SAND2007-1237C

# Low Voltage E-Beam Diagnostics

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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company,
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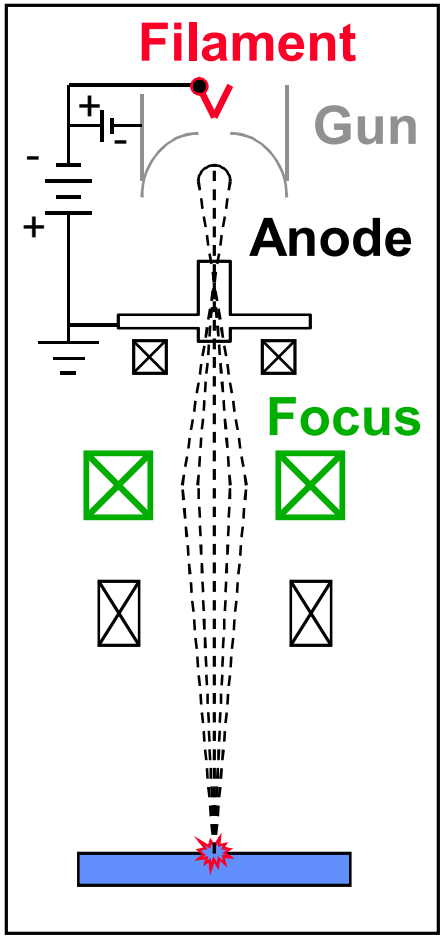
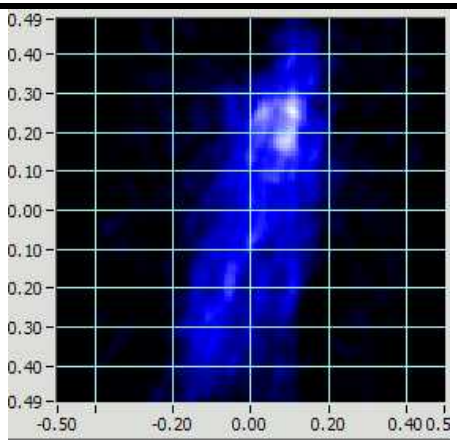
# Background

- Upgrade existing HV (120kV) machine
  - KCP procuring several LV (60kV) machines
- Ordered ~ 2004
- Received ~ early 2006
- Labview based system
- Typical new installation issues
  - Door frame, alignment coil, drift tube, etc
- Beam quality issues
- Limited experience with low voltage
- Rely on HV comparisons, faraday cup profiles, LLNL and R.F. experience
- Trade secrets, black magic and science?

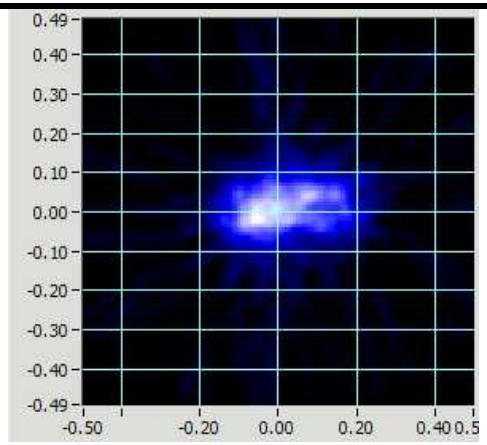


# Faraday Cup Profiles Low and High Voltage

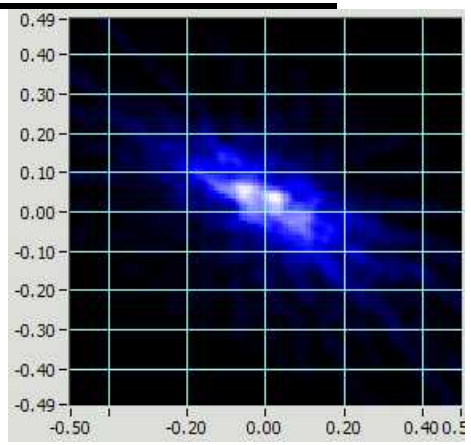
**Low Voltage**
**Ribbon Gun**
**Ribbon Fil.**
**60kV, 5mA?**
*"Old Coil" CR*




