# Mitigation of RF Gun Breakdown by Removal of Tuning Rods in High Field Regions

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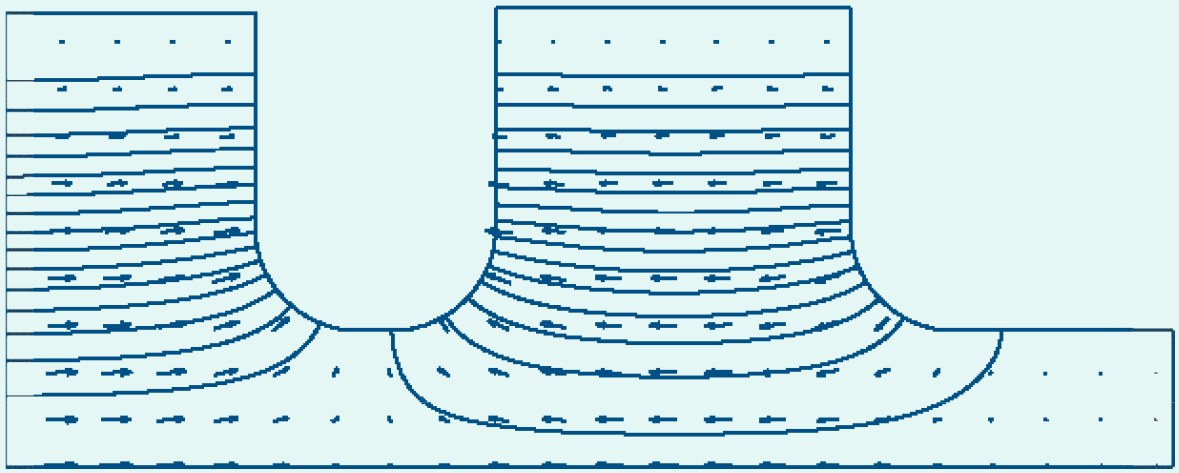
# Outline

- The 1.6 cell RF gun
- Gun tuning
- The RF breakdown problem
- The “stretching” solution

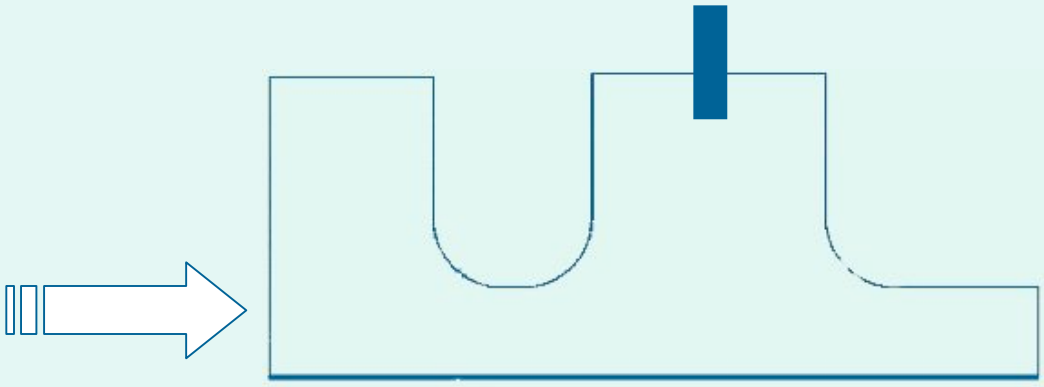
- 1.6 cell S-band photoinjector
- Two cells, two-mode standing wave, accelerating "$\pi$ " mode at 2856 MHz



- Popular design: UCLA, SLAC GTF, SLAC ORION, ANL APS, BNL ATF, BNL SDL, LLNL, U. Md., U. Tokyo, SPARC

# Gun Tuning

- Two coupled LC circuits
- Pushing/pulling cathode capacitively tunes half-cell
- Tuning rods inductively tune full-cell
- Set field balance (mode separation)
- Set final frequency ($\pi$) by temperature



