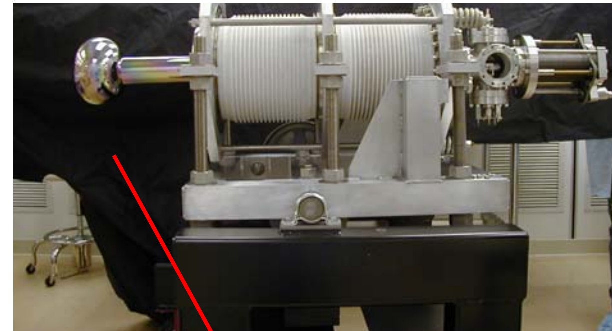
Performance of the 10 mA DC GaAs photocathode gun in the JLab 10kW Upgrade IR FEL

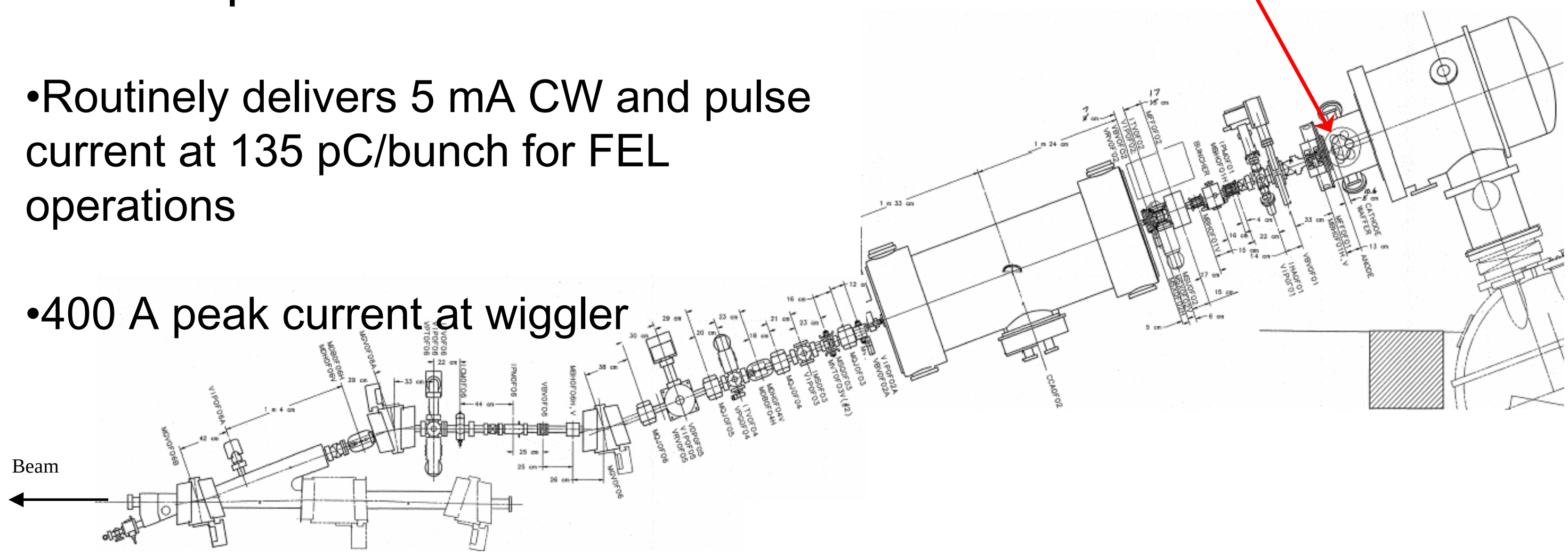
C. Hernandez-Garcia, T. Siggins, S. Benson, D. Bullard, H. F. Dylla, K. Jordan, G. Neil, M. Shinn, R. Walker

JLab 10 kW Upgrade IR FEL Injector demonstrated performance

- Pulsed operation at 8 mA/pulse (110 pC/bunch) in 16 ms-long pulses at 2 Hz repetition rate
- CW operation at 9.1 mA (75 MHz) with 122 pC/bunch
- Routinely delivers 5 mA CW and pulse current at 135 pC/bunch for FEL operations
- 400 A peak current at wiggler

