Some UMER Gun Physics

Why Study ?

- Because it's there (unavoidable) and interesting.
- Halo and emittance originating at the source very difficult to reduce.
- Despite nearly a century of study, much is not known.
  - (Although some that was known has been forgotten.)
- Direct source measurements can be very difficult.

Physics is complex

- Space-charge important in the source region even for systems where it is not important downstream.
  - Beam is not in initial equilibrium.
  - Current and emittance are insufficient to adequately describe the beam.
  - Need the distribution function, including internal correlations - difficult to measure.
- Beam characteristics are often sensitive to small details in the gun design.
- Transients can be complex and important (Prof. O'Shea).

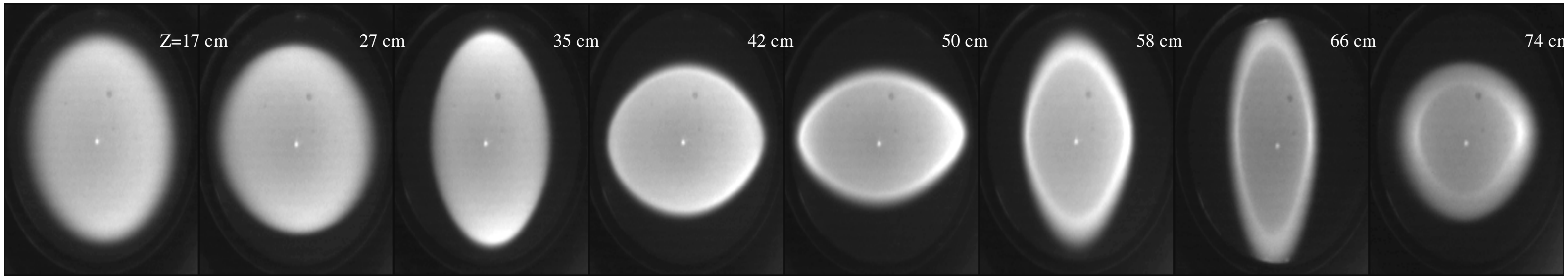
Difficulties – Experimental

- Space charge complicates interpretation of any measurements.
- Insertion of measurement apparatus can change the beam transport.

OUR METHOD:

- Primary diagnostics are phosphor screen and current monitor
- Use simulations (WARP code) along with experiment to infer behavior.

Lack of Initial Equilibrium Launches an Inward-Travelling Wave



Cathode

z ~ 0.15 – 1 m

A uniform temperature across the beam is not in equilibrium with a linear applied focusing force. The particles with an excess pressure at the beam edge, compared to the quadratic falloff required for equilibrium, stream outward and are then reflected into the beam.

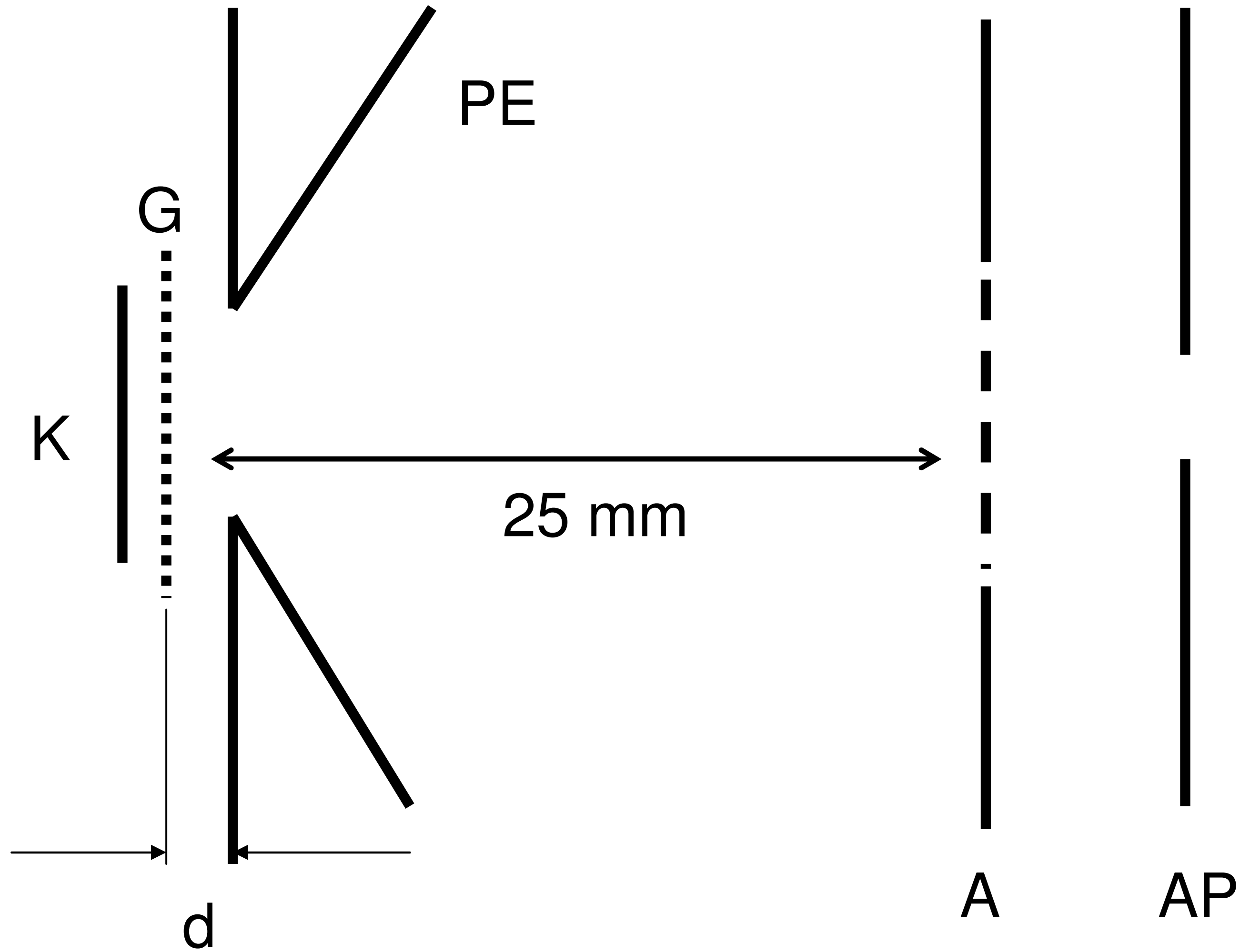
*Bernal, Kishek, Haber, and Reiser, PRL, **82**, 4002 (1999).*

