RF Electron Gun Mechanical Repair

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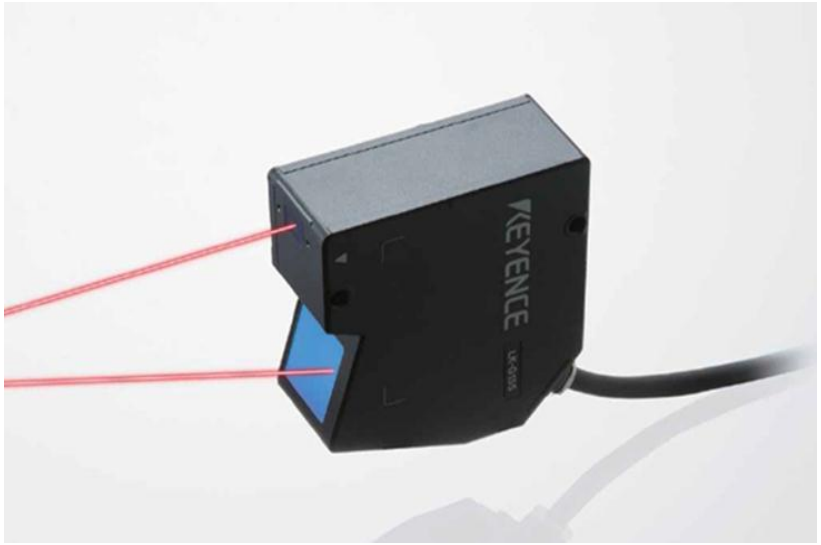
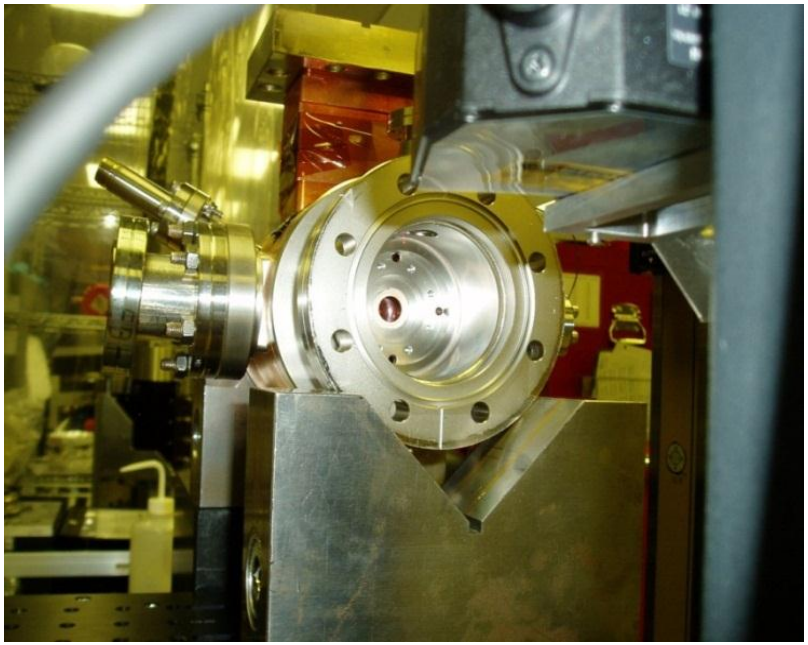
Advanced Photon Source

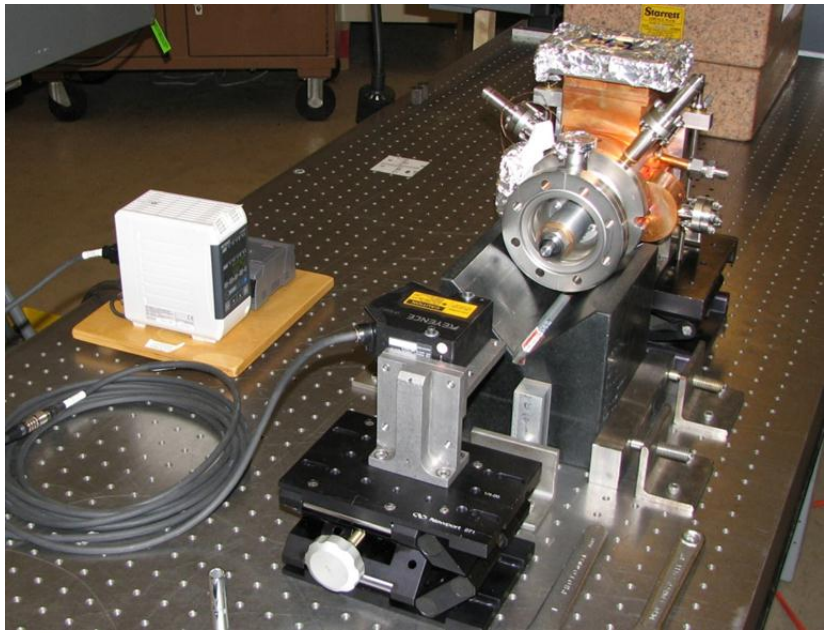
Argonne National Laboratory

2013 APS Accelerator Systems Division Seminar Series

WELCOME!



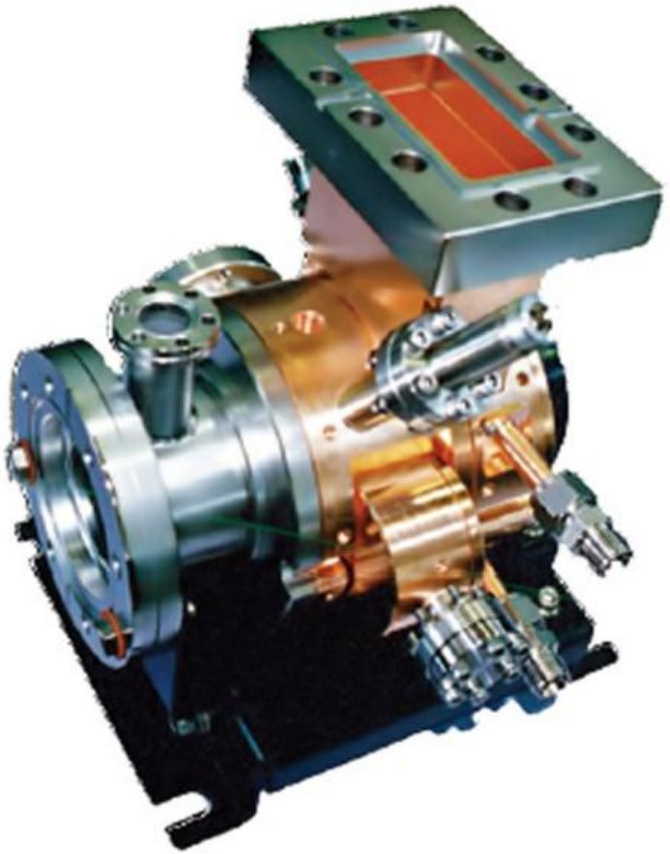


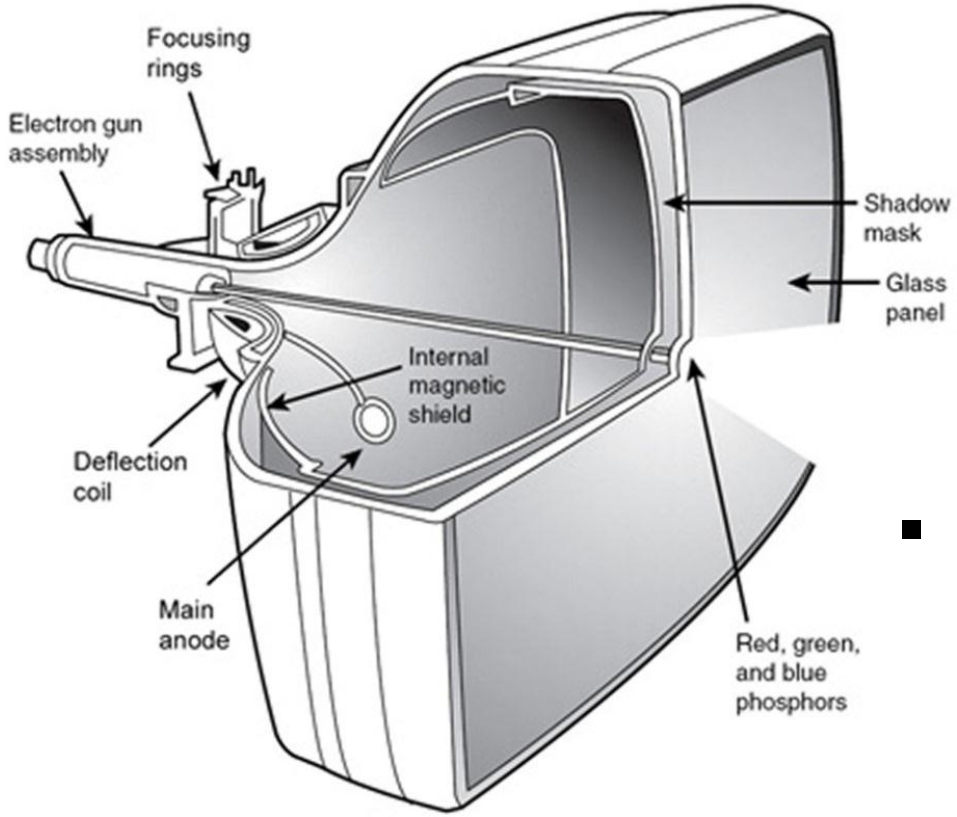


- BACKGROUND
- PROBLEMS ARISE
- IMPROVISED LASER SCANNER
- DISTORTION REVEALED
- REPAIR OF THE RF GUNS
- CATHODE CAPTURE
- SUMMARY
- CURRENT WORK