Focus -10 mA

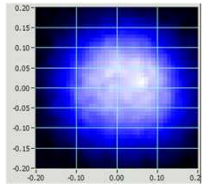



Focus 563 mA

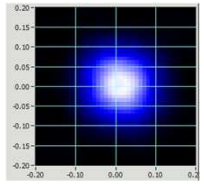



Focus +10 mA

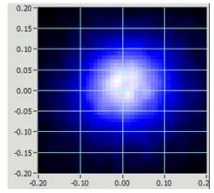
**High Voltage**
**Ribbon Gun**
**120kV, 5mA?**



Focus -10 mA



Focus 710 mA



Focus +10 mA

- **Image scales are consistent**
- **Faraday cup profiles using LLNL MFC**
- **Initial concern for LV was 90° rotation**



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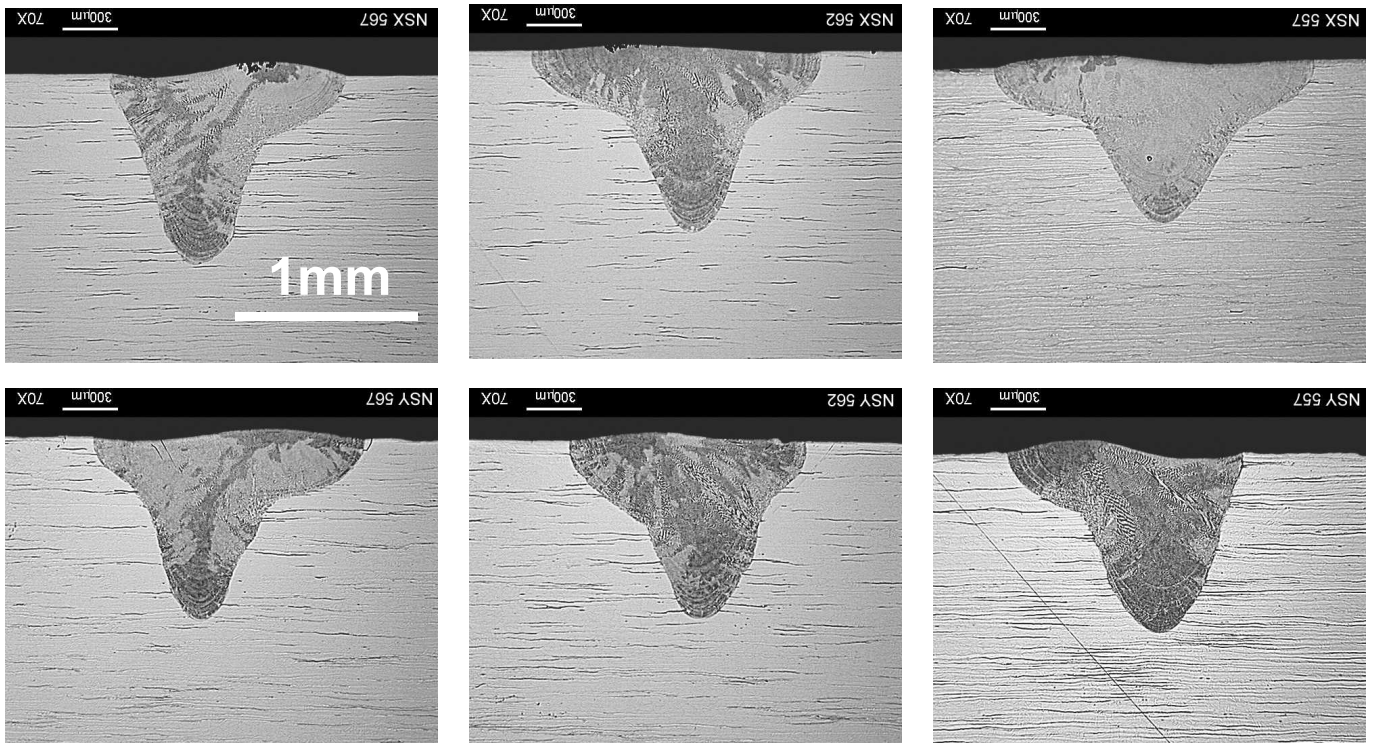
# Focus Current Effects