*Kishek, O'Shea, Reiser, PRL, **85**, 4514 (2000).*

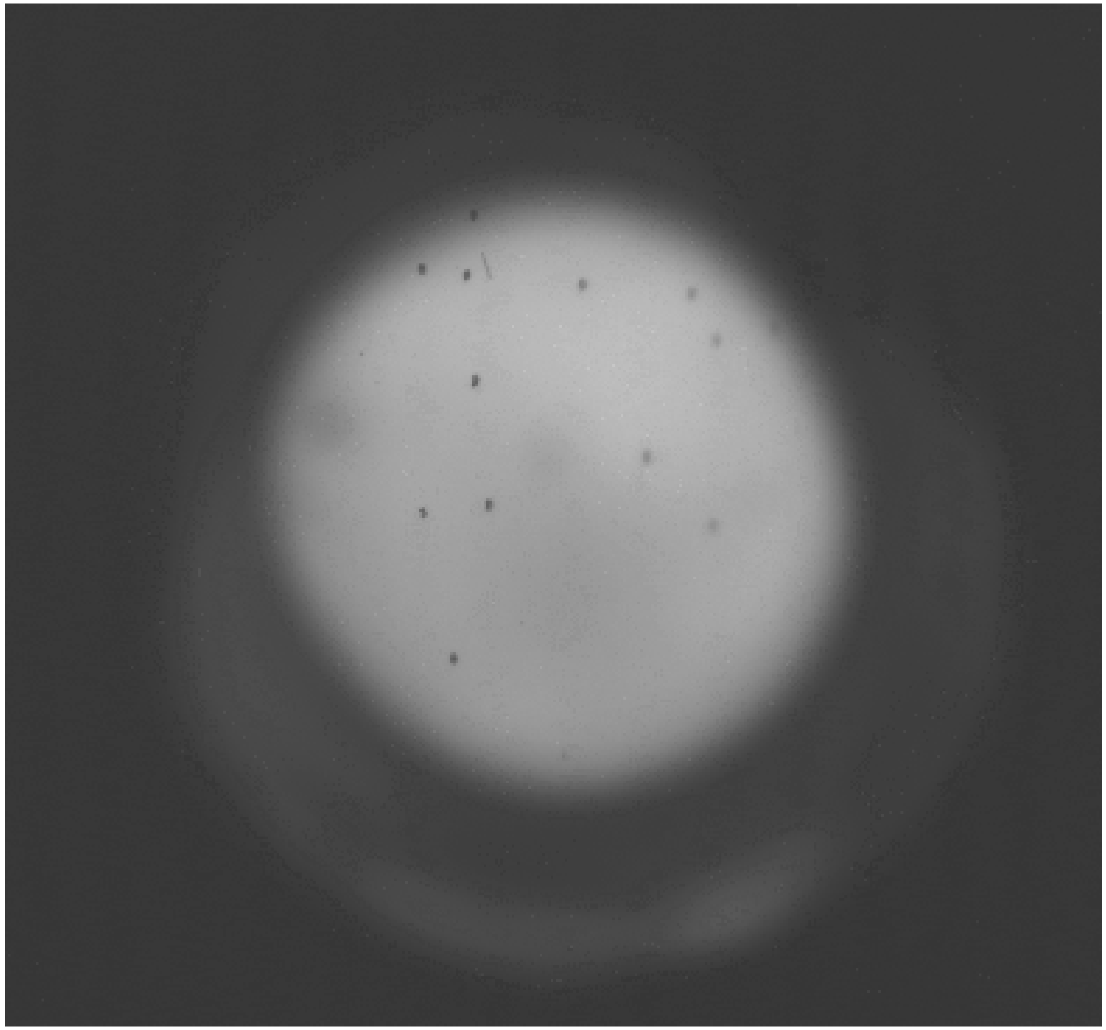
Reiser, Sec. 7.3.5, 7.3.6.1

EXAMPLES on
UMER gridded gun

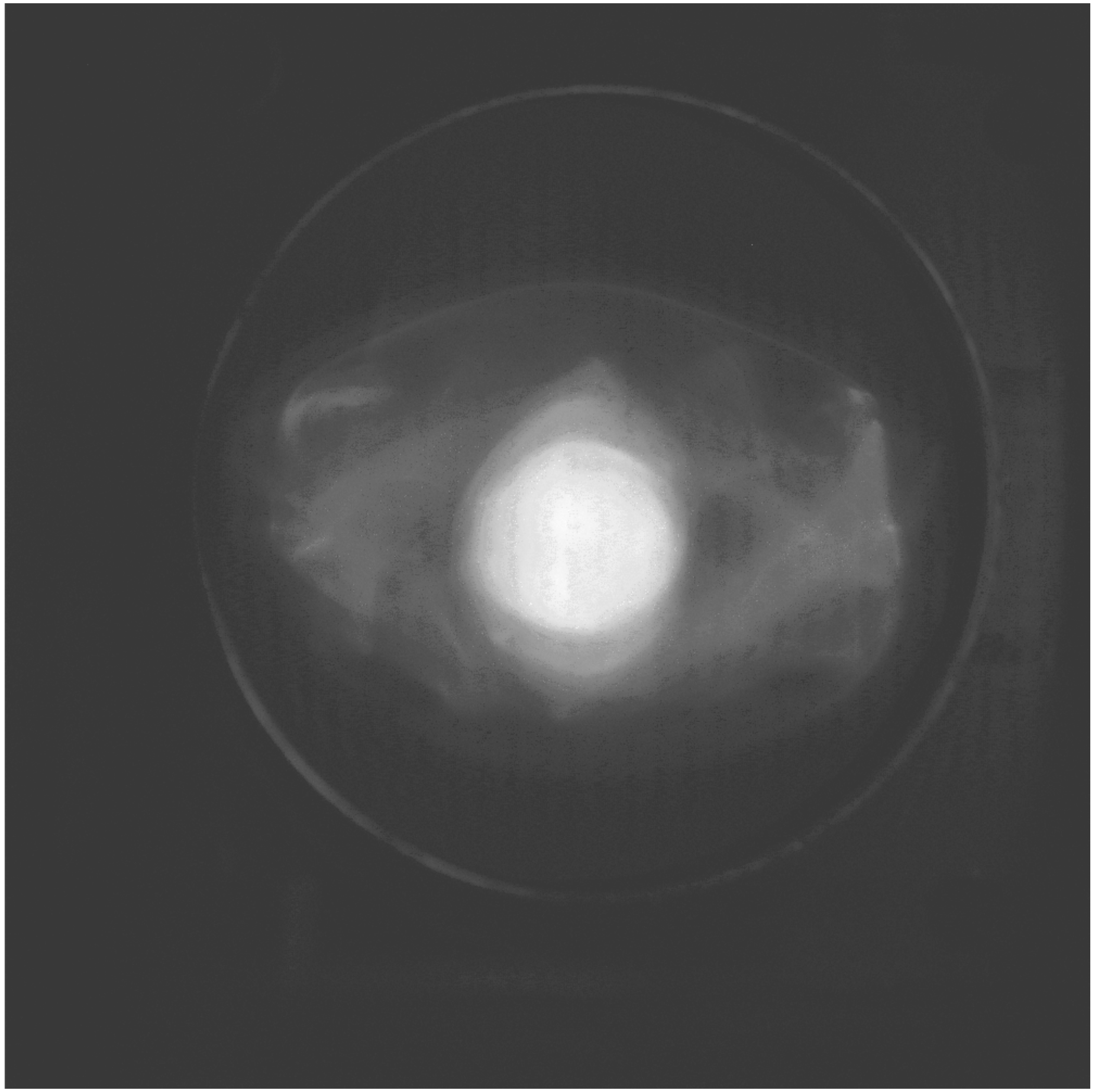
- Halos.
- Hollow Velocity Distribution – Pinhole Scan
- Virtual Cathode Oscillations.