# Tuner Breakdown

- Condition to > 7 MW

  Breakdowns occur, often catastrophic damage

⇨ New limit, much lower

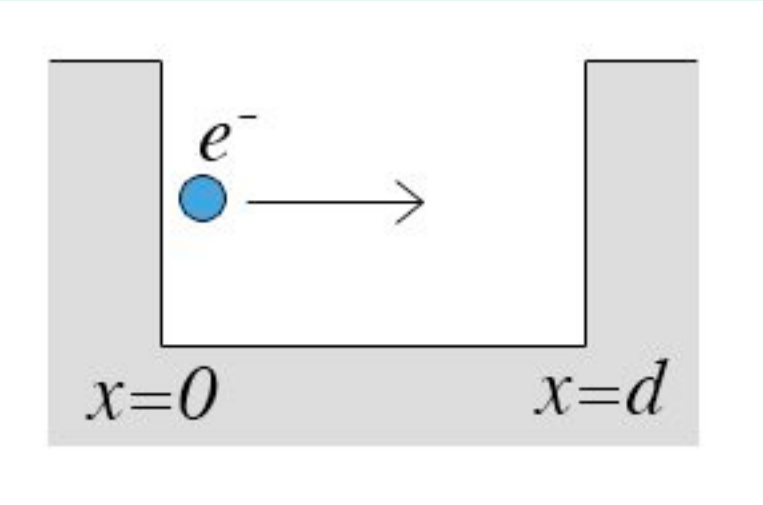
- Examples:

  UCLA Neptune limit ~ 4.5 MW

  LLNL PLEIADES < 4 MW

- Lots of evidence in situ points to tuners…

# Multipactoring



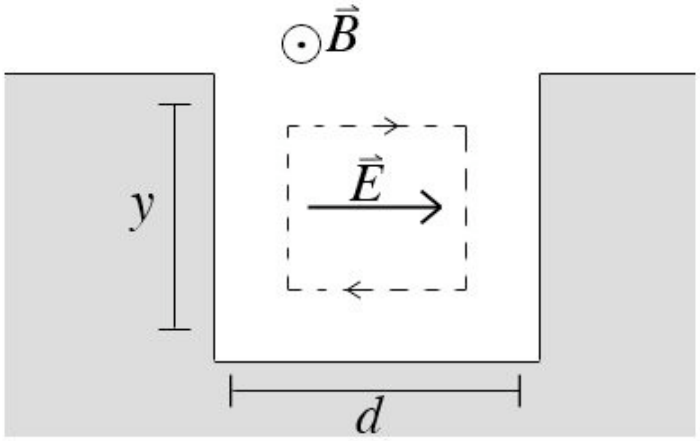

$$m\ddot{x} = eE_0 \sin\omega t$$

$$x = \frac{eE_0}{m\omega^2}\left(\omega t - \sin\omega t\right)$$

"resonance" condition $\omega t = \pi$

$$E_0 \approx 0.58d \ \text{MV/m}$$ $d$ in mm

# Field in Gap




$$\oint \vec{E}\cdot d\vec{l} = \frac{1}{c}\iint \frac{\partial \vec{B}}{\partial t}\cdot d\vec{A}$$