The injector is driven by a 350 kV DC GaAs Photocathode Gun



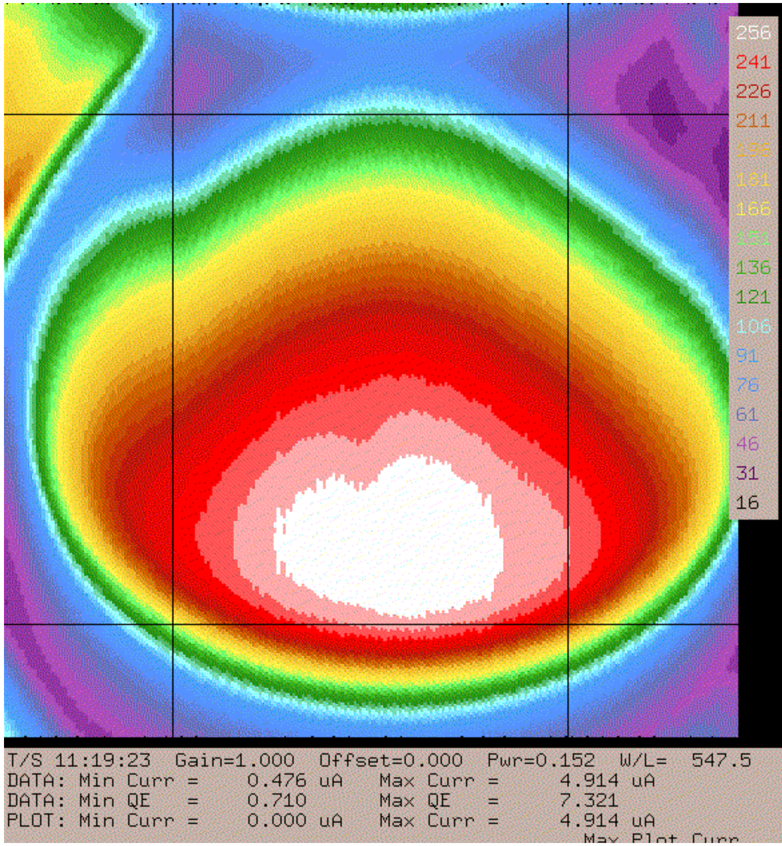


GaAs photocathode performance: over 450 C delivered without QE replenishing!

- 3 months without re-cesiation
- About 96% of previous QE is recovered with each re-cesiation
- Established 5.23% QE by measuring drive laser power at 55 mW to get 1.1 mA CW at 135pC, while the scanner reported 2% QE
- For new cathode, scanner reports ~7% QE, then the extrapolated initial QE should be ~15%

	Beam time (hours)	Delivered charge (Coulombs)
Pulse	131:03	56
CW	**43:55**	**417-450**
Overall totals	174:58	473-506