BACKGROUND

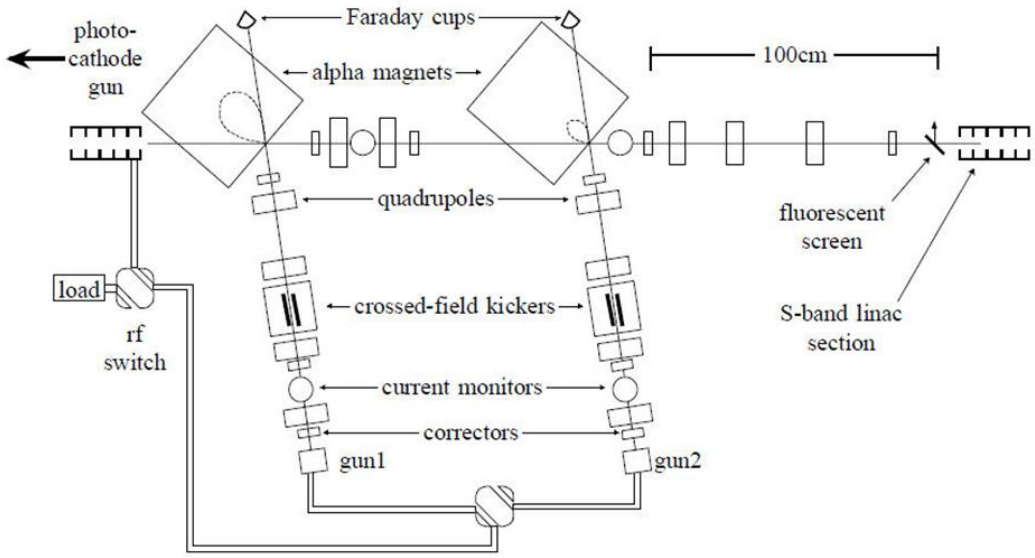
- Electron guns are used in electron microscopes, electron beam welders, old CRT monitors and televisions and as sources for particle accelerators



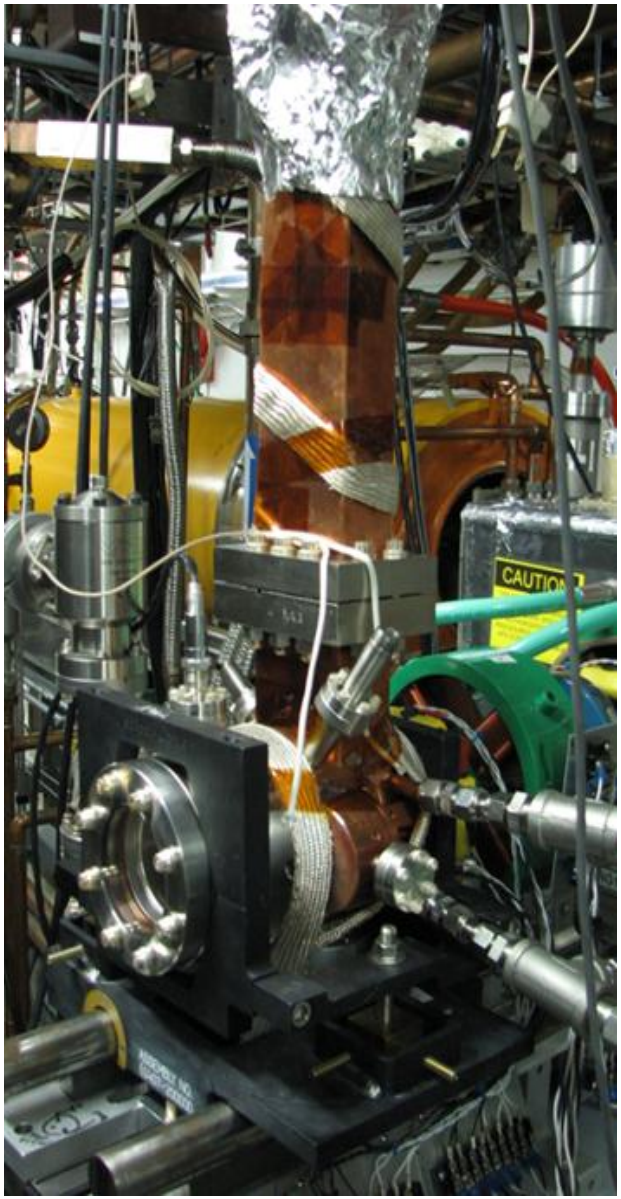


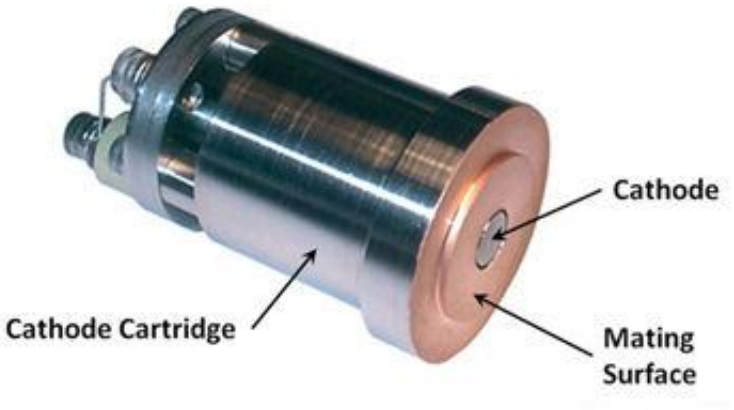
- Rf thermionic electron guns developed at SLAC / SSRL for the Stanford Positron Electron Accelerating Ring (SPEAR) project

- Rf thermionic electron gun / alpha magnet system subject of M. Borland's Ph.D. thesis
- System produces a bunched, high brightness electron beam
- Three generations of rf guns have been used as injectors at the APS since 1997
- APS procured three new rf guns in 2001

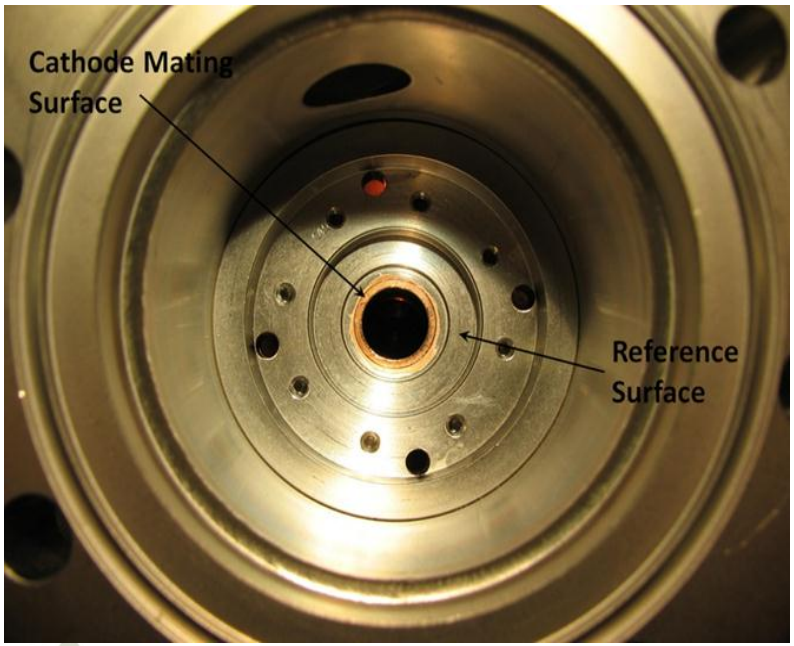


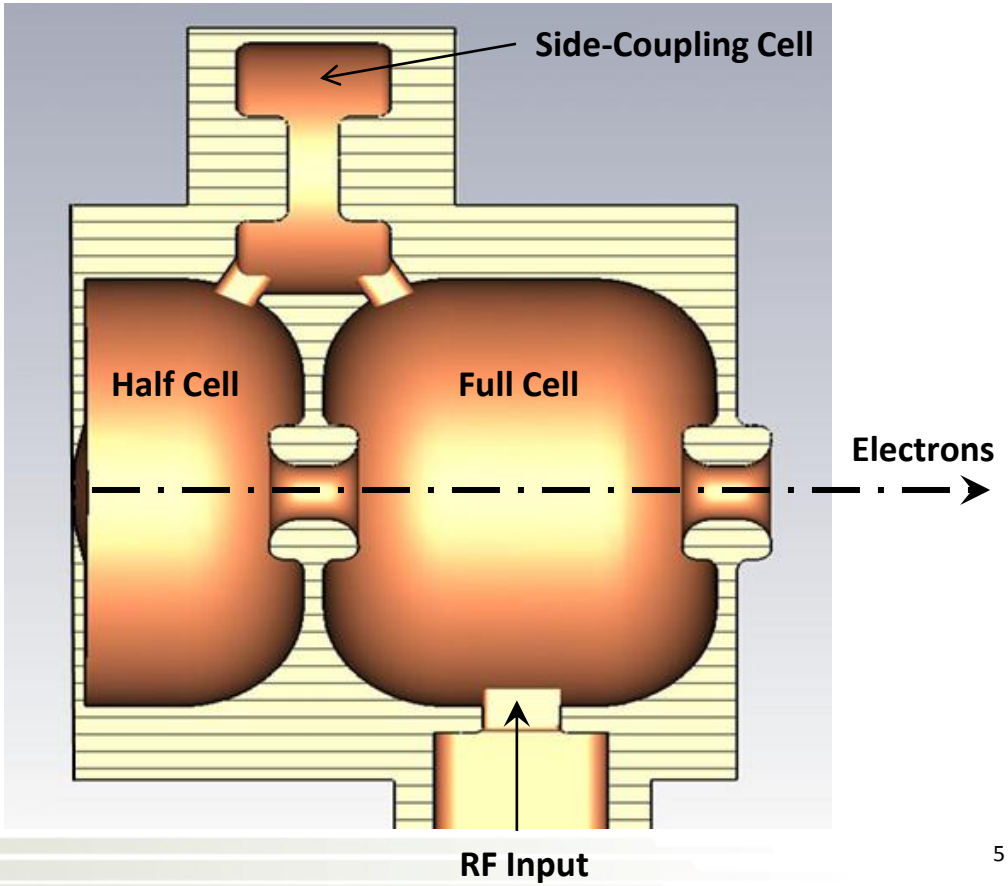
APS main injector layout. Trajectories in the alpha magnets are to scale.