Schematic of UMER gun showing cathode (K), cathode grid (G), Pierce electrode (PE), gridded anode (A), and aperture plate (AP). The space between cathode grid and back of the Pierce cone is d.



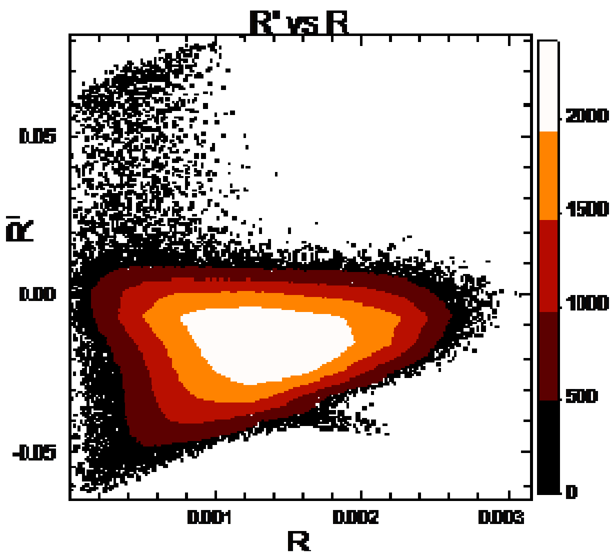
Phosphor screen image showing halo particles ~30 cm downstream of the aperture plate. Beam has passed through 3 mm diameter centered aperture (~20% of current), and focusing solenoid magnet. Note that the small spots are damage spots on the phosphor screen.



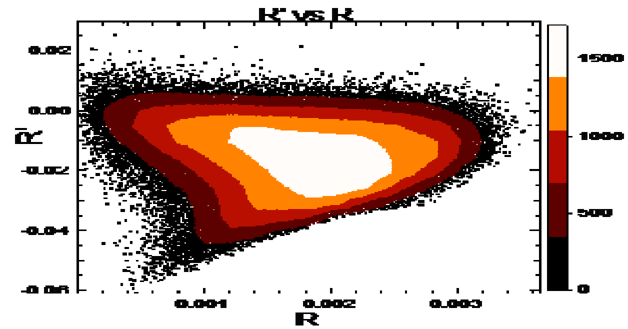
Initial halo can introduce considerable downstream complexity.
Aligning such a cross section can be tricky.

What causes halo?

- Halo was enhanced after cathode was changed.
- Edge of emitter is a long-known source of stray beam.
- Gap between cathode-grid and and back of Pierce-cone difficult to control
- A good job for simulation (WARP).