$$Ed = \frac{1}{c}\dot{B}yd$$

$$|E| = \frac{\omega}{c} y|B|$$

$$|B| = 0.52|E|$$
$$k = 2.405/a$$

$$|E| \le 10 \ \text{MV/m}$$

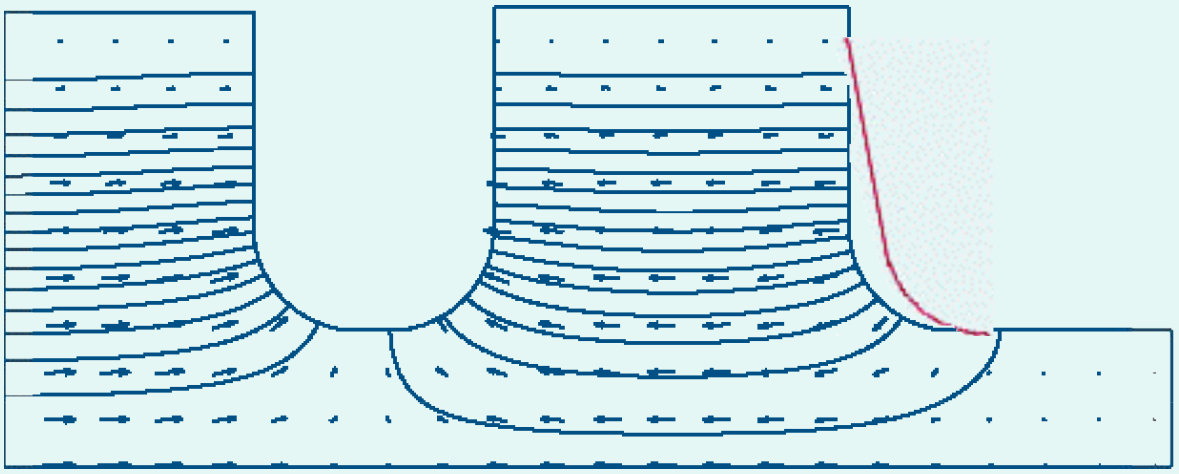
# The Solution

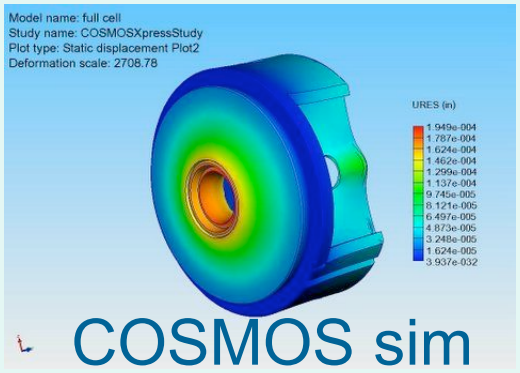
- Abandon inductive tuning with tuning rods
  - lose 2 MHz and a tuning knob!
- Cathode tuning not enough… requires lowering temperature too far
  - 44 KHz/deg ⇨ lower by ~ 45 deg

⇨ Stretch the full cell itself!!

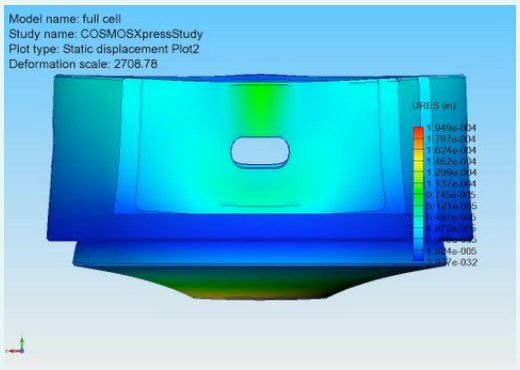
# SUPERFISH Model

- 2856 MHz $\pi$ mode
- 2 MHz requires ~150 micron displacement of downstream wall in full cell