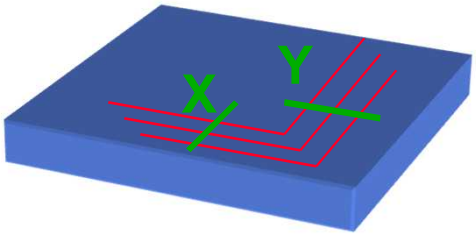
**X**

**Low Voltage**
**Ribbon Gun**
**Ribbon Fil.**
**60kV, 5mA?**
**30 ipm**
*"Old Coil" CR*

**Y**




**Focus +5mA** **Focus 562 mA** **Focus -5mA**




- **Small changes in focus current, but big changes in beam power distribution**
  - **Deep penetration shift**
  - **Width of weld pool different in x and y**

**This is a real issue!**



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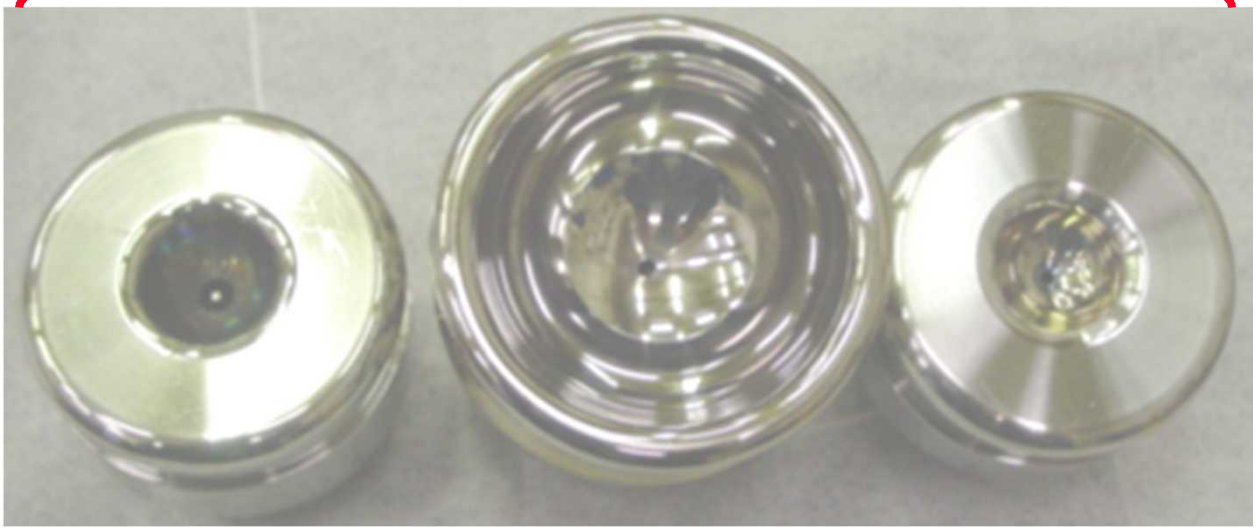
# E-beam Guns