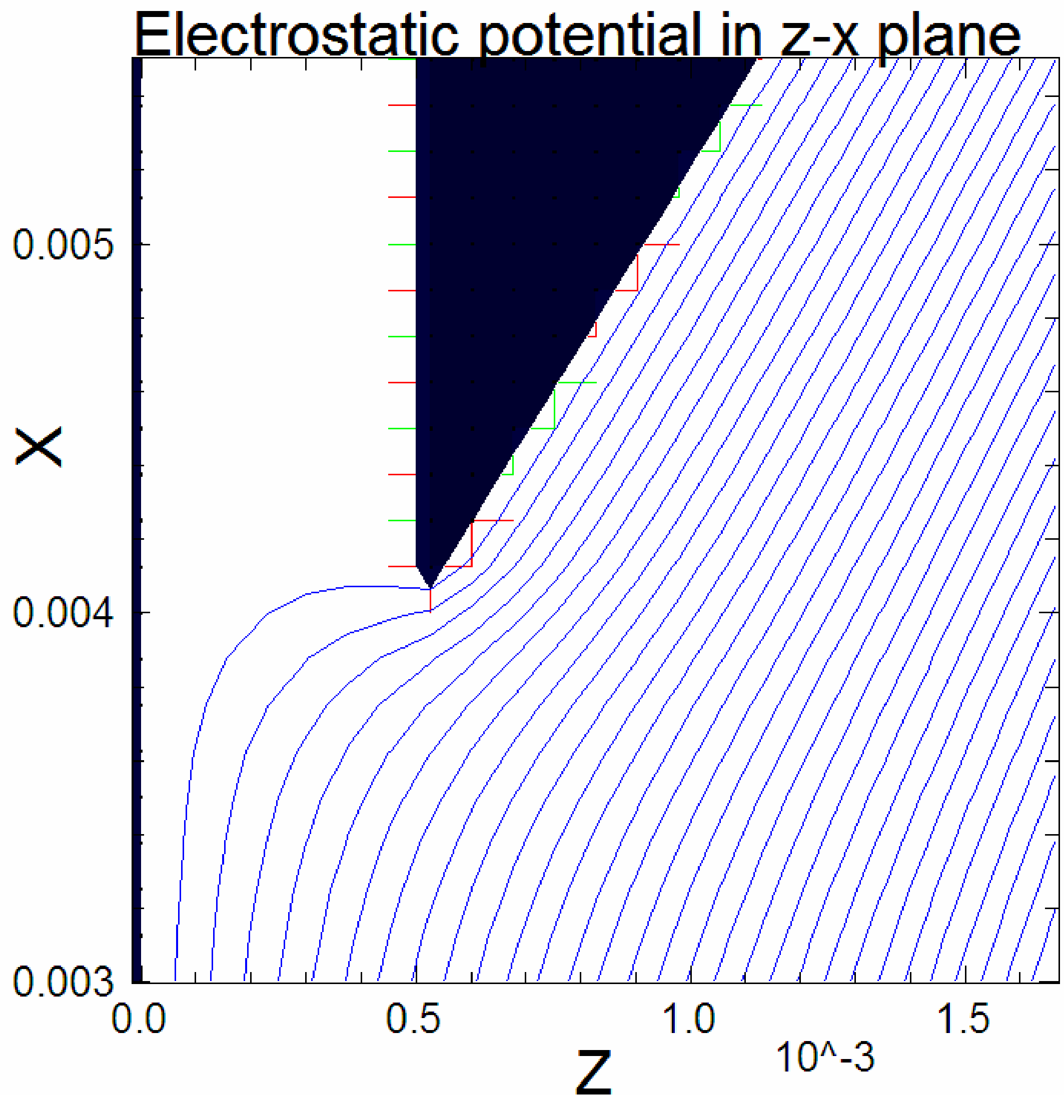


d = 0.5 mm



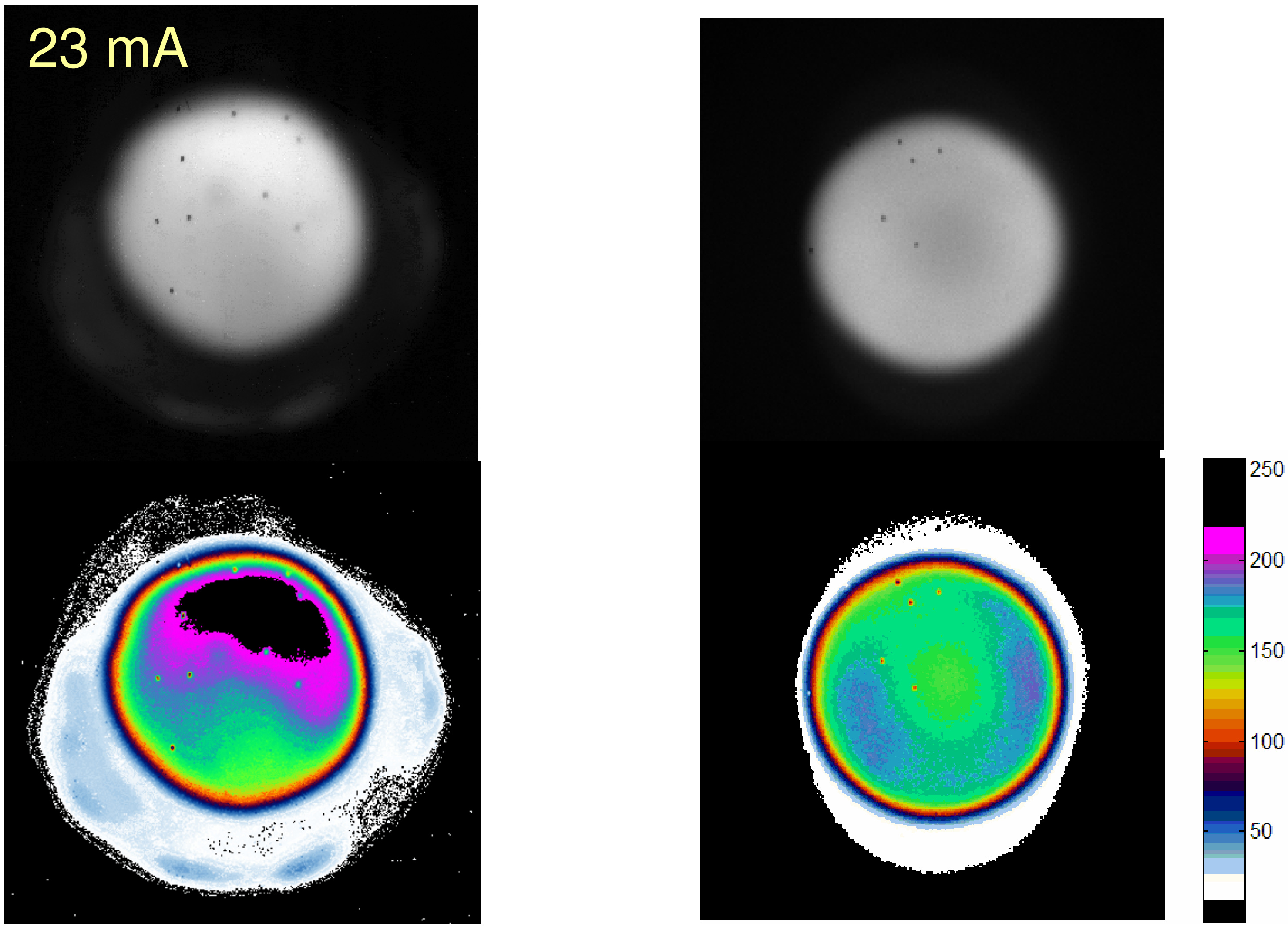
d = 0.1 mm

Simulations predict that halo is produced by the gap between the back of the Pierce focusing electrode and the cathode grid. Note that the simulations predict that the halo is in phase space at the aperture plane so that it is not removed by the aperture, as observed.