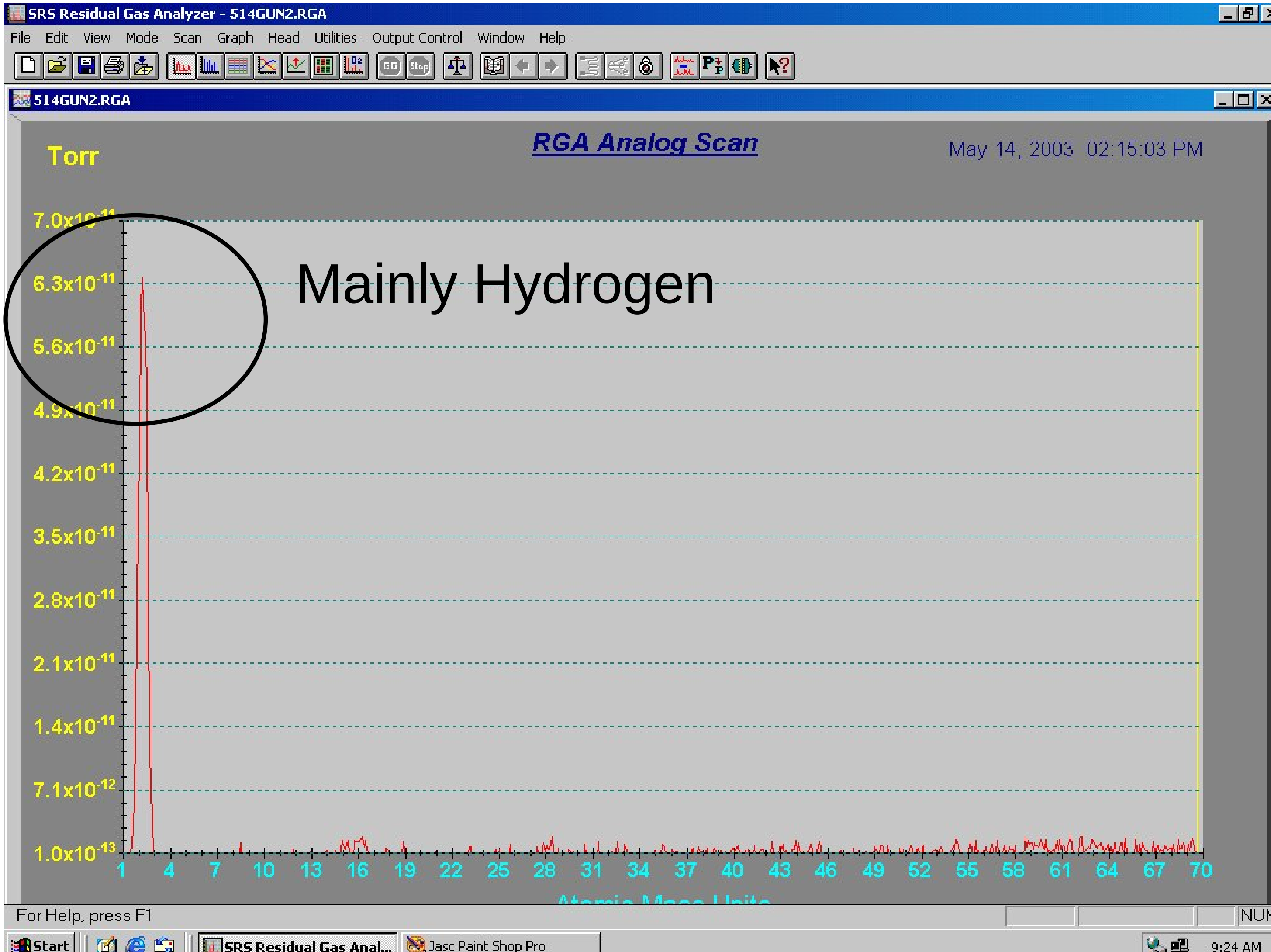
Cathode Archiver by W. Moore and A. Grippo