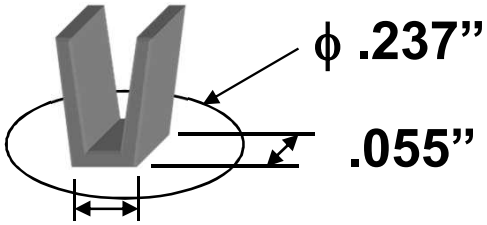
## Standard Configurations



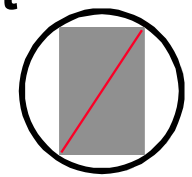
**Ribbon – LV**
**Up to 150mA**

**Ribbon – HV**
**Up to 60 mA**

**Hairpin - LV**
**Hole ϕ .100”**




**Low Voltage**
**Hairpin Gun w/**
**Ribbon Filament**
**Hole ϕ .100”**
**Diagonal 0.093”**





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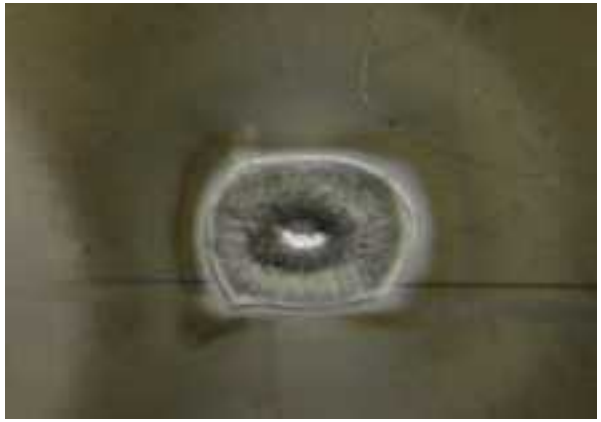
# Diagnosing the Problem

- Rotated the gun in the LV machine – no effect
- Turned off coil currents
- Melted with 0 mA focus current
  - Found peaking problems
- Compared our HV to our LV

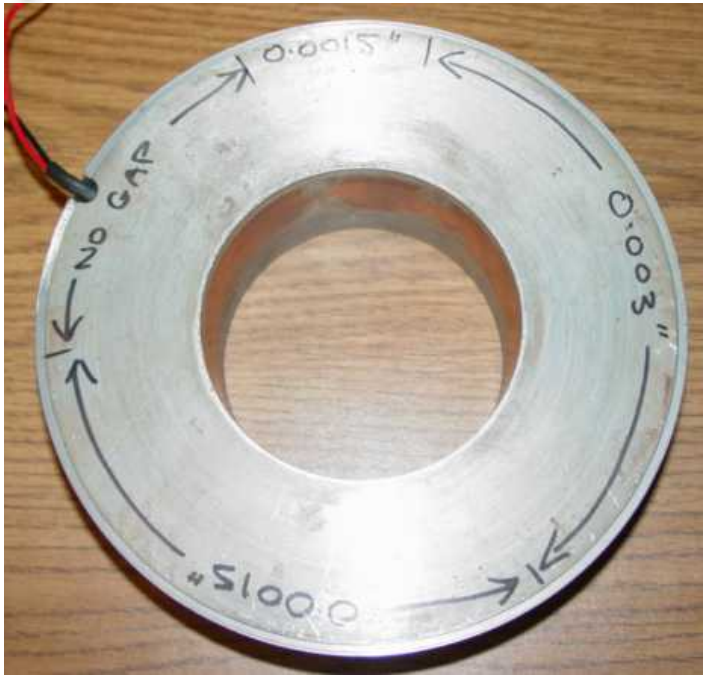
LV Machine
Ribbon filament
"Ribbon gun"
60kV, 10's mA