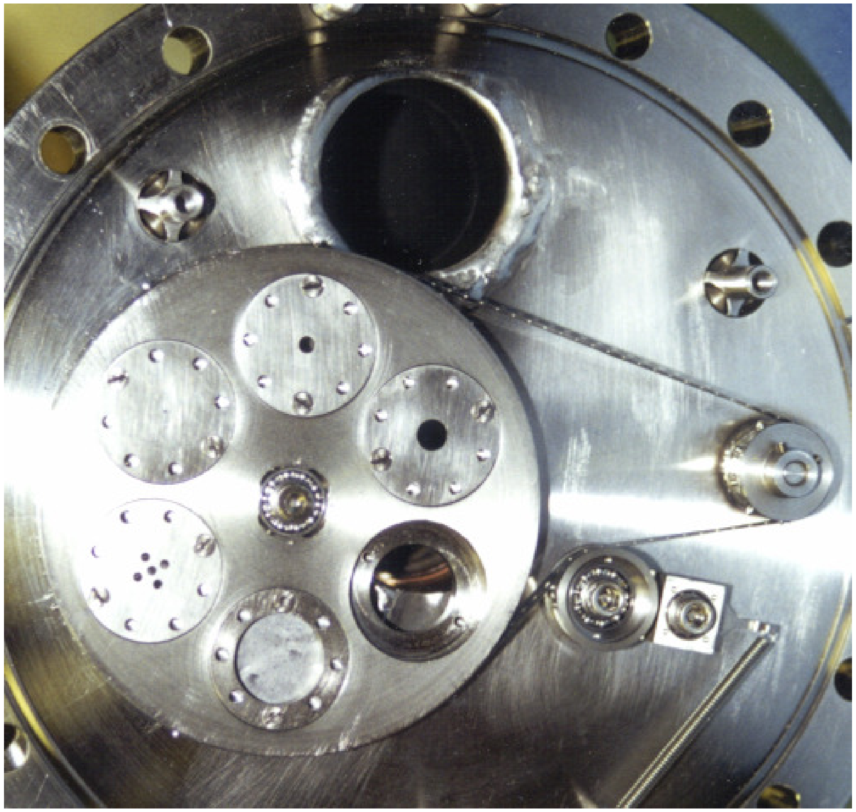
Expanded-scale plot of equipotential lines showing distortion in the vicinity of the edge of the Pierce cone. Edge particles are accelerated inward by resulting fields

Before After

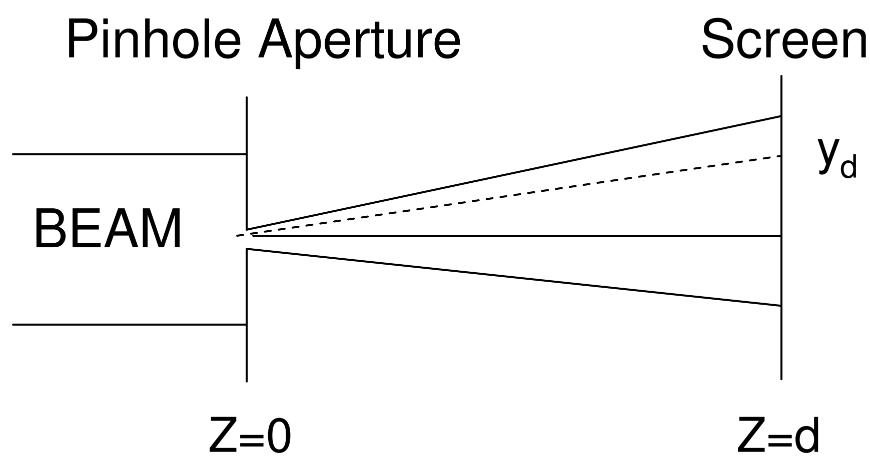


Decreasing gap verified simulated prediction. (Also note improvement In alignment.)

Use of a Pinhole to Measure Velocity Distribution



Aperture wheel, holes can be scanned across beam.



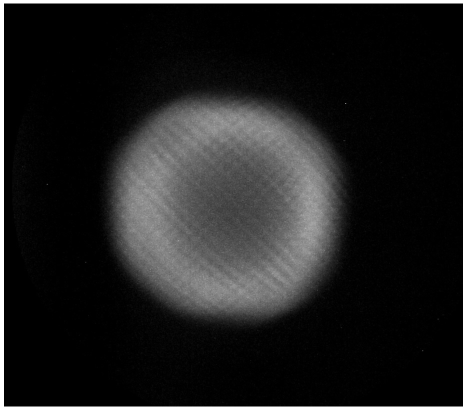
$$Y_d = y' d,$$
$$y' = v_y / v_z$$

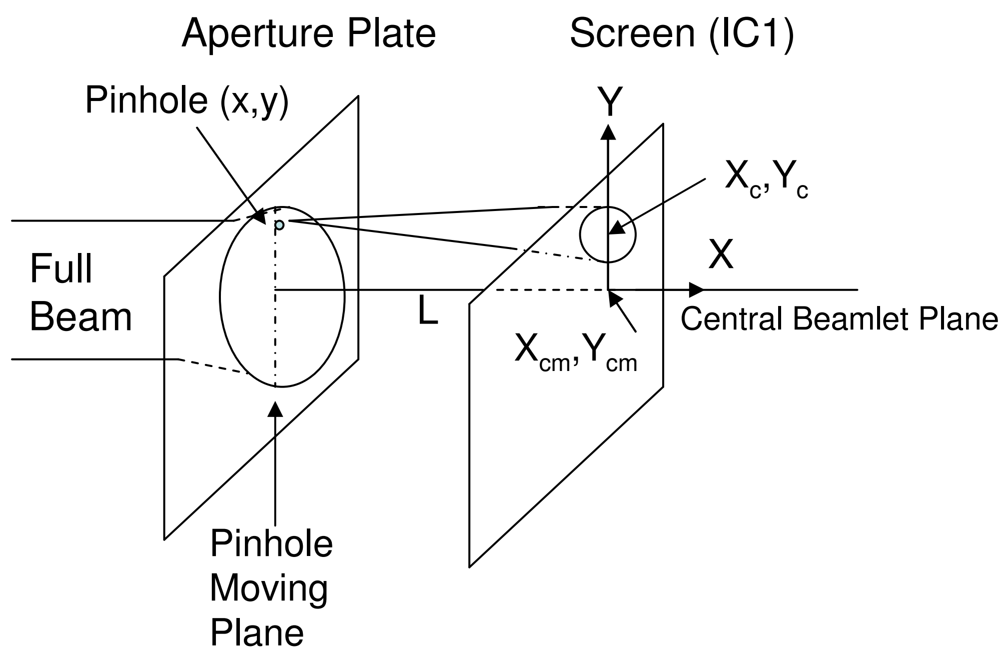
Particles hit screen with transverse displacements proportional to their transverse velocities.