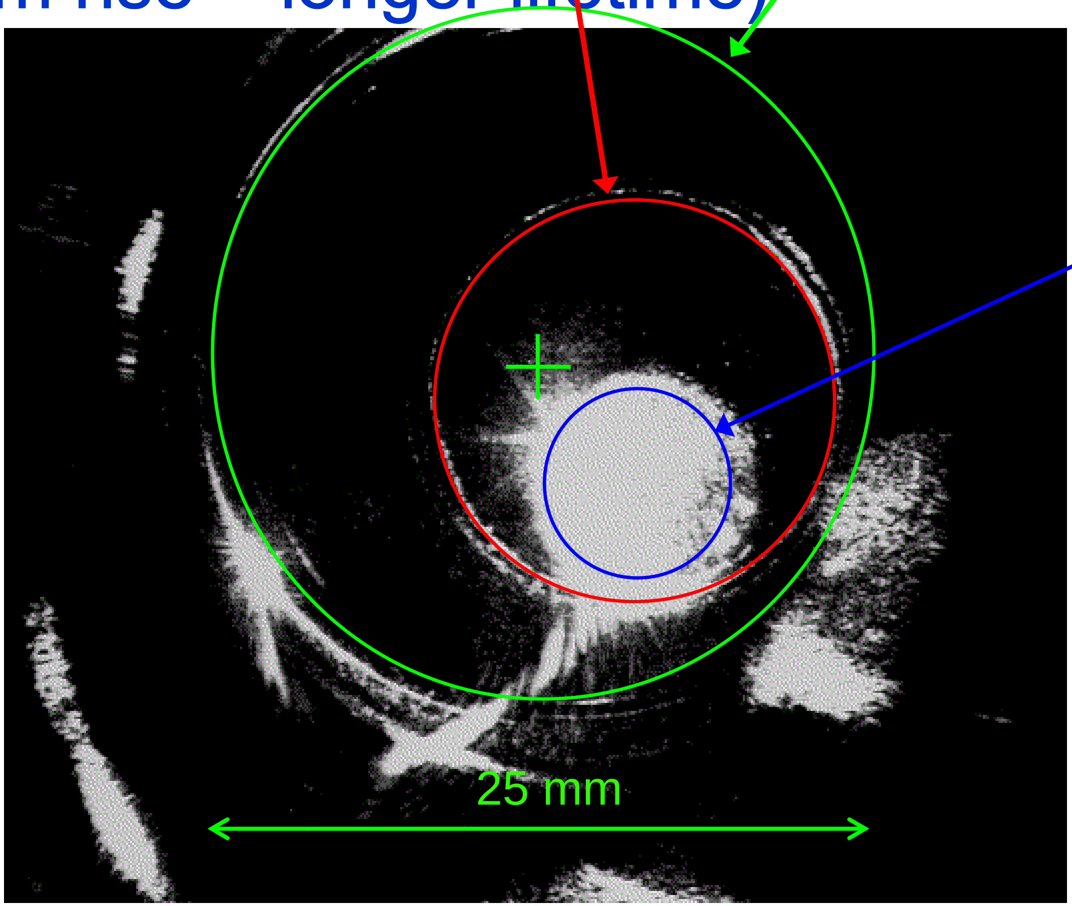
Typical cathode scan using green He-Ne

Key factors for cathode performance

Improved vacuum (EG ~3E-11 Torr H_2 corrected)