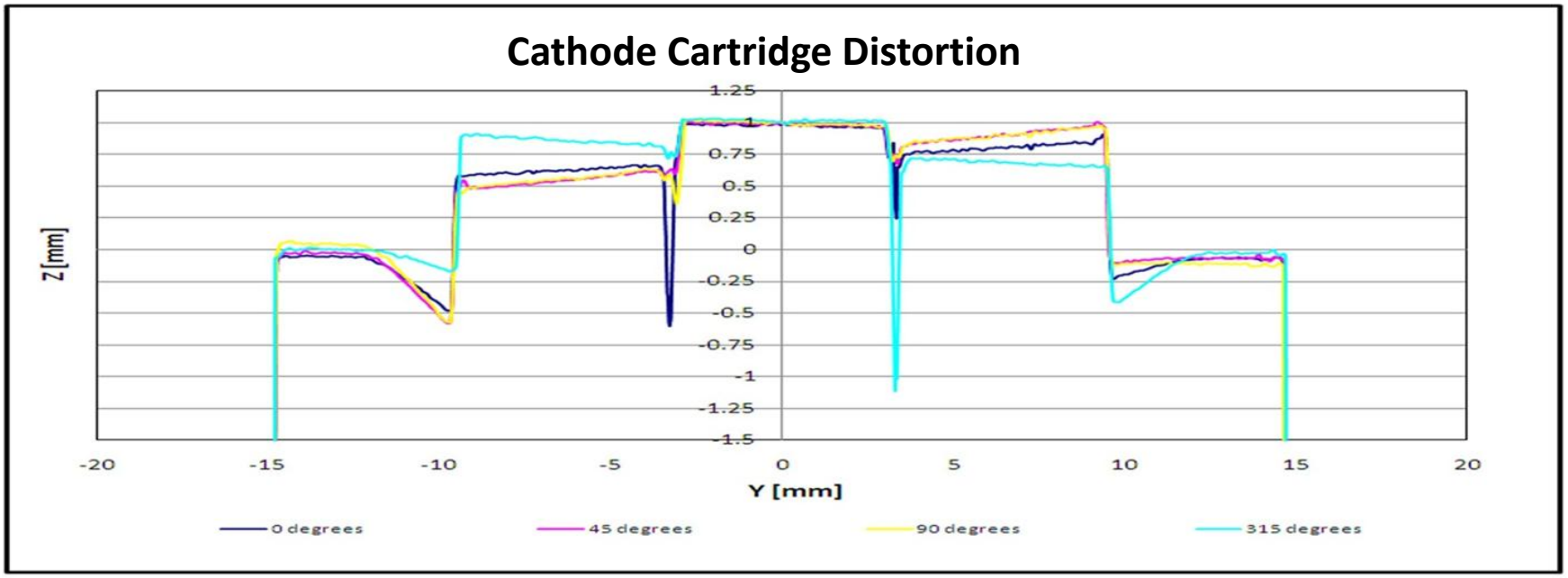
- Cathode heated 800^{o} C to 1,200^{o} C
- Electrons emitted off cathode into cavity energized by microwaves
- Electrons accelerated by microwaves and injected into the LINAC



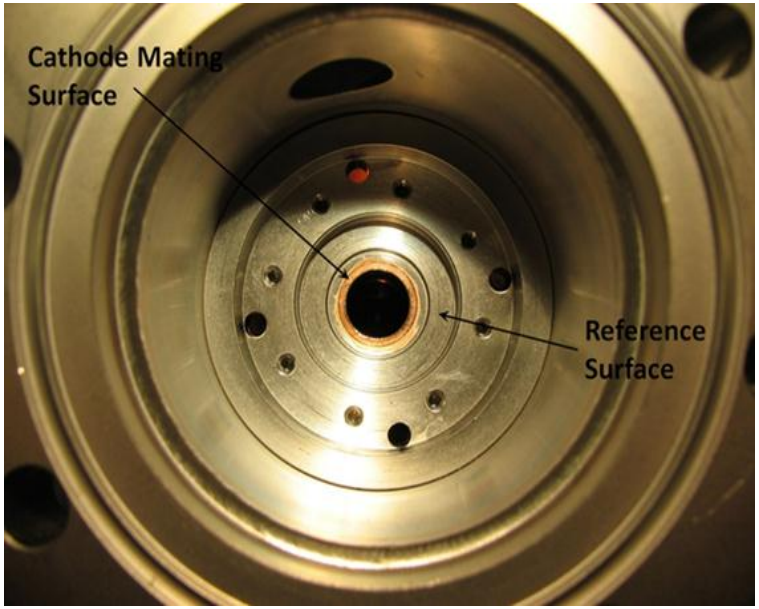


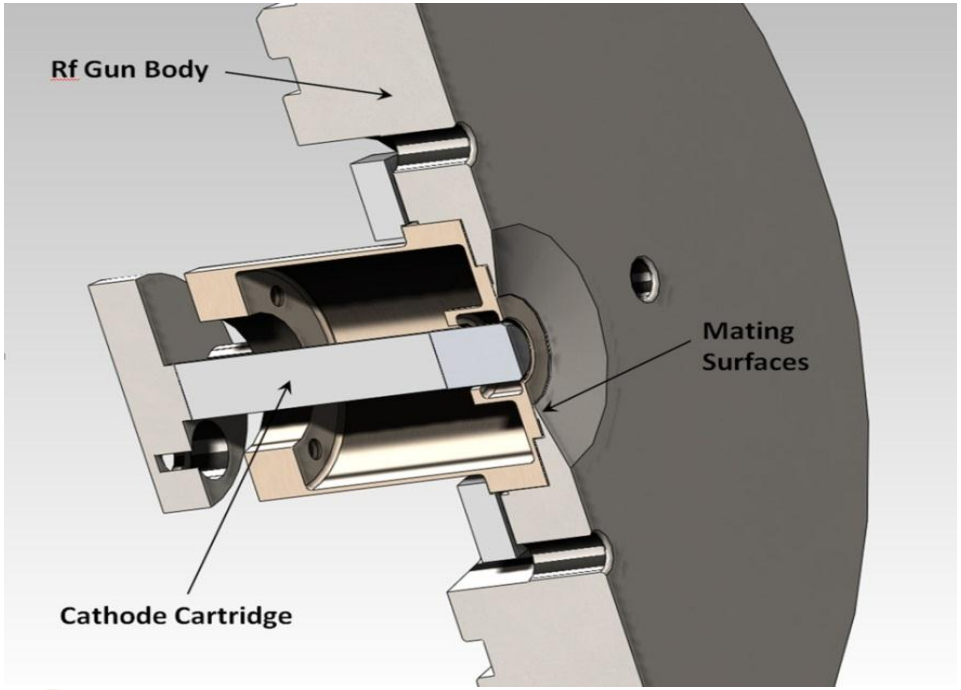
PROBLEMS ARISE

- Cathodes replaced in 2009; temperature and reflected power problems arose soon after
- Two rf guns failed in 2010 due to excess reflected power; spare rf guns were installed
- Further failures could limit capabilities; worst case temporarily suspend APS operations



- Inspection of cathode cartridges revealed distortion
- Rf gun mating surfaces suspected to be distorted as well
- Cathode mating surface difficult to reach, 75 mm in from flange opening

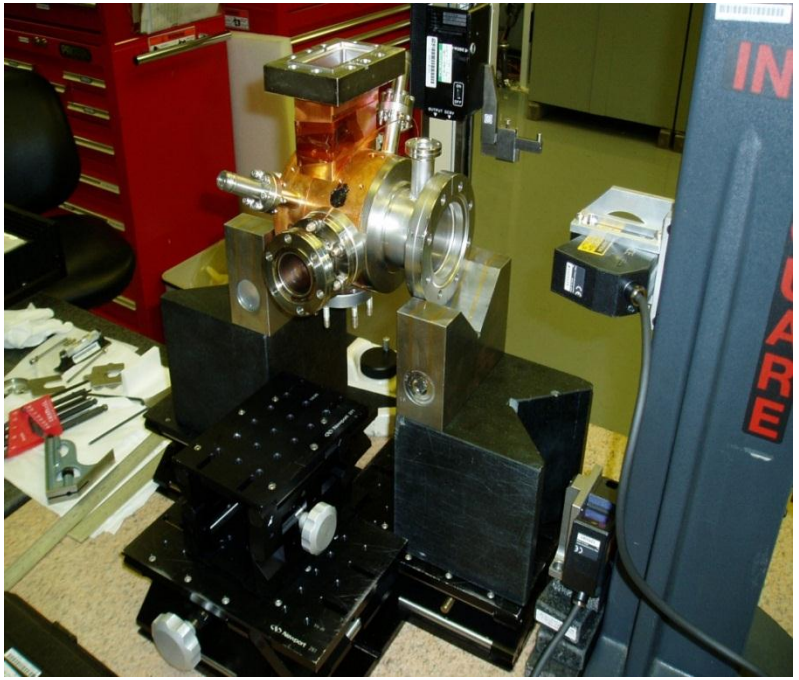




- No instrument available to profile the surface at the needed resolution
- Improvised measurement system developed to measure mating surface

IMPROVISED 2-D LASER SURFACE SCANNER

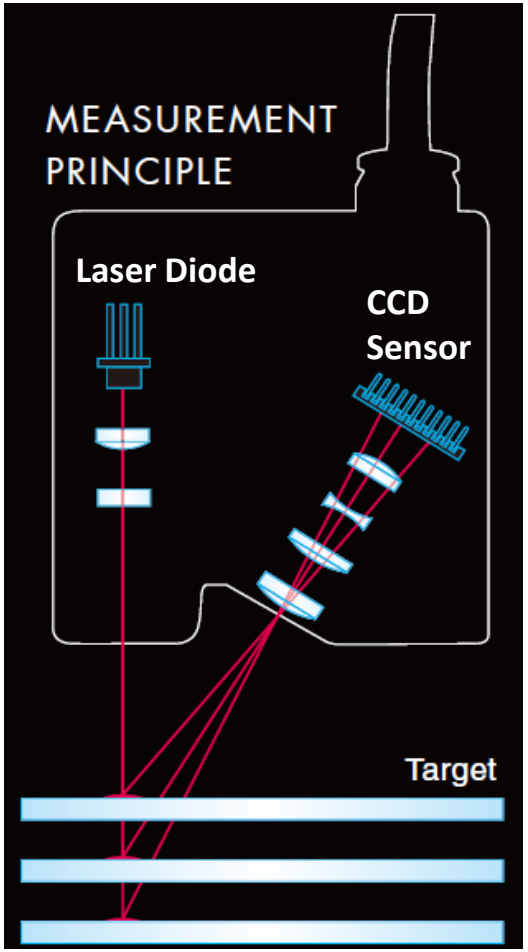
- Developed using equipment on-hand at APS
- Two Keyence laser sensors measure orthogonal axes
- Scanning sensor mounted to vertical translation
- Synchronous data output