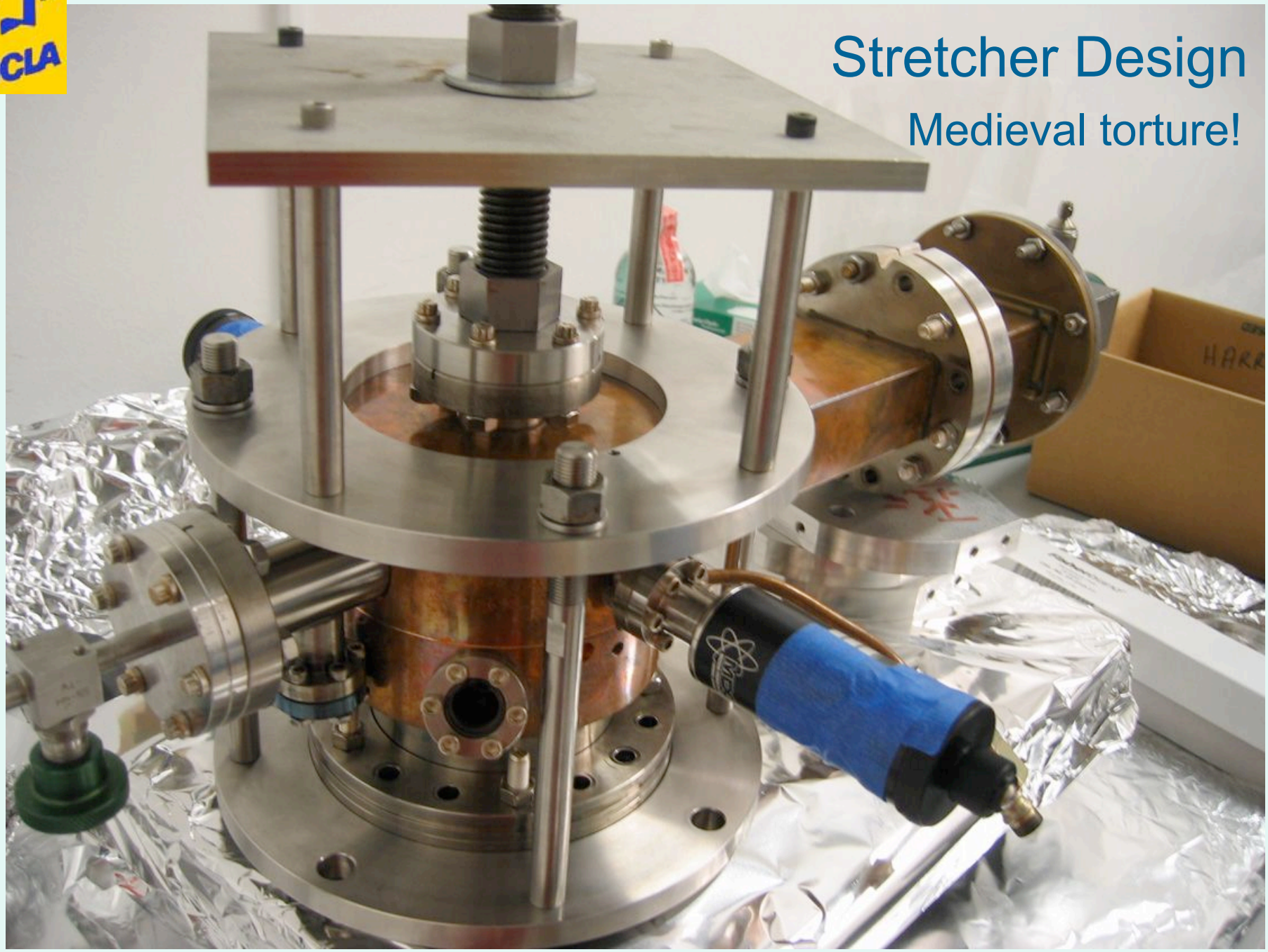



COSMOS sim



# Stretcher Design

## Medieval torture!