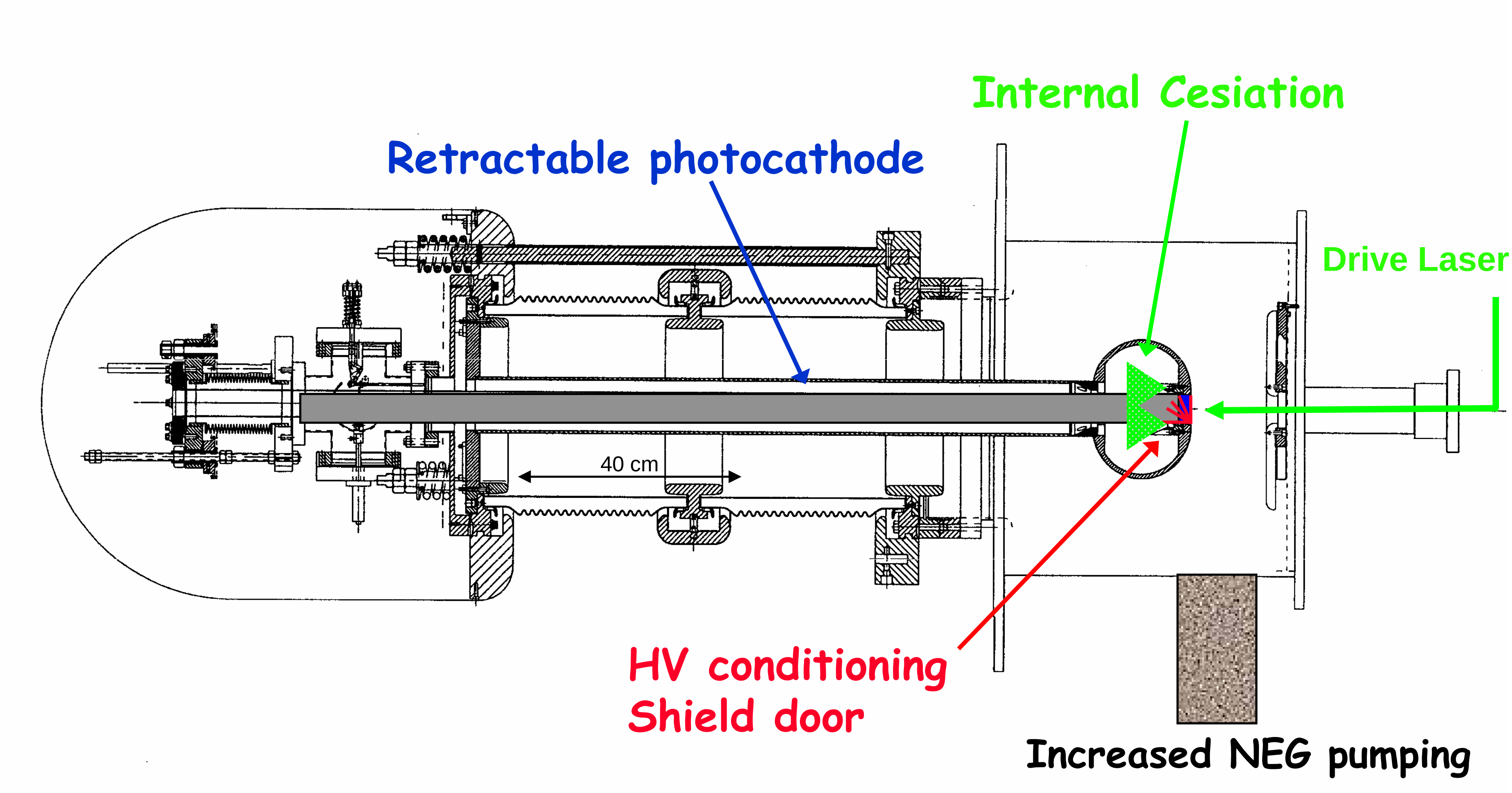
Used different bulk material (AXT GaAs wafer) with anodization to reduce active area and cleaner drive laser transport optics (less scatter light > less halo > less vacuum rise > longer lifetime)



Off electrostatic center illumination means reduced QE degradation by back-ion bombardment in illuminated area