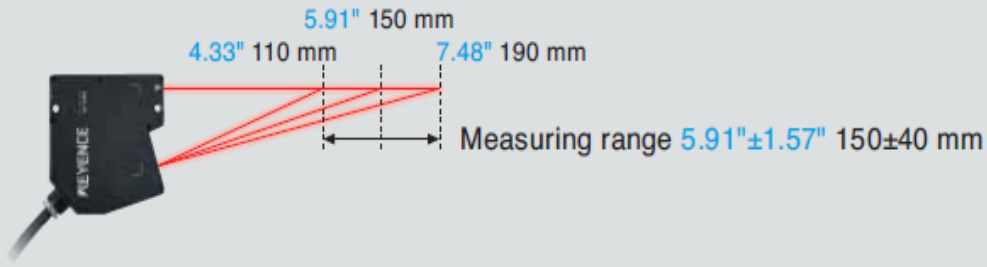


- Coordinates ascertained by combining the data in spreadsheet
- Laser signal reflected from any surface on to a CCD array

Laser Displacement Sensors

- LK-G 152 and LK-G 157 sensors
- Range of +/- 40 mm at 150 mm
- 0.5 μm resolution
- Data recorded using Keyence LK-Navigator freeware
- Diffuse or specular surface reflectivity
- Capable of measuring through a transparent medium such as glass



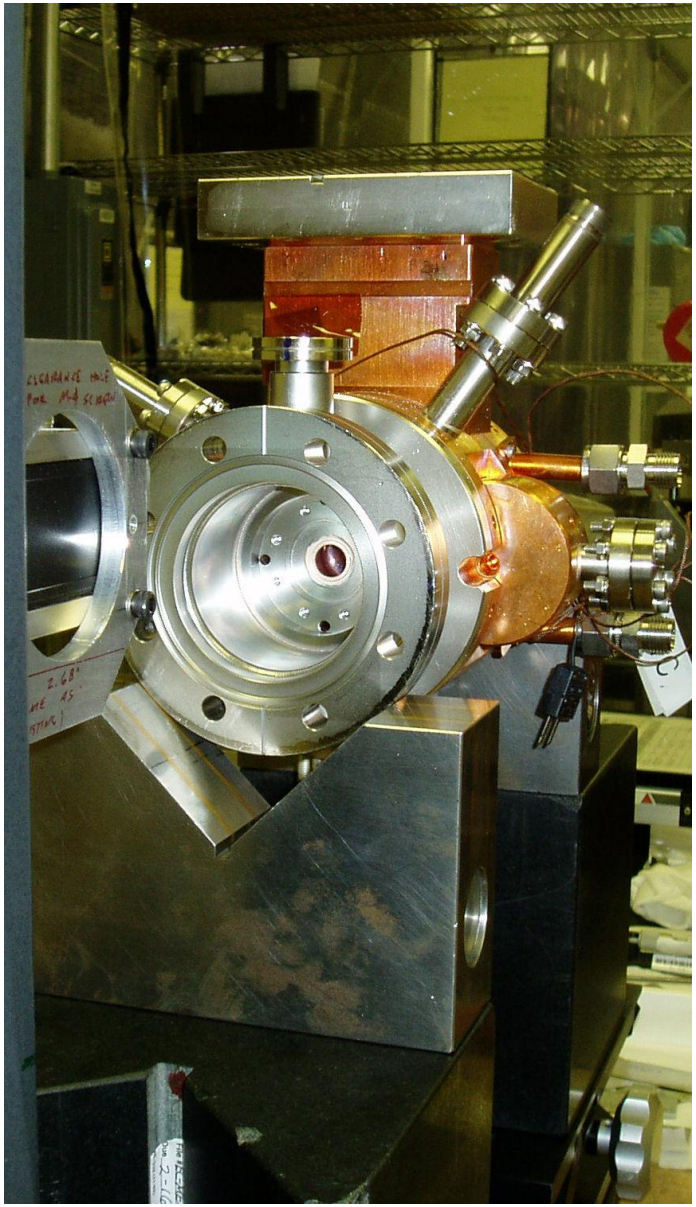
Small spot	LK-G152		0.02 Mil 0.5 μm	Ø4.72 Mil Ø120 μm
Wide beam	LK-G157			4.72x66.93 Mil 120x1700 μm

Vertical Translation

- Indi-Square model 18 used for vertical translation
- Translation accuracy is 2.5 μm over 500 mm of travel
- Designed to accept a typical dial indicator head
- Sensor head weighs 290 grams; Counterweight added for balance
- Despite added weight the translation was smooth and precise

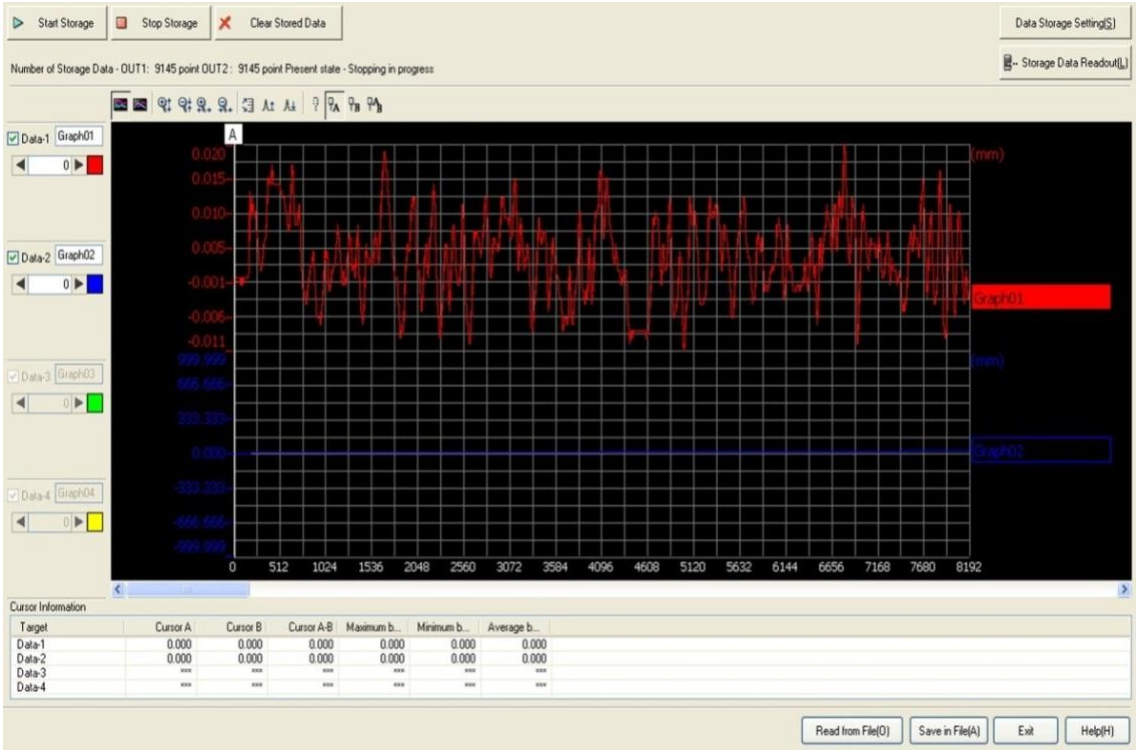
Orientation & Measurement

- Rf gun bodies rested in v-blocks
- Primary surface placed at optimum distance from sensor head
- Gun bodies set parallel to translation
- Scans across azimuth angles of 0, 45, 90 and 315 degrees
- Common reference plane allows overlay of scans across different angles



Data Collection and Processing

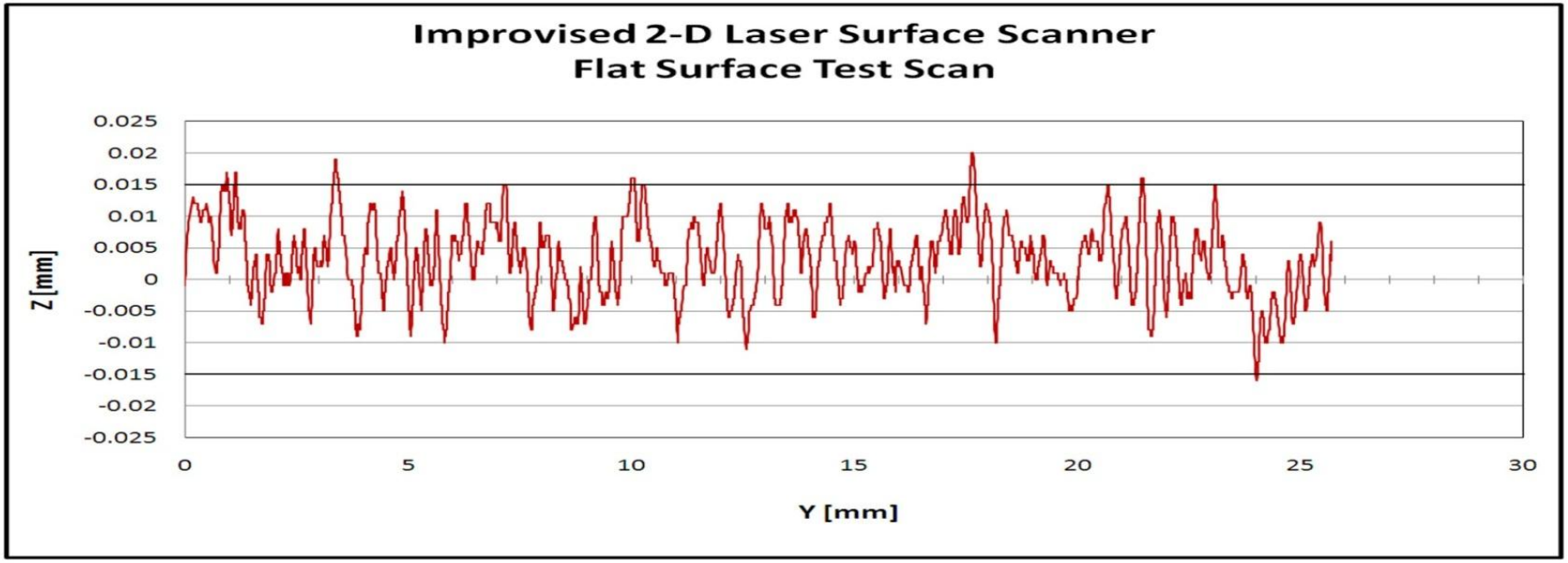
- Data collected using the LK-G3001 controller and laptop with LK-Navigator freeware
- Saved as a .csv file; opens as a single column; cut and pasted into a coordinate worksheet