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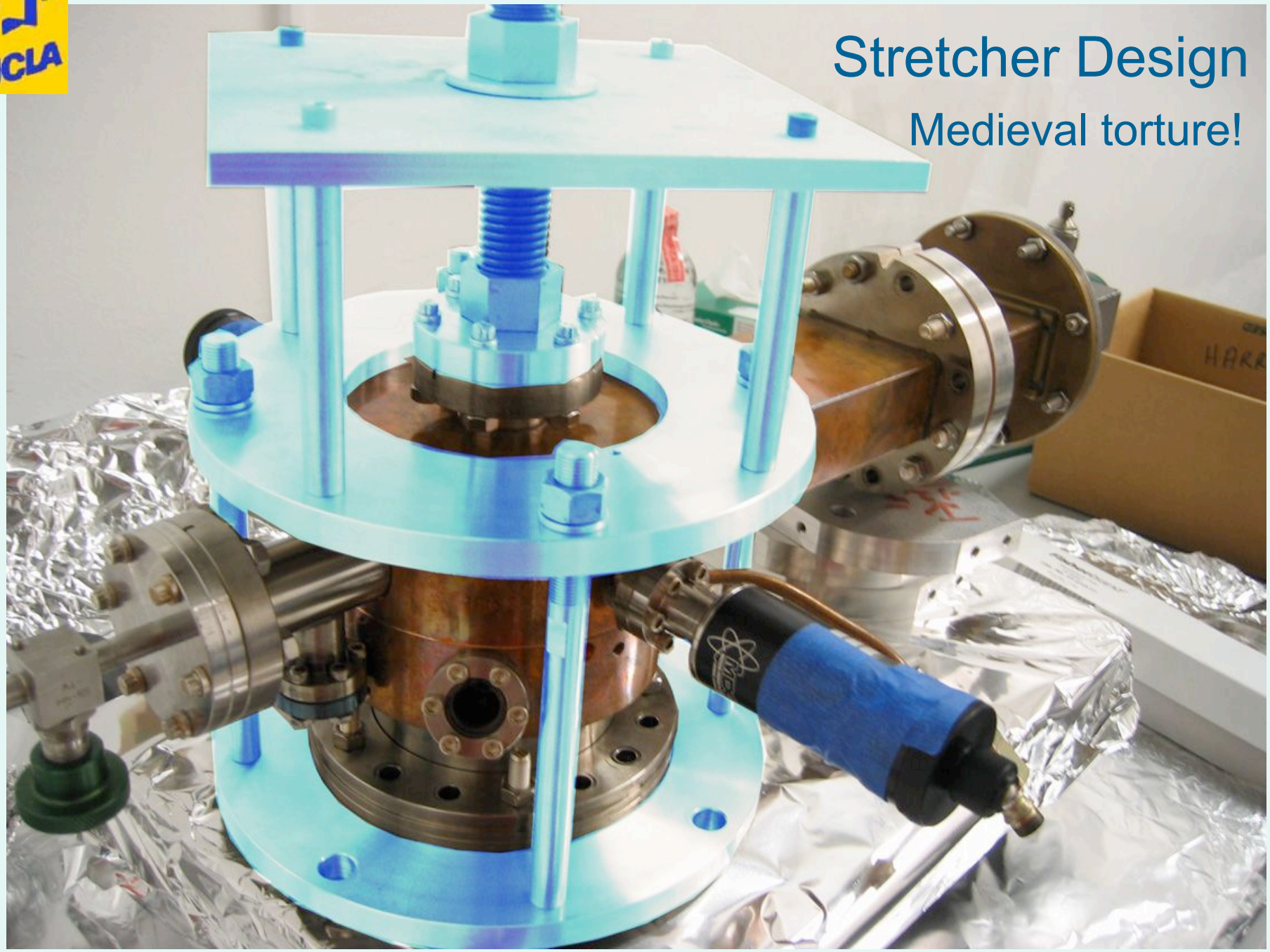