UMER Gun Produces Hollowed Velocity Distribution

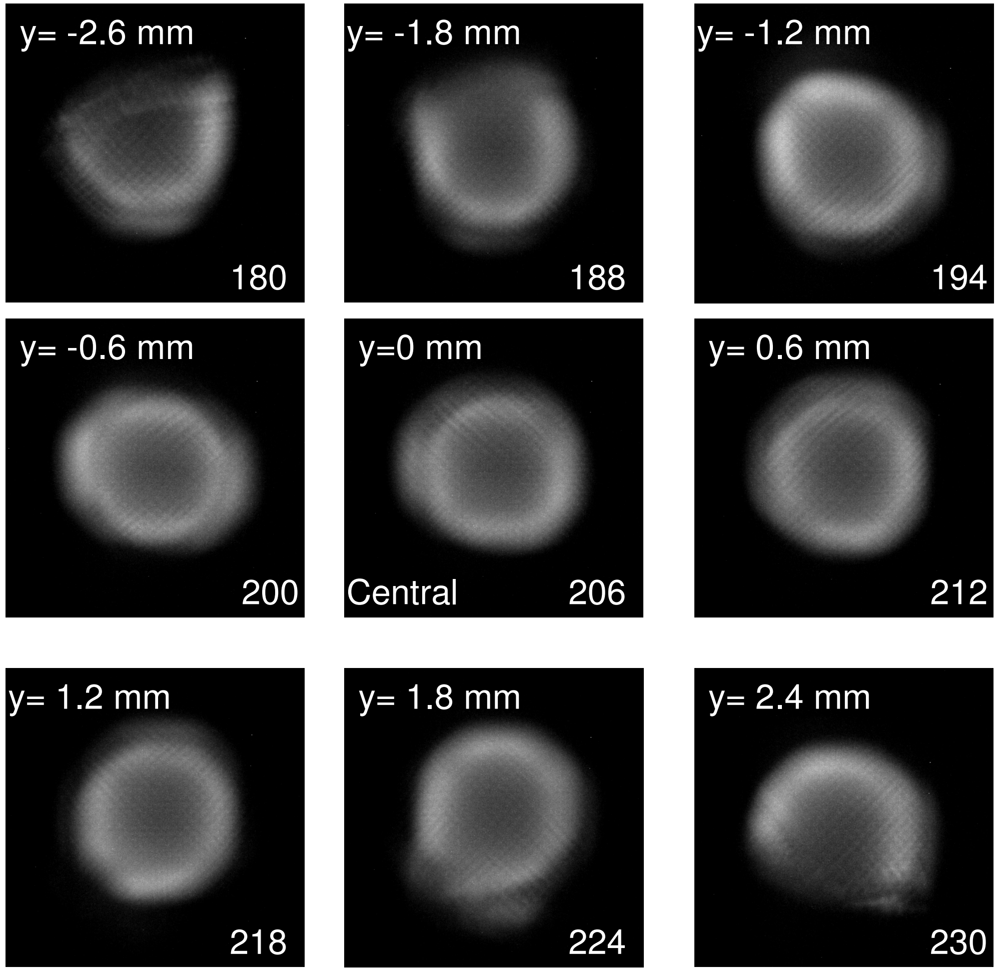
The virtual cathode that forms downstream of the cathode grid preferentially reflects particles passing between the grids. As a result, under nominal operation, the beam has a hollowed distribution in velocity space.

Image from centered pinhole



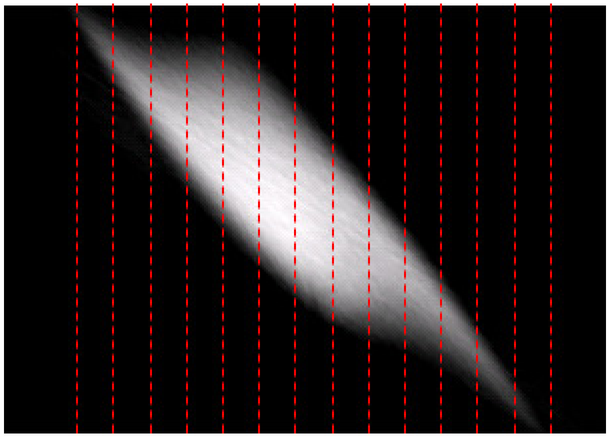


Scanning the pinhole across the beam measures the Full phase space distribution along the scanned diameter. Assuming axisymmetry, the full distribution can be inferred.

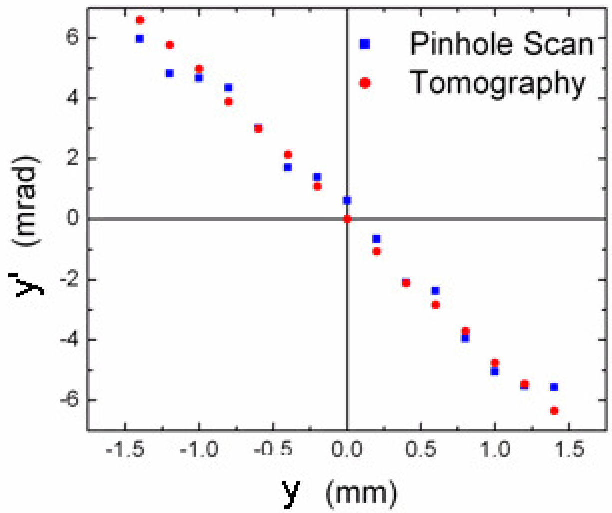


Transverse distribution is relatively constant across the beam.