- Synchronous measurement mode
- Coordinates adjusted to fit common centerline; Overlayed to produce an abstract 3-D view in a 2-D graph

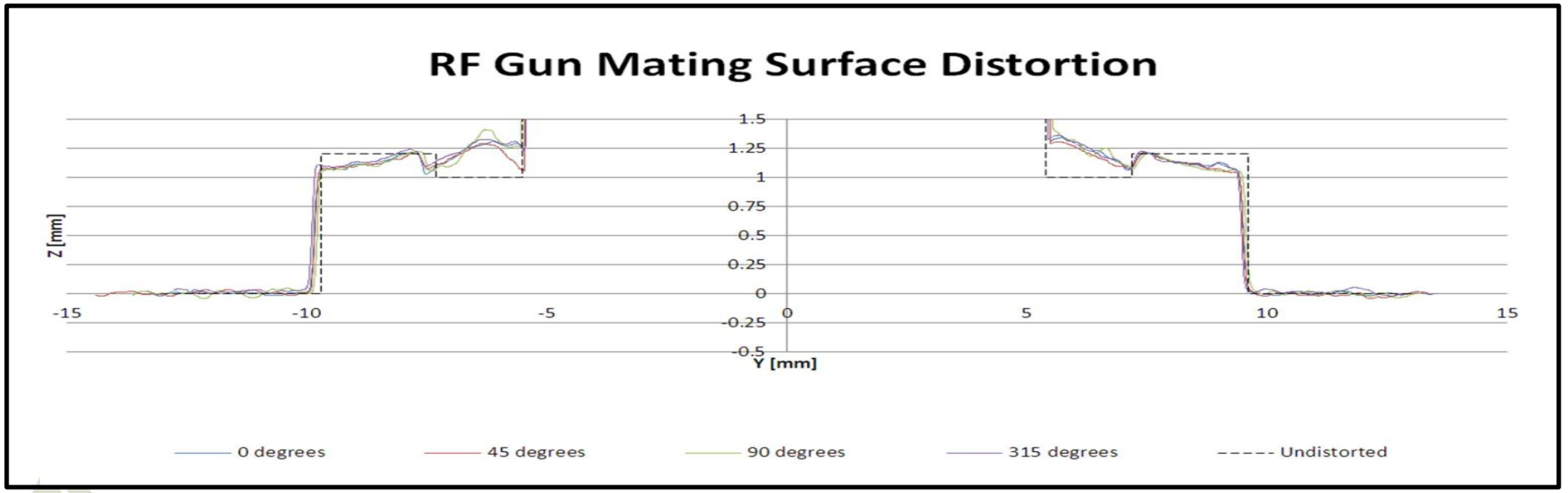
Error Analysis

- Accuracy initially estimated to be +/- 5 μm
- Further analysis indicates accuracy is closer to +/- 15 μm
- Decrease from initial estimate attributed to noise produced by the motion of the sensor head during translation
- Accuracy might be improved through refinements in motion control for the translation



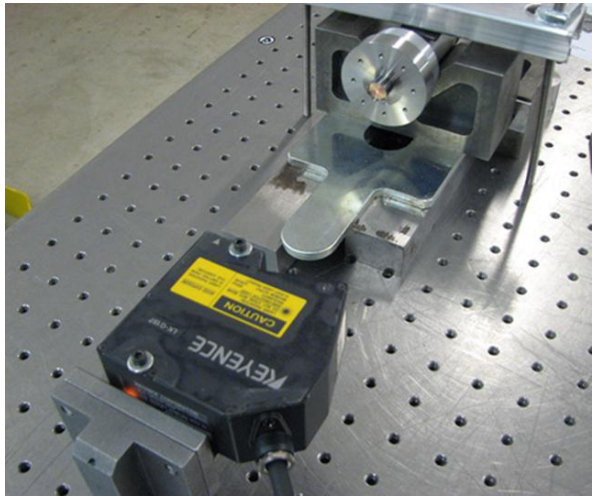
DISTORTION REVEALED

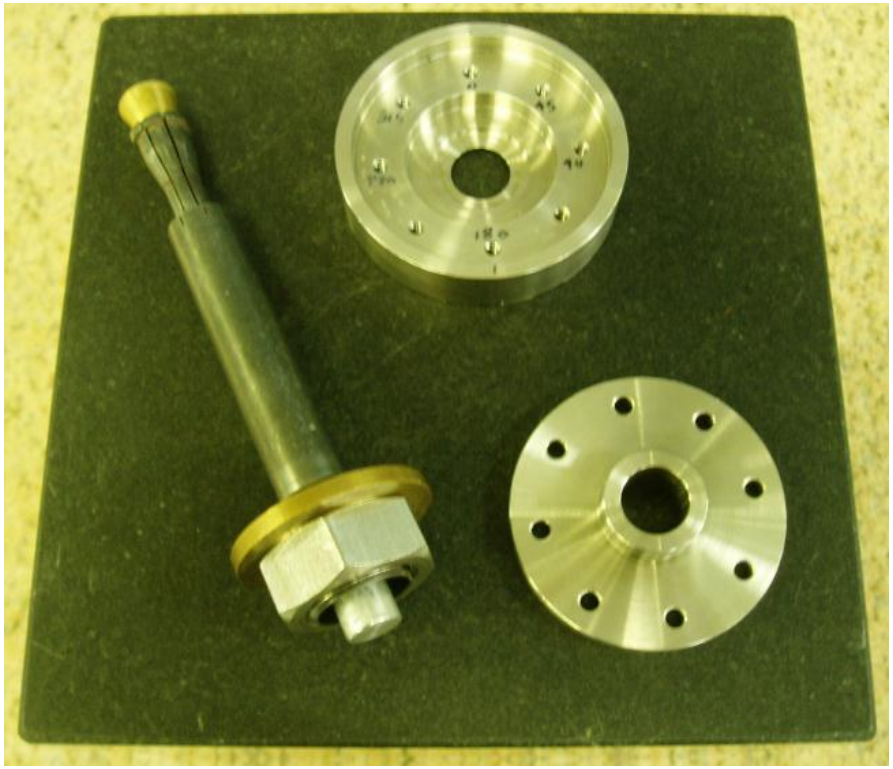
- Coordinate plots revealed distortion.
- Flat mating surface seals rf cavity from leakage and acts as a thermal and electrical conductor.
- Distortion caused by over-tightening of eight #4-40 screws that secure the cartridge within the gun body; now thought to have originated with the vendor.
- Source of problems discovered, but what now?



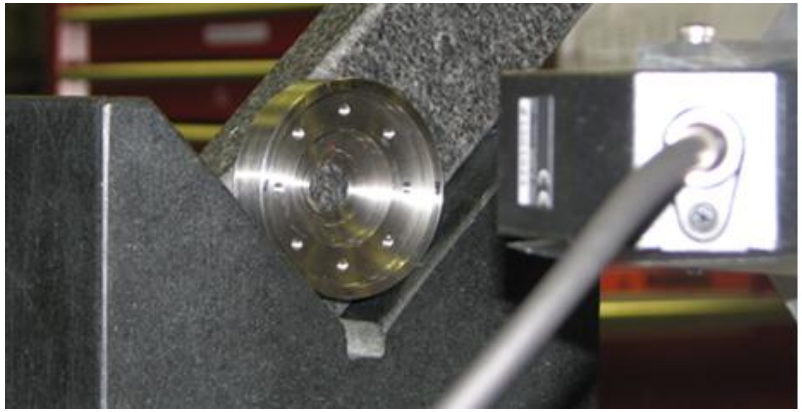
REPAIR OF THE RF GUNS

- Alternatives were explored including replacement, modification, and repair.
- Replacement and/or modification would be costly