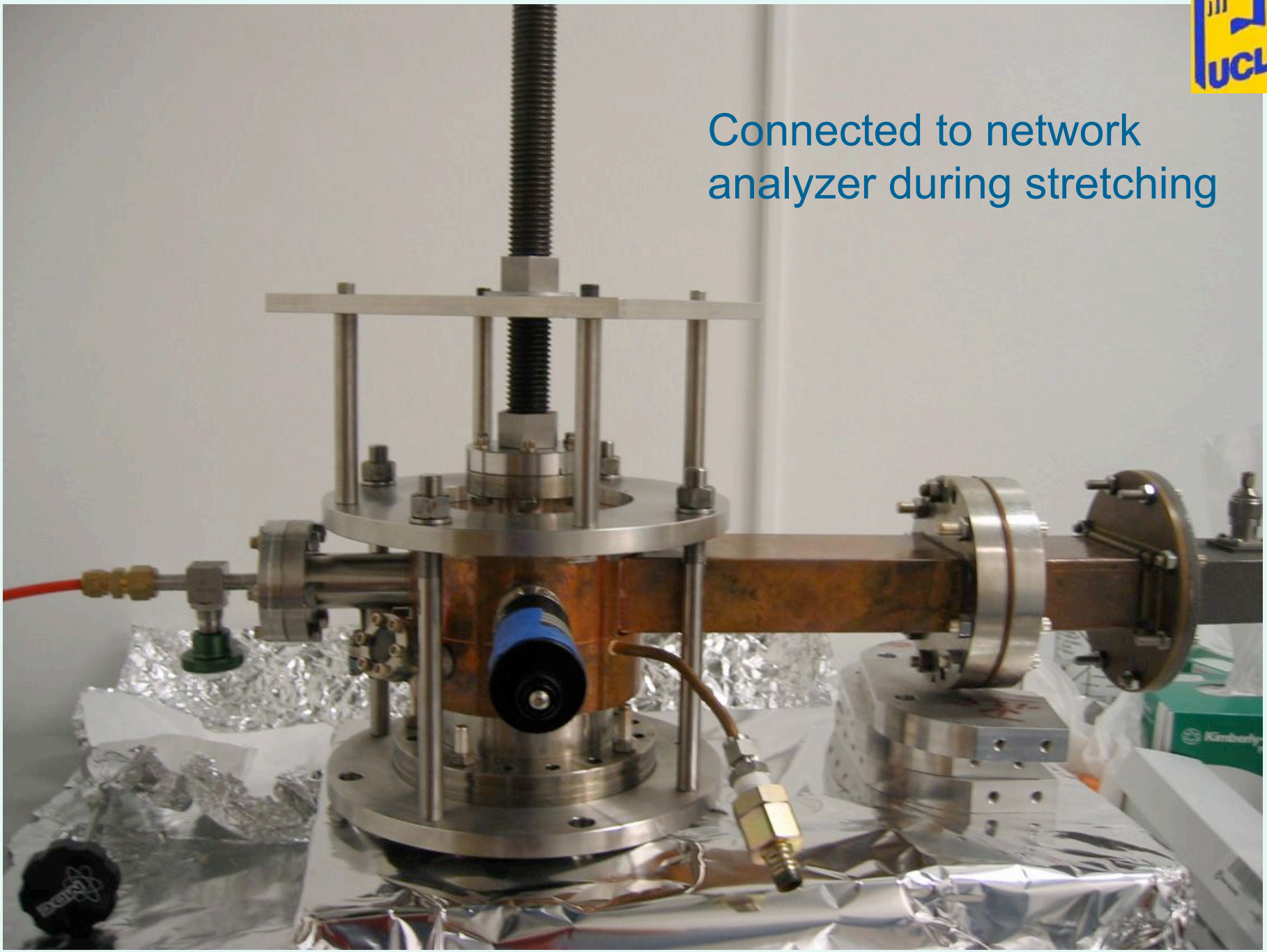
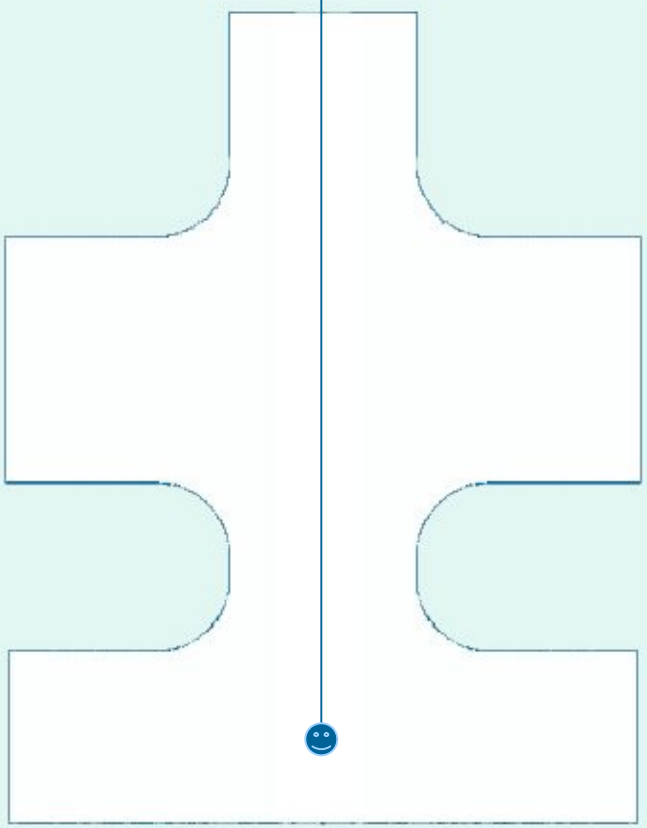