Cathode at 5 mA CW

Key features for gun performance

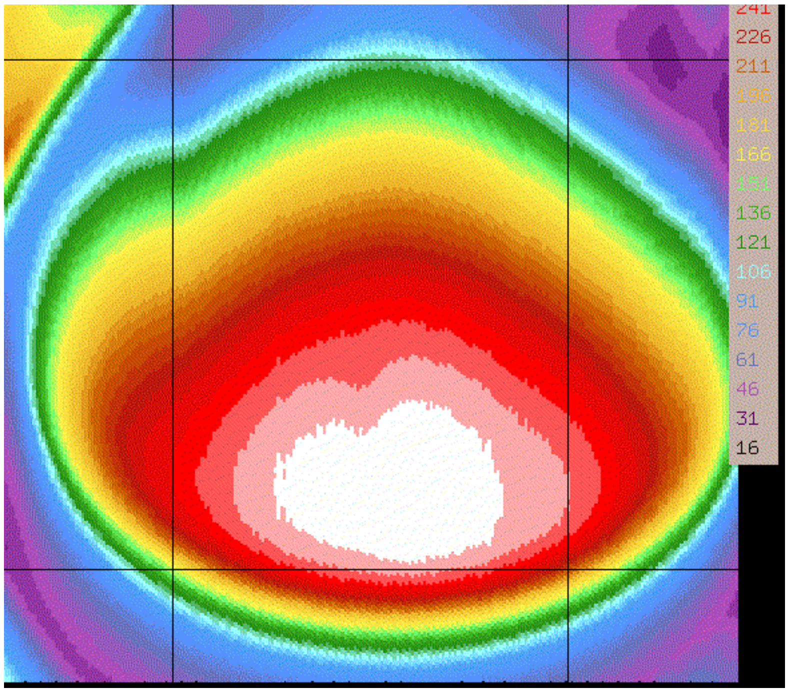


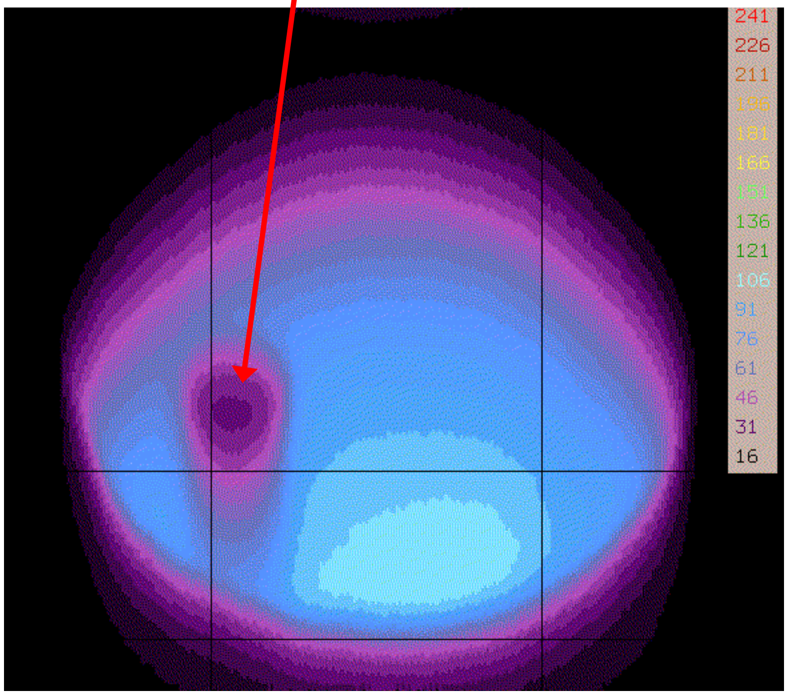
Cathode lifetime issues for 100 mA CW (135pC @ 750 MHz) operation