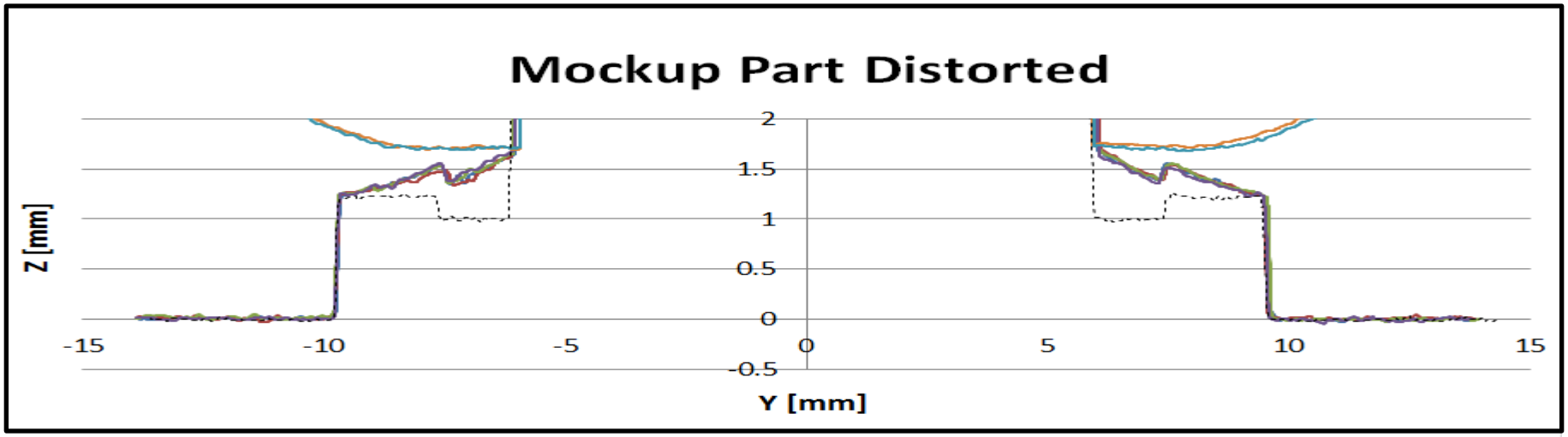


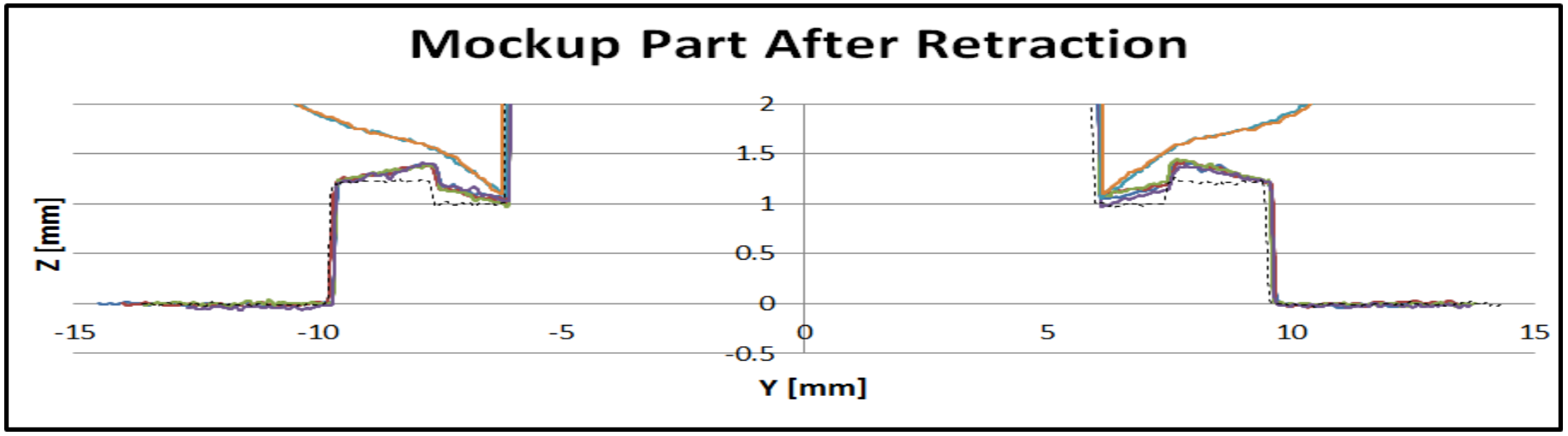


- Decision made to repair the damaged guns
- Special retraction tool designed by E. Traktenberg was tested successfully on a mockup

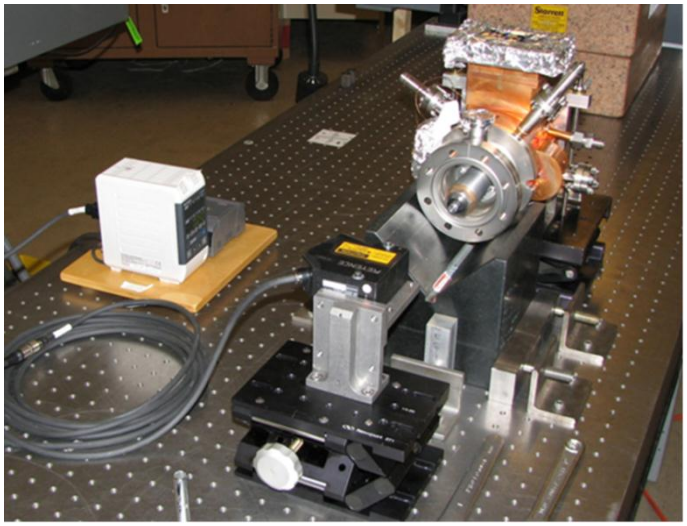


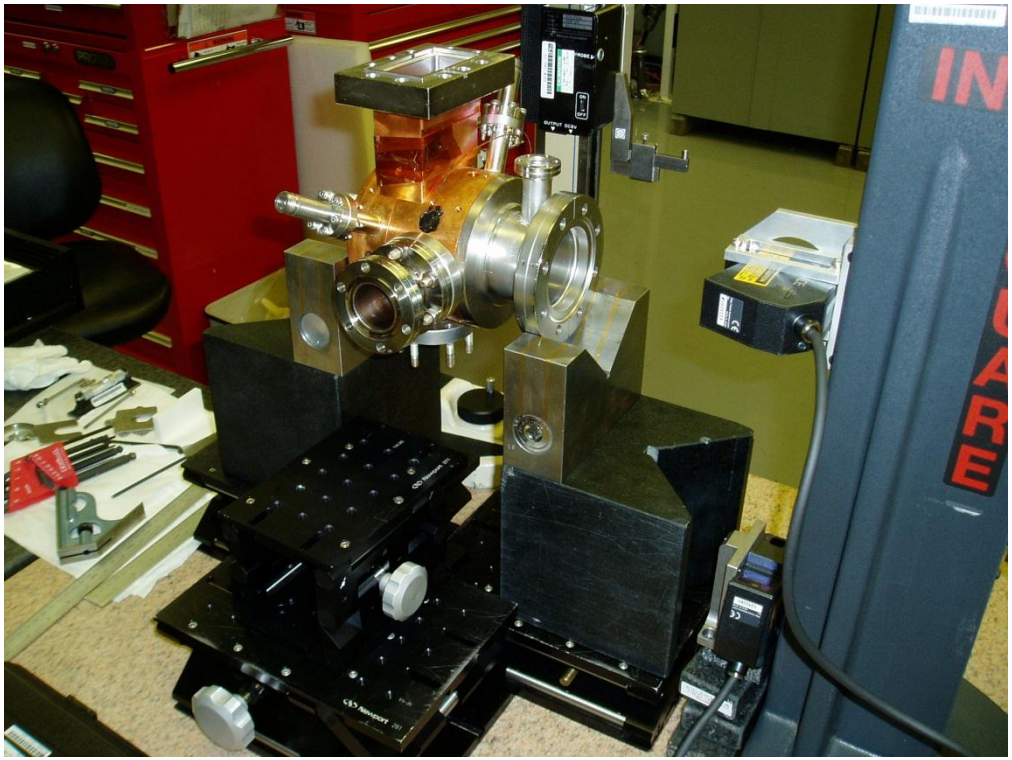
MOCKUP TEST RESULTS

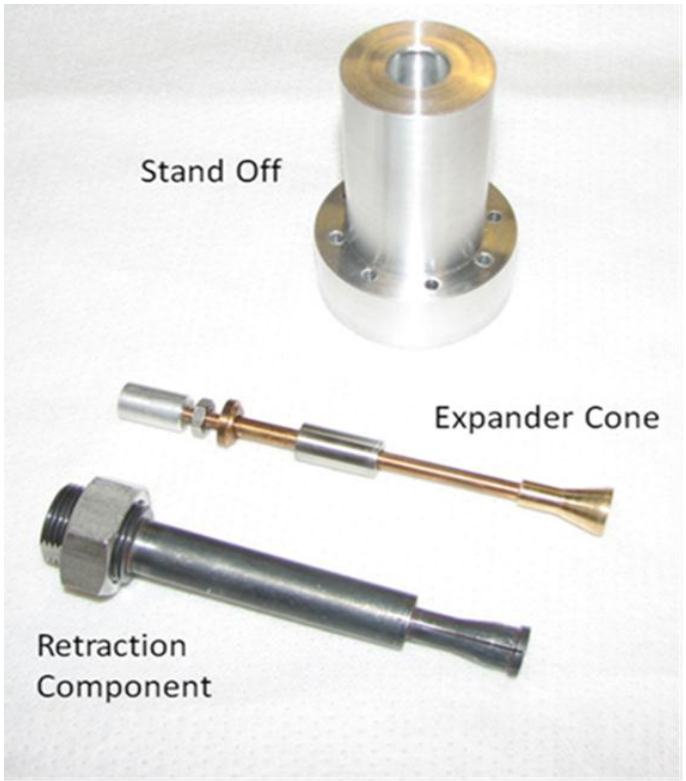




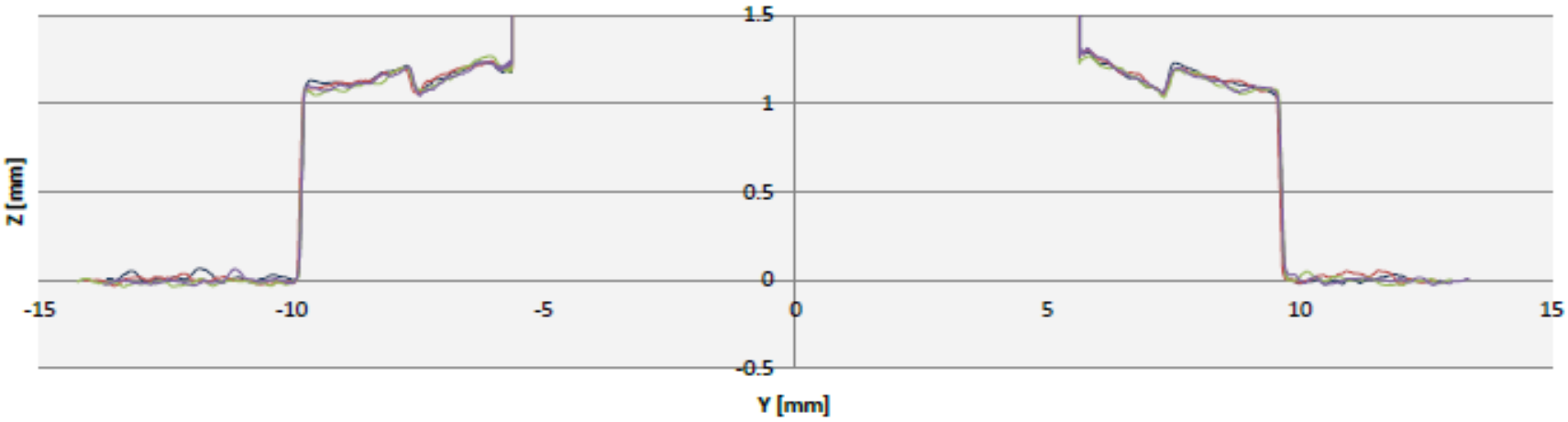
- Efficacy of the tool proven in the mockup test
- Successful repair was performed on two rf guns in March / April 2011



