
Lifetime measurements



First results

- We believe the lifetime is dominated by outgassing in the beam dump. The beam line is short, and some fraction of gases produced in the dump leaks into the gun (despite differential pumping) and poisons the GaAs crystal. We expect the lifetime will be much longer when the gun is connected to a real beam line.
- As we run high current beam the vacuum situation in the beam dump slowly improves.

Pressure change in the beam dump (1 mA current)



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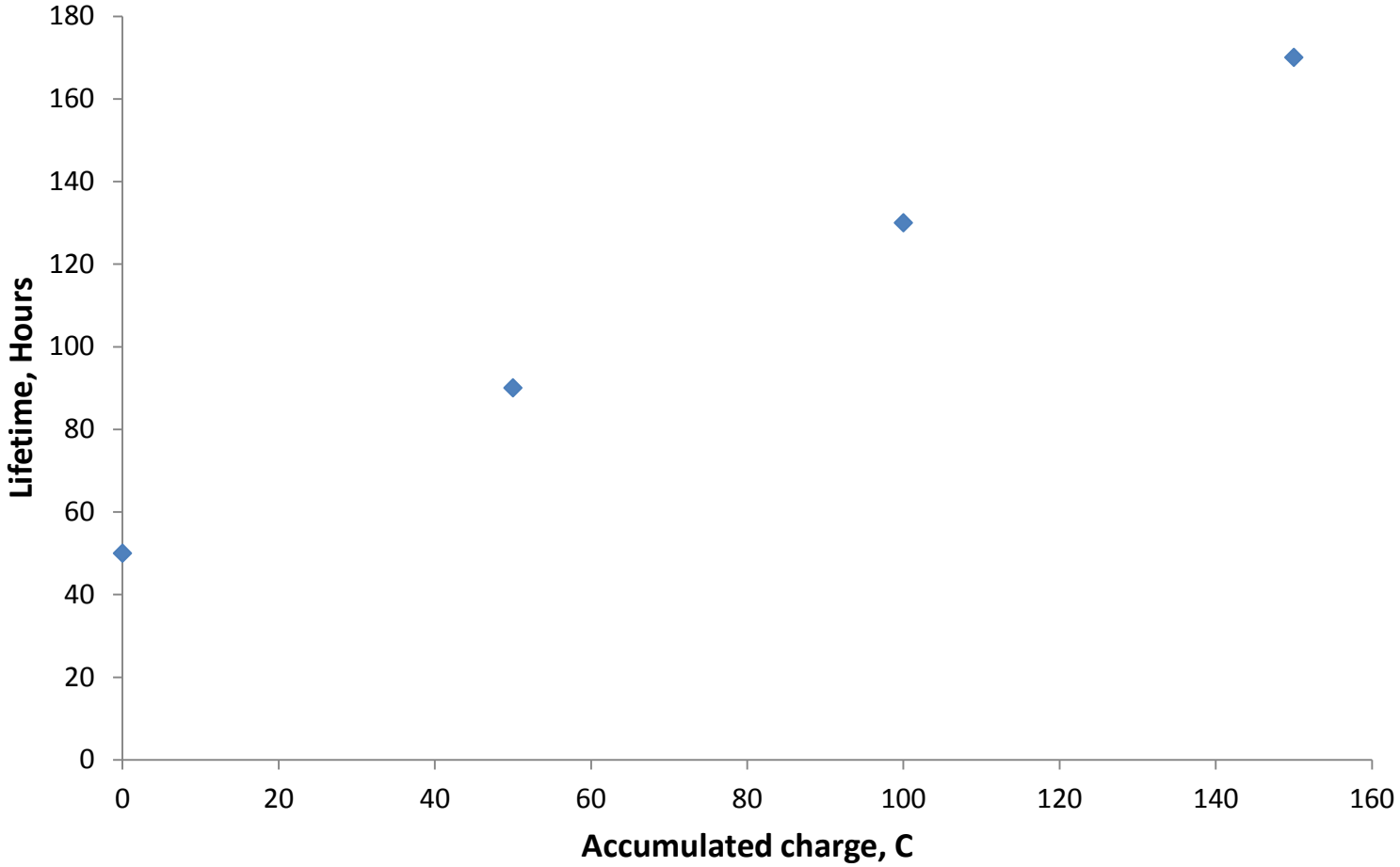

Conclusions

- With a fresh crystal, the gun produces 5 mA current with laser power of about 0.15 W. The gun is designed to take up to 40 W of laser power. This means that even in the current configuration we can run 5 mA for about 300 hours before the cathode needs to be reactivated.
- As we run high current beam the vacuum situation in the beam dump slowly improves.
- We believe that we‘ve built a gun that meets the Linac-Ring version of eRHIC.
- It would be inadvisable to use the current gun for real experiments. The installation was used heavily over the last years, and many parts show wear. At the very least all moving parts, valves, NEGs, Cs strips and PBN heaters need to be replaced. But we also gained invaluable experience, and we figured out what modifications need to be done to improve the reliability of the installation significantly.
- If we were given the opportunity to build a production gun for eRHIC, due to the experience we've gained in developing our prototype gun, the system would be reliable and capable of producing a stable beam for experiments.