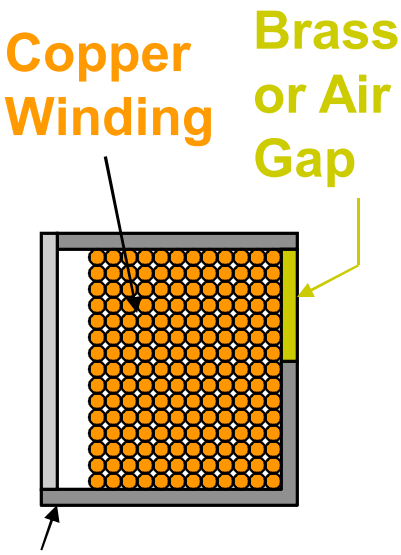


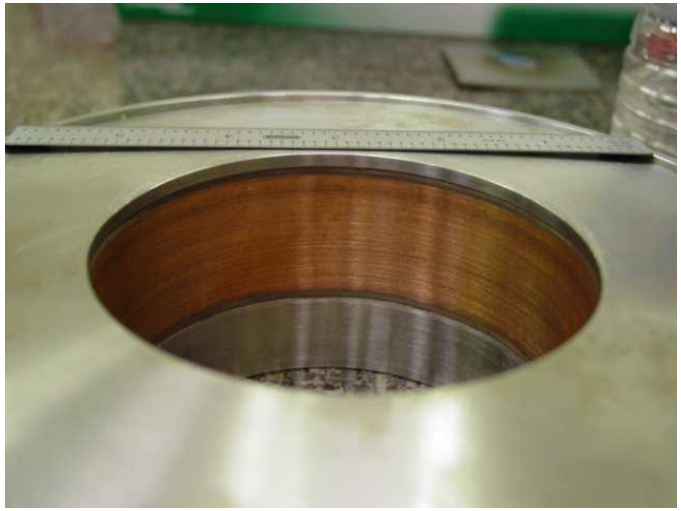
HV Machine
Ribbon filament
120kV, 30 mA

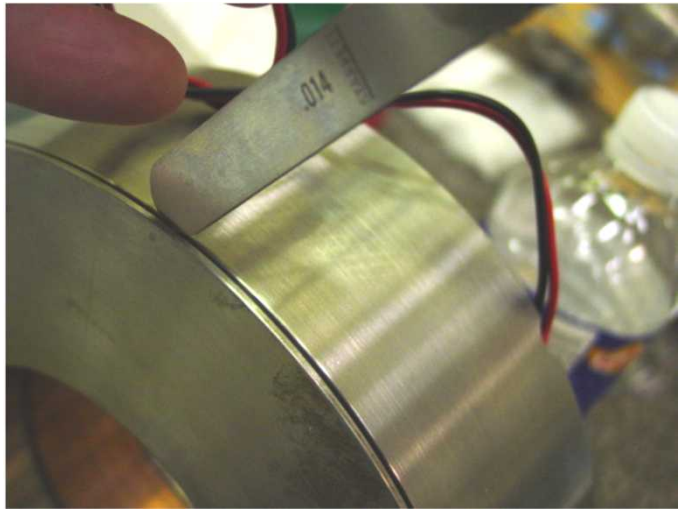
**Concluded that any issues that may exist with our LV guns were not root cause issues**