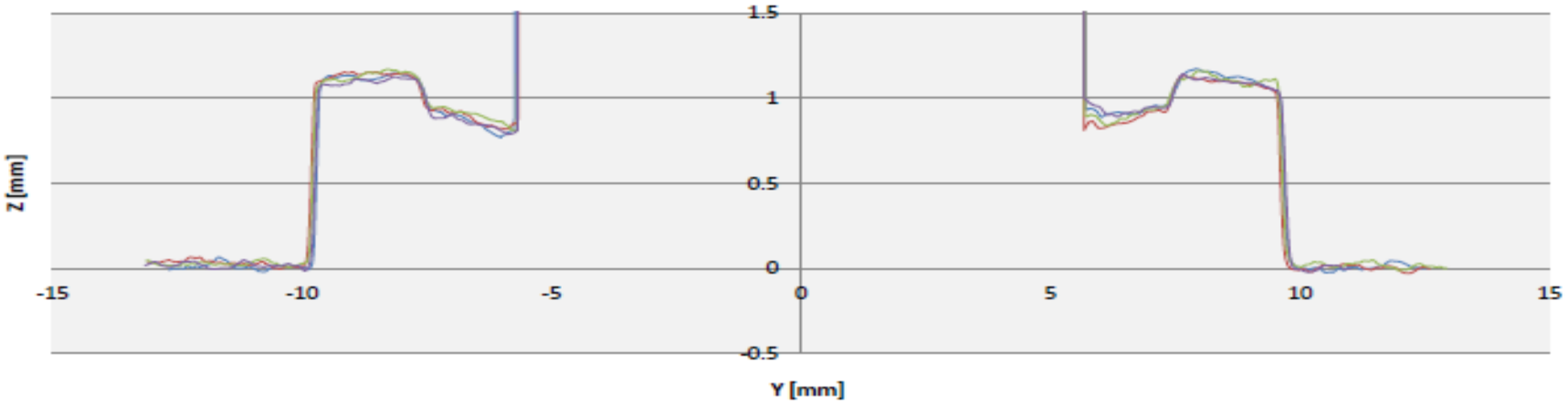




Mating Surface Prior To Repair

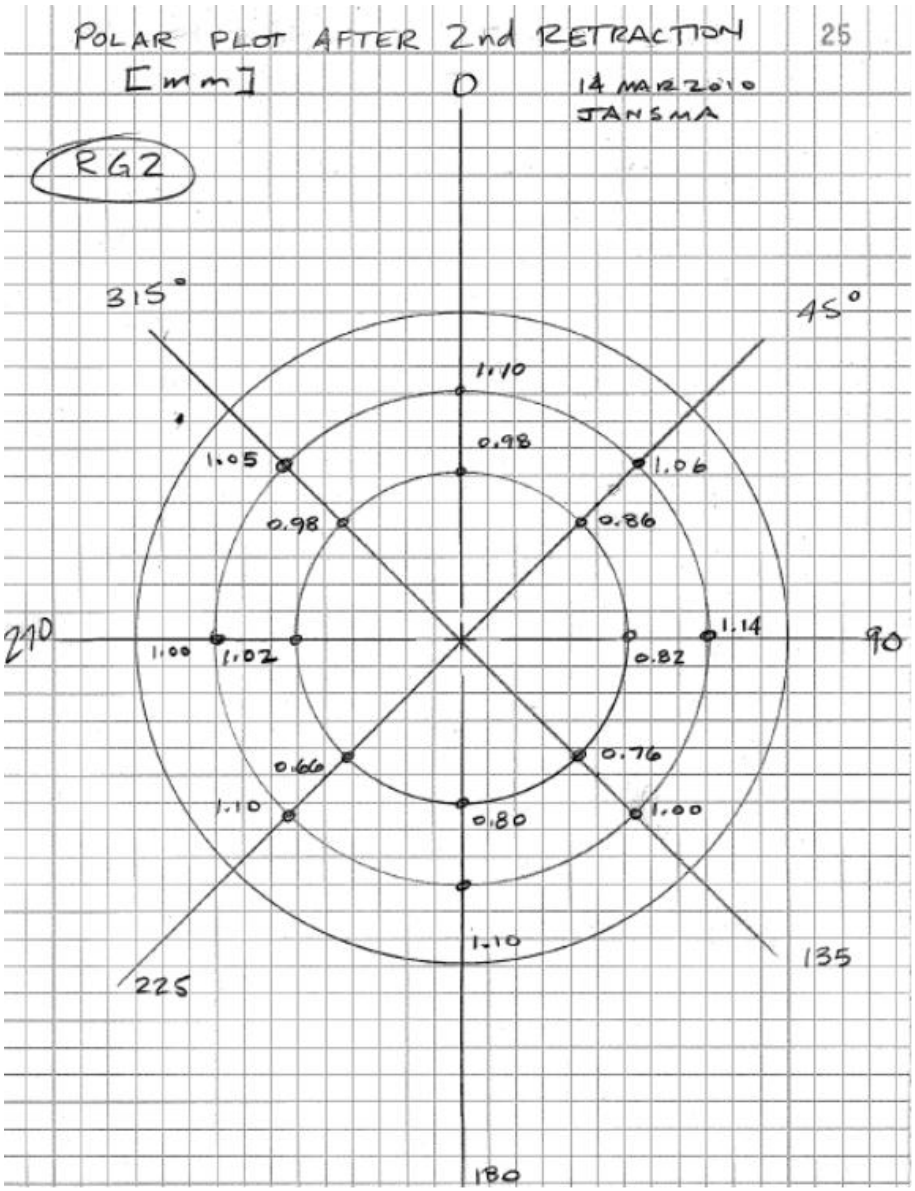


Mating Surface After 500 µm Retraction

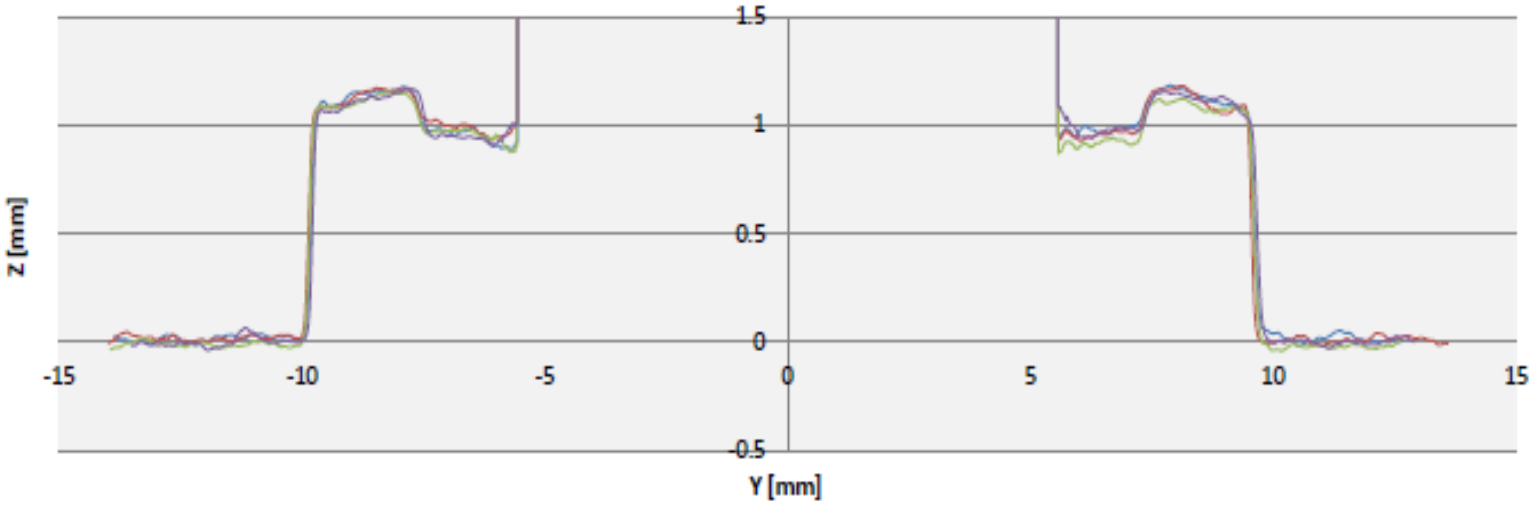


- Polar plot used to identify locations for push back

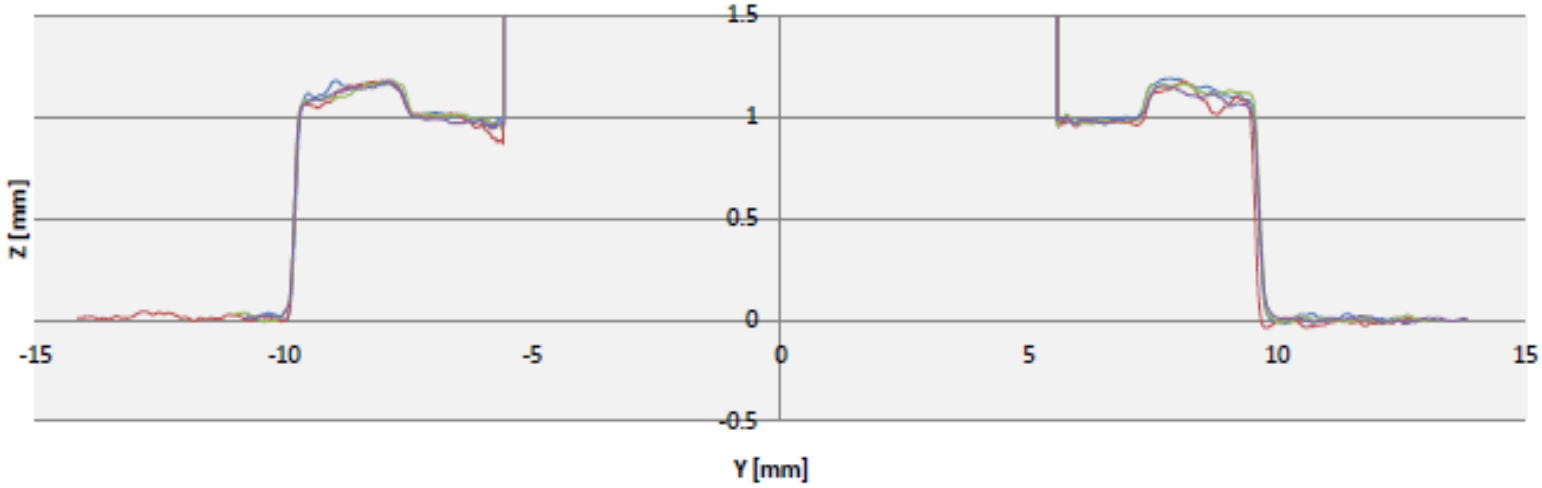
- Tools for retraction and push back



Mating Surface After Push Back

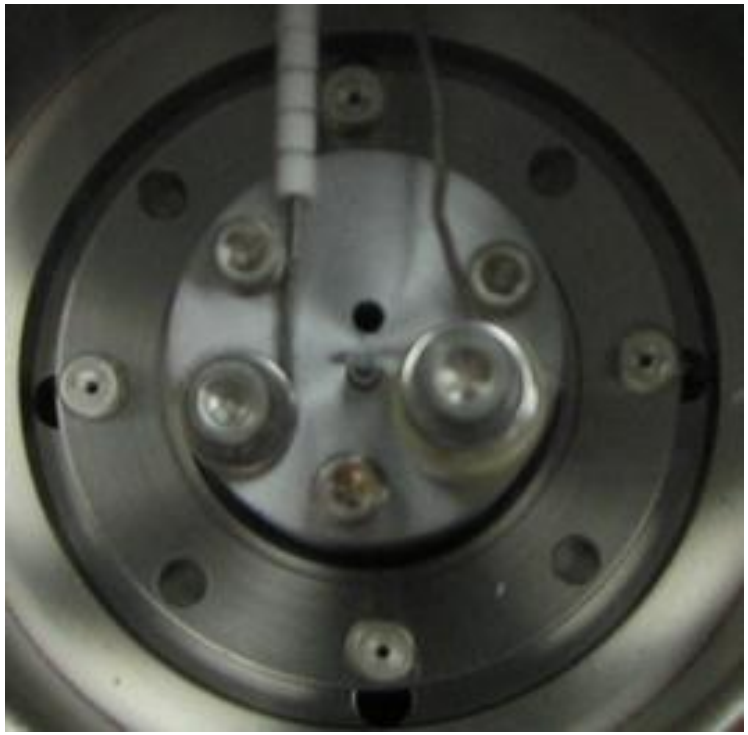


Final Profile of Mating Surface After Polishing



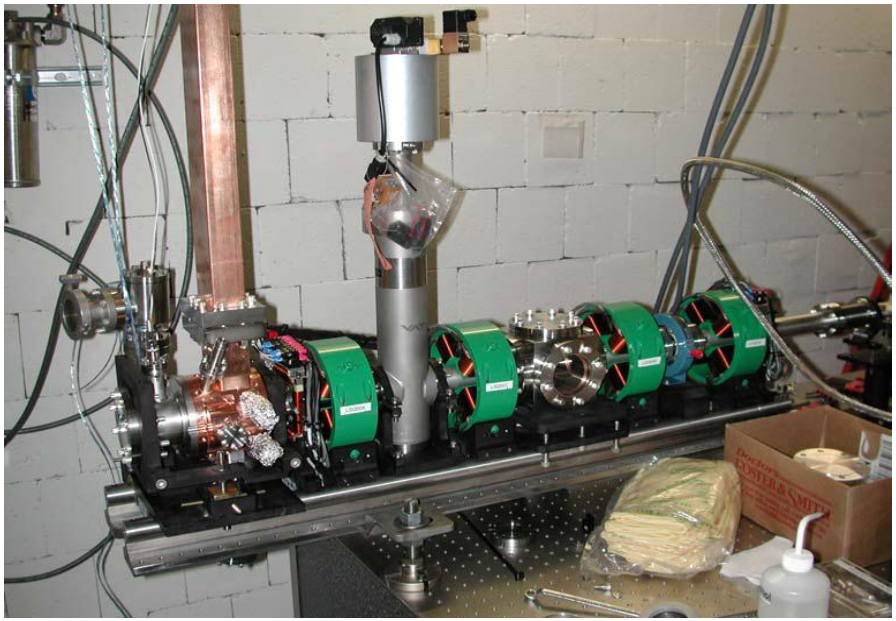
MODIFIED CATHODE CAPTURE

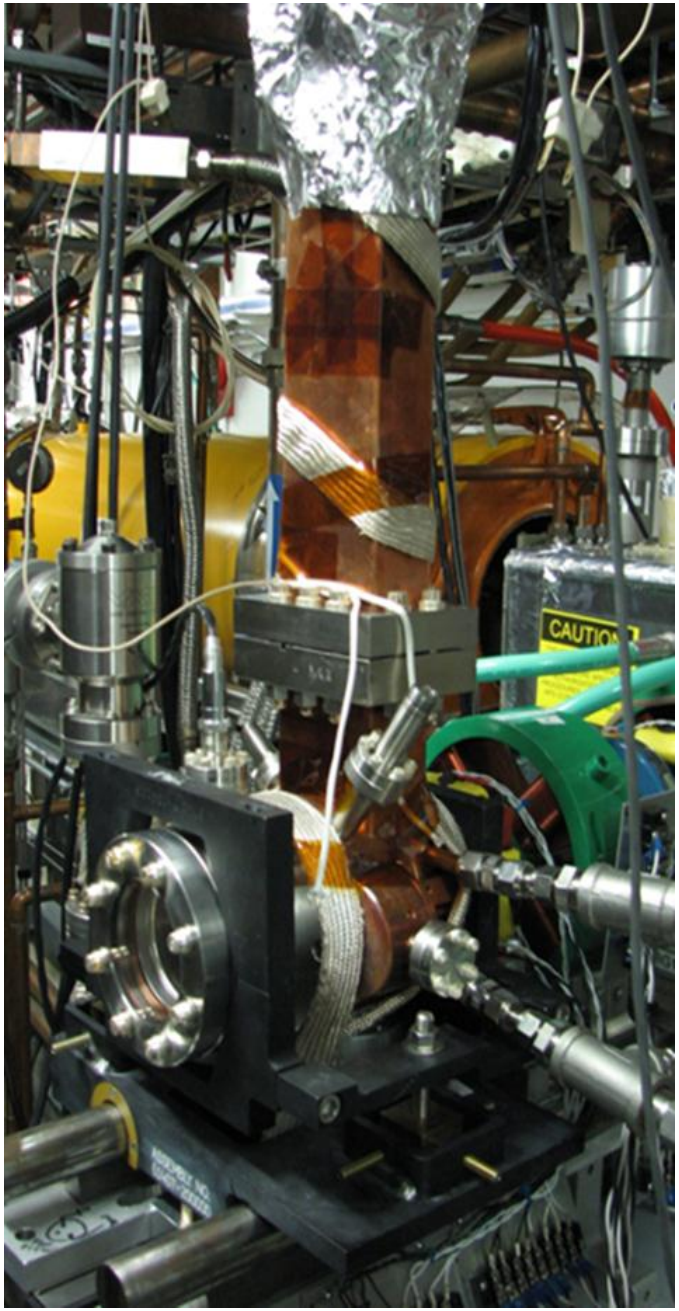
- Damage caused by over-tightening the cathode cartridge
- Torque of 0.2 inch pounds will deflect surface by 25 μm



- Screws seated against primary retaining ring with little / no torque applied
- Second retaining ring screwed to primary ring, clamping the eight primary screw heads between the two rings

SUCCESS!





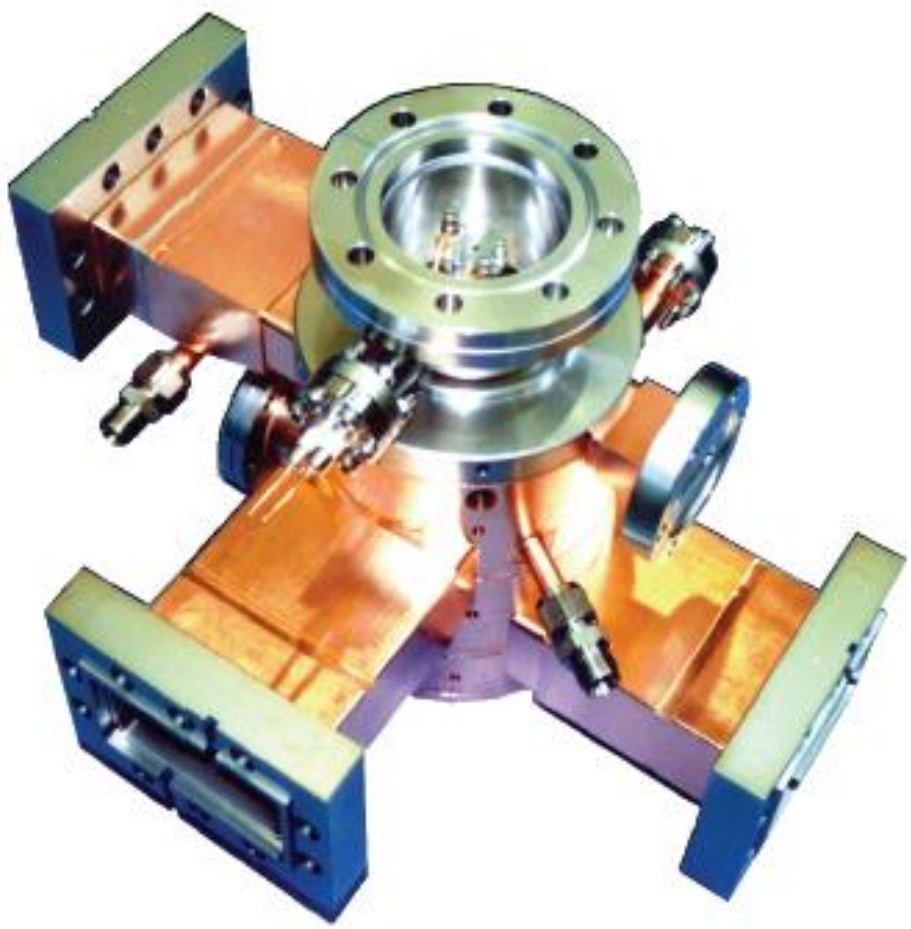
- After repair the rf guns were rigorously tested in the APS Injector Test Stand
- The 3G1 and 3G3 guns are currently being operated in the APS Main Injector

SUMMARY

- In 2009 problems arose in the APS rf thermionic electron guns after replacement of ageing cathodes
- To identify and characterize the problems a laser surface scanner was improvised at the APS using equipment on-hand
- A special tool was designed to retract the damage discovered in the rf guns
- New cathode cartridge capture system prevents further damage
- Repairs not perfect; goal to restore functionality; successful in this regard
- Both guns still operational after almost 2 years
- Substantial savings; rf thermionic electron guns cost about $70,000 each

CURRENT WORK

- Two more rf guns underwent the repair process in 2012
- 3G2 and BBC guns had same damage to cathode mating surface
- Damage found in the 3G2 gun indicates problem originated at vendor; gun had never been opened by APS personnel
- BBC gun repair supports graphene window test



Ballistic Bunch Compression Rf Gun

THANK YOU FOR ATTENDING!

Acknowledgements:

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