VACUUM

HALO

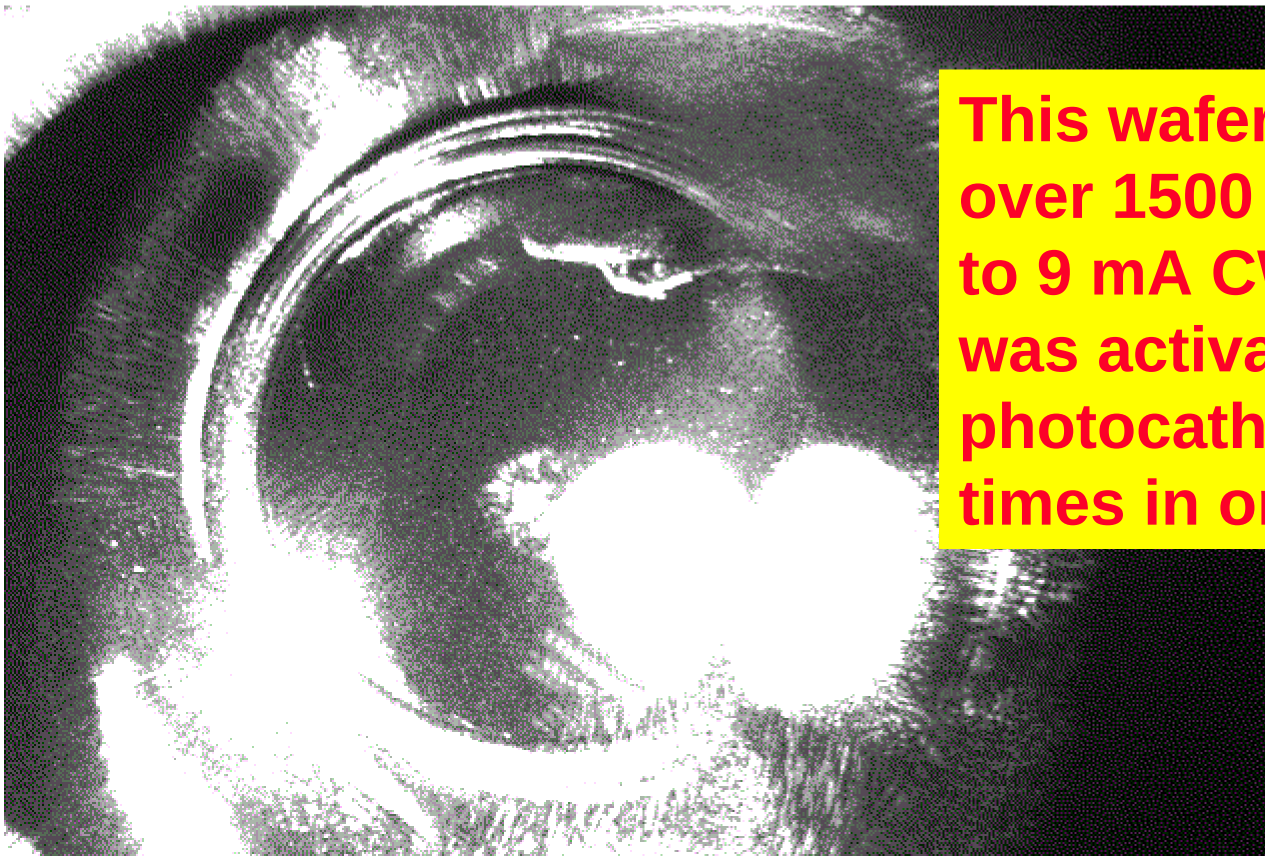
Need better background vacuum (mid E-12 Torr) to prolong QE lifetime and reduce back-ion bombardment





We are trying to reduce overall H2 load in the bulk material by using 316LN SS and vacuum firing, as well as NEG coating for gun chamber

Need to minimize drive laser scatter light and keep using anodized wafers to minimize halo. Halo reduces QE lifetime, not to mention its effect in transporting beam



This wafer delivered over 1500 C, got us to 9 mA CW, and was activated into a photocathode 12 times in one year

Cathode at 7 mA CW

Conclusions

1. Demonstrated 9 mA CW performance with over 450 C delivered between re-cesiation

2. Demonstrated 1.1 mA CW with 5.23% QE and 55 mW of SHG drive laser power on the cathode. This scales up to prediction for 100 mA with 5% QE and 5 W SHG

3. Halo and lower background vacuum need to be addressed for +100 mA CW guns

4. We reduced halo by cleaning drive laser optical transport, and by reducing the GaAs cathode's active area with anodization

5. We prolonged cathode lifetime and QE by improving vacuum in the gun-cryounit drift

6. Despite divots on the electrostatic center of the cathode caused by cryounit trips, the performance of the 2 cathodes is unaffected thanks to off-center drive laser illumination

Open questions

- Can the cathode dark current (field emission) stay below ~10 nA at gradients larger than 6 MV/m? (presently 4.2 MV/m @ 350 kV)
- Main sources of field emission may come from bulk GaAs damage due to back-ion bombardment when the cryo-unit trips off. This increases the pressure in the gun chamber killing the cathode QE, and makes divots on the cathode (cathode performance not affected so far by divots) but may fracture GaAs wafer
- Will this situation worsen at and beyond 100 mA? How often will find ourselves in the situation of changing GaAs wafers (i.e. breaking vacuum)? Hey, hey! Load-lock gun chamber?