# Focus Coils



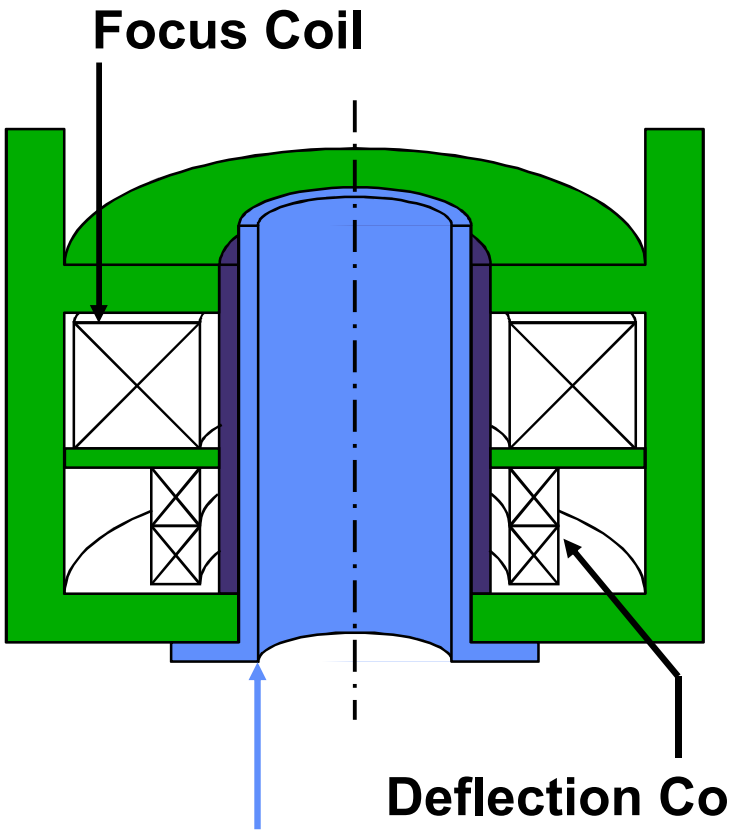






- Initial thought was focus coil issue
- Original coil may have hysteresis
- Received second coil with “improved” ferromagnetic alloy – but had sizeable gaps
- Coil fabrication not trivial
- Top and bottom

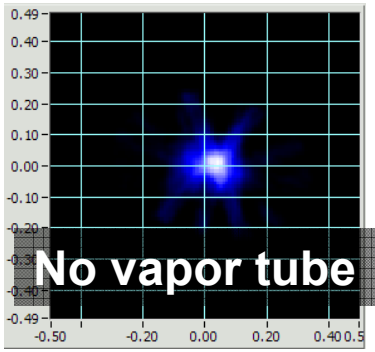
Original Coil (Left)  Replacement (Right)

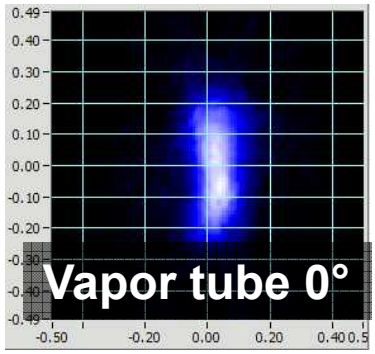
# Vapor Tube

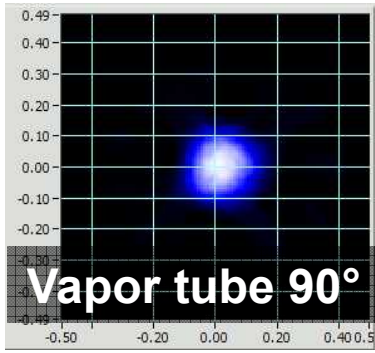



Lower Column Details

- Tube is nominally an austenitic stainless
- Around circumference slight Magne-gage readings 0 to 0.5 FN
- Tube position had significant beam quality implications
  - Removing, Rotating & Shimming
- 2nd tube was different and nonmagnetic, but base wasn't – FN 3