Connected to network
analyzer during stretching

# Retuning for Field Balance

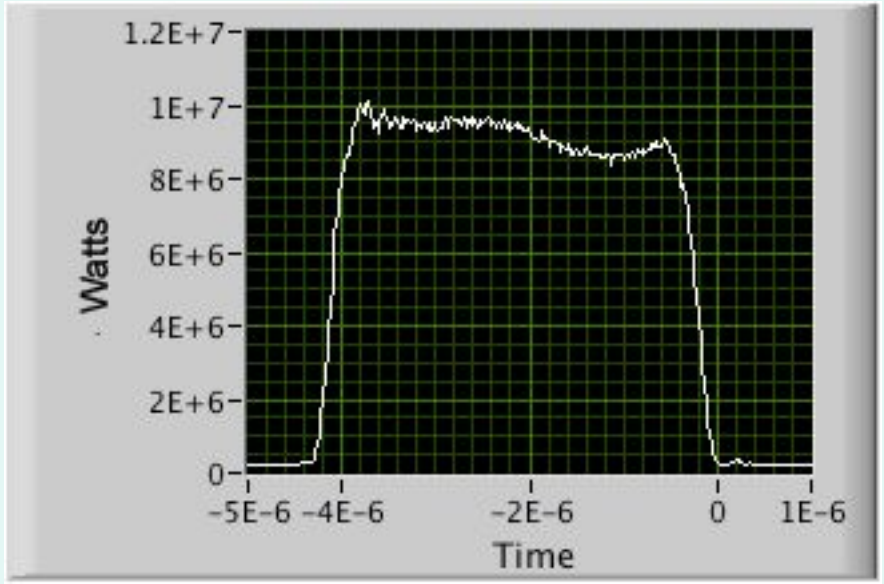


- Bead drop frequency perturbations should show 40 KHz difference due to presence of fiber:

  231.25 KHz 1/2 cell, 193.75 KHz full cell
- Coupling excellent, $\beta$ = 1.007
- Structure distortions not significant… GUN SHOULD WORK.

# High Power Conditioning

- Reached ~ 8.4 MW with unpolished Cu cathode
- Reached ~ 9 - 10 MW with polished Mg cathode
- Up from ~ 4.5 MW !! Gun does work! Better!!!



# Conclusion

- Tuners cause problems with electric breakdown
- Gun can accommodate much more RF power without tuners
- This feature now designed in
  - Experience at ORION (UCLA/SLAC built, 15 MW)
  - SPARC gun also leaves tuners out of circuit
- Stretching was successful
  - May apply (with risk) to other guns?