Centroid variation vs position measured directly from the pinhole scans can be compared with the centroid of the phase space from the tomographic reconstruction (Dr. Stratakis)



(a)



(b)

Virtual Cathode Oscillations

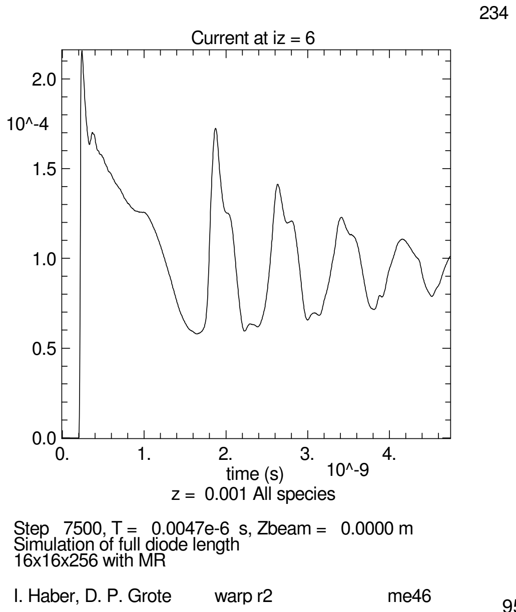
- Extra charge from the overshoot can then suppress the following current.
- This can cause a relaxation oscillation know as a virtual cathode oscillation.
- Delay in buildup of charge in the cathode-to- anode gap can cause emitted current to “overshoot” steady-state value.

(“Virtual cathode” because minimum potential moves downstream of actual cathode.)

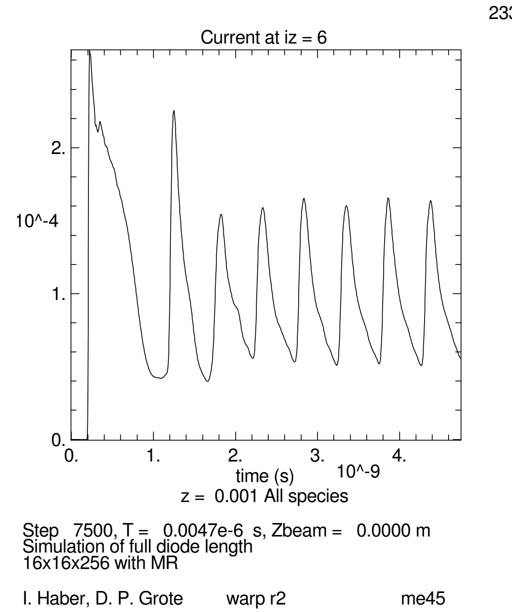
*Haber, et. al. NIM A **577**, 157-160 (2007).*

Current vs. time for different grid voltages (~ 0.6 mm from the cathode)