Low Voltage
Hairpin Gun
Ribbon Fil.
60kV, 5mA?
New Coil
553 mA focus



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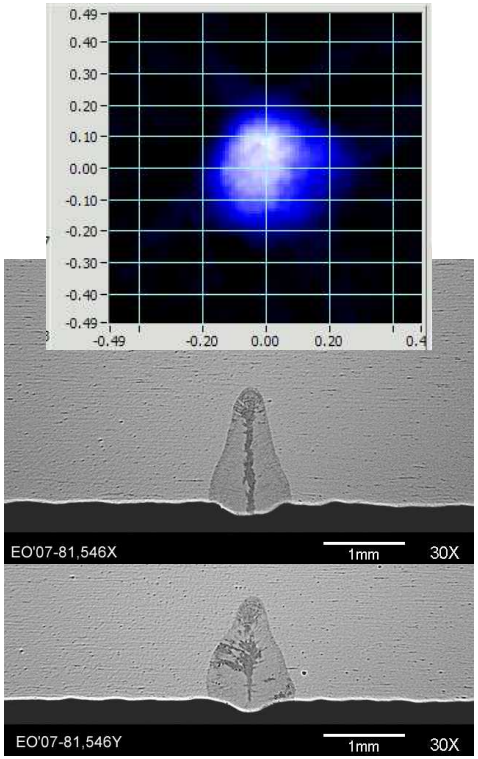
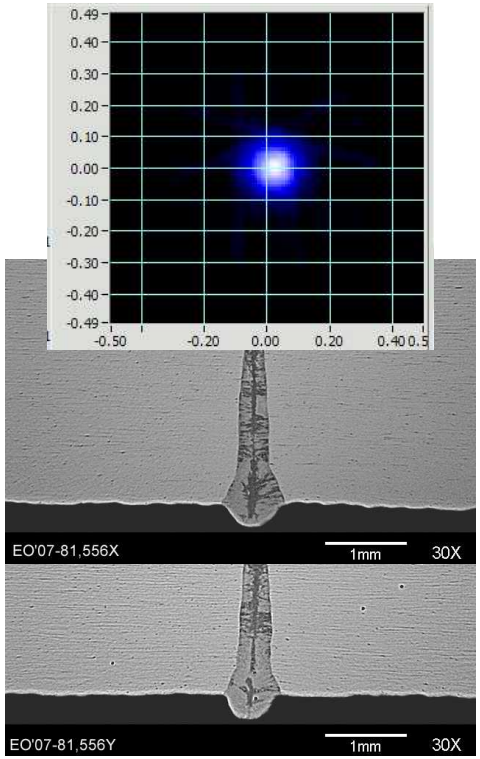
# “Optimized” Configuration

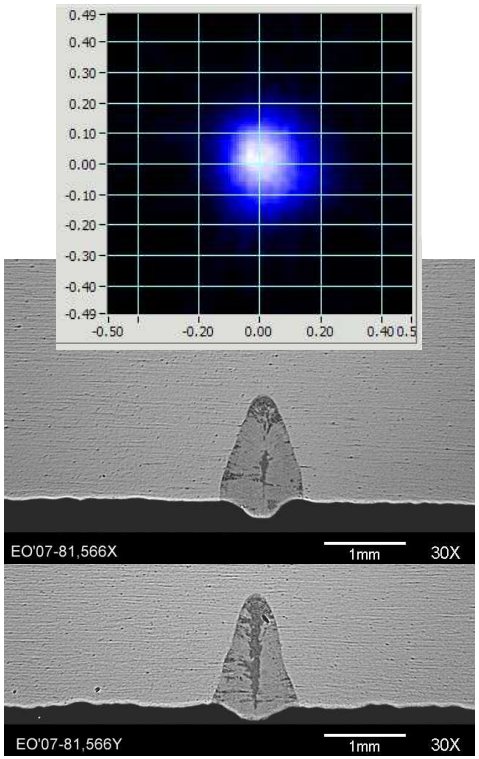
- Low Voltage
- Hairpin Gun
- Ribbon Fil.
- 60kV, 10mA, 60ipm
- Tube Optimized




Focus -8/10 mA




Focus 556 mA




Focus +8/10 mA

- There must be more to the story???
  - Rotate the Gun – little difference
  - Rotate the Tube – large difference

# Future Experiments

- Change the filament
- Flip coil over
- Fabricate new vapor tube from other material
- Characterize the ribbon gun and filament
- Optimal hole diameter

# Summary / Lessons Learned

- Three continued areas of interest
  - Guns, Coils and Vapor Tube
- The symptoms are much improved, but is the problem really any better?
- Long-term viability of ribbon filament in hairpin gun?
- Future of the vapor tube
- Faraday cup provided fast, cheap and reliable means for assessing the value of changes
- Relearning need to be deliberate, take good notes and stay organized

# Acknowledgements


- John Elmer, Todd Palmer and Alan Teryua
- Joe Michael
- Paul Burgardt
- Andy Gardea