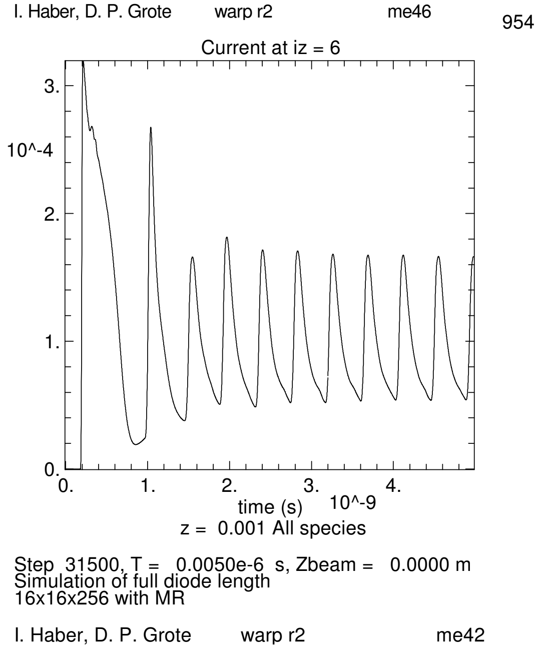
20V



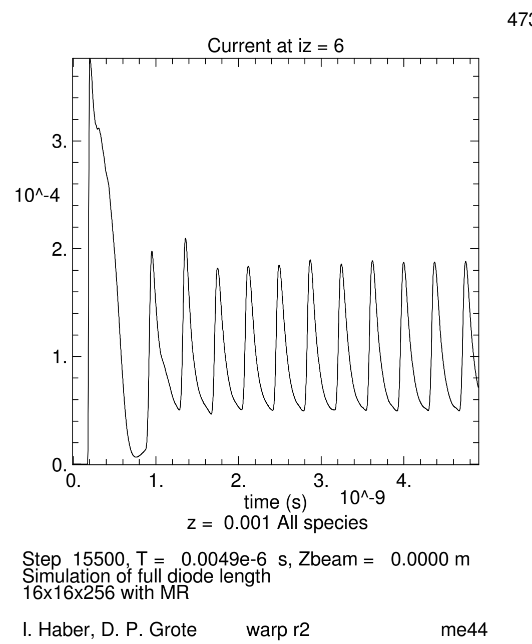
25V

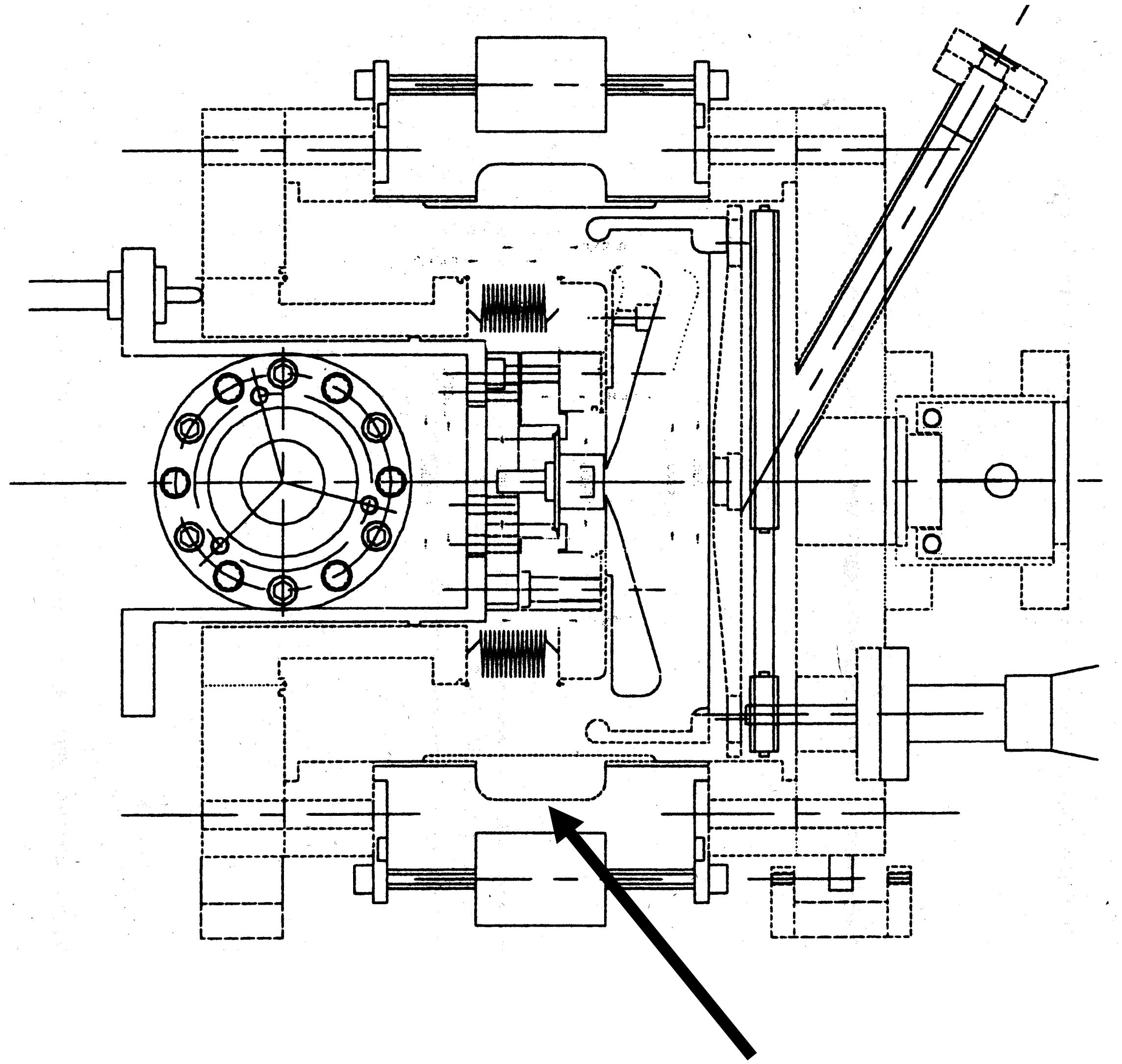


30V

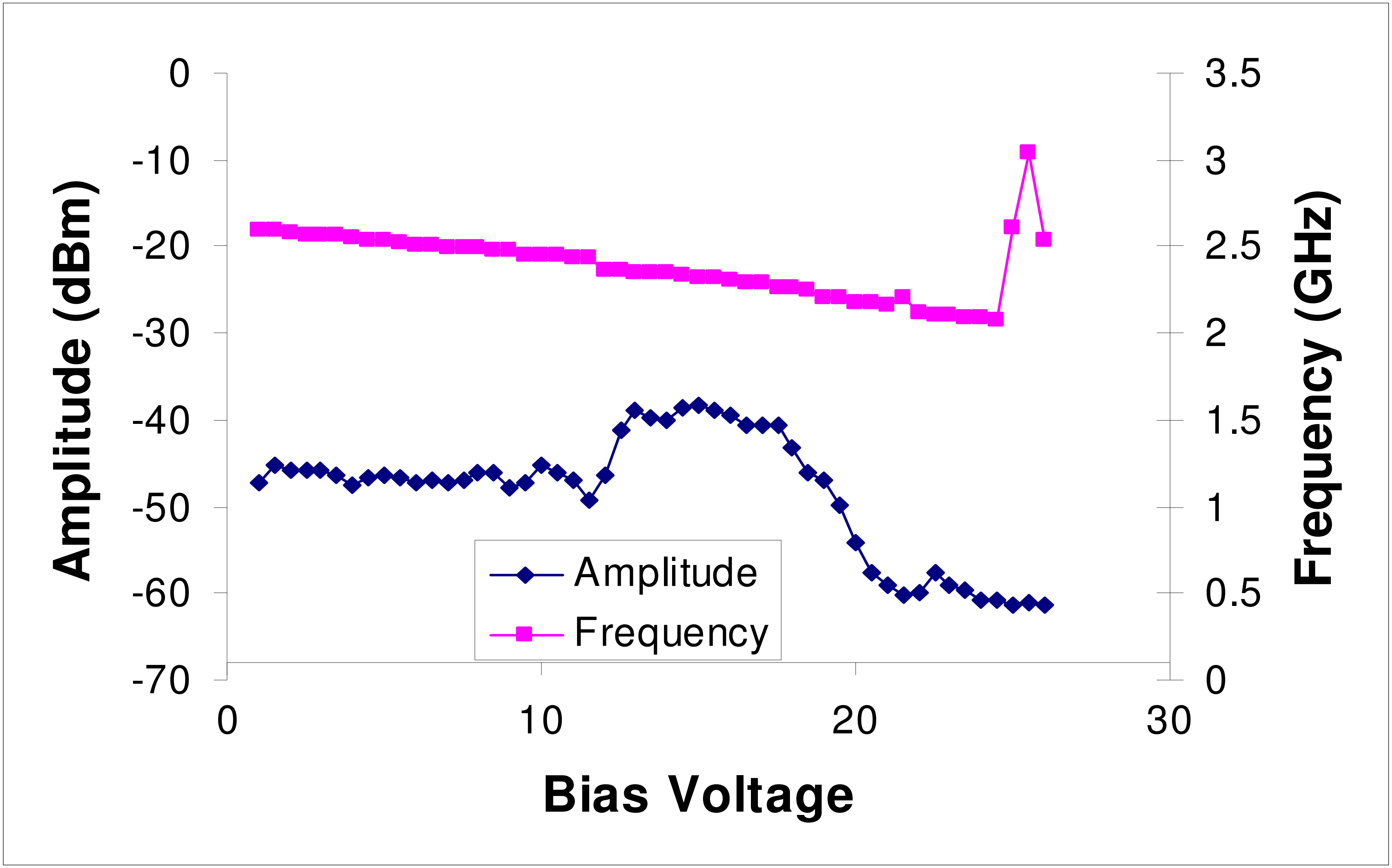


35V





Full gun structure - loop probe placed near insulator.



Amplitude (dBm)
0
-10
-20
-30
-40
-50
-60
-70
Frequency (GHz)
3.5
3
2.5
2
1.5
1
0.5
0
0
10
20
30
Bias Voltage
Amplitude
Frequency