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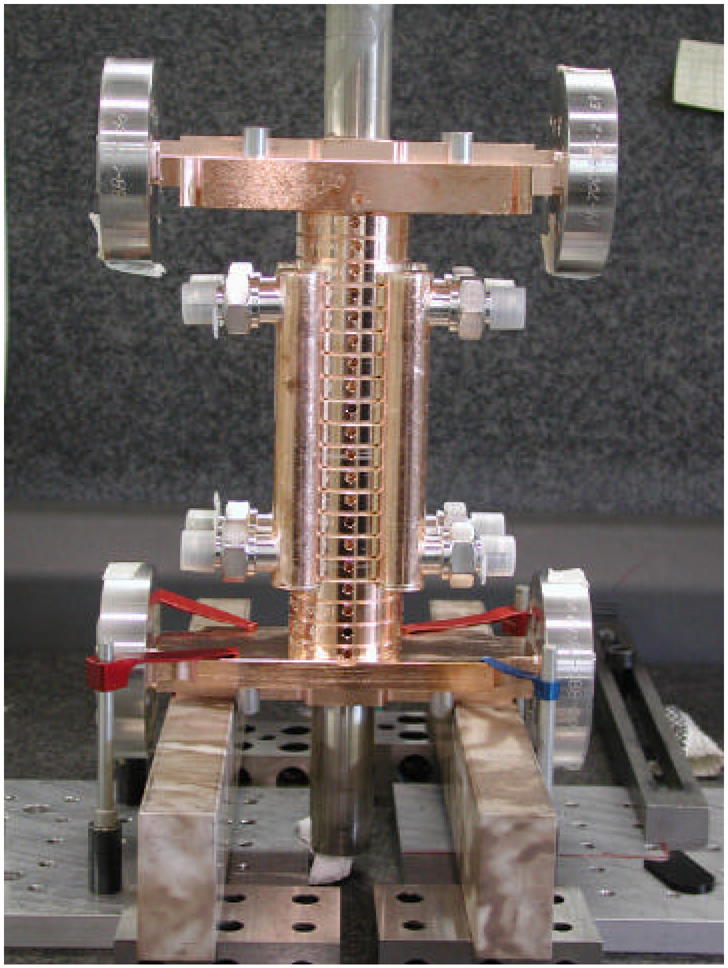
Status of X-Band Structures Fabrication

- Our First X-Band Structure
- Progress of RF Factory at IB4
- Assembly of FXA-001
- Measurements of FXA-001
  - Mechanical and RF (see right)
- The Next Steps and The Plan

We have our first X-Band structure.



FXA-001 Setup for Mechanical QC at Fermilab
Technical Division, 08/01/01

- It is about 20 cm long.
- It is named FXA-001.
- Note the cells, couplers, rf flanges, water pipes, beam tubes.
- It took a little more than nine months.

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RF Factory Elements
(Norbert Holtkamp, David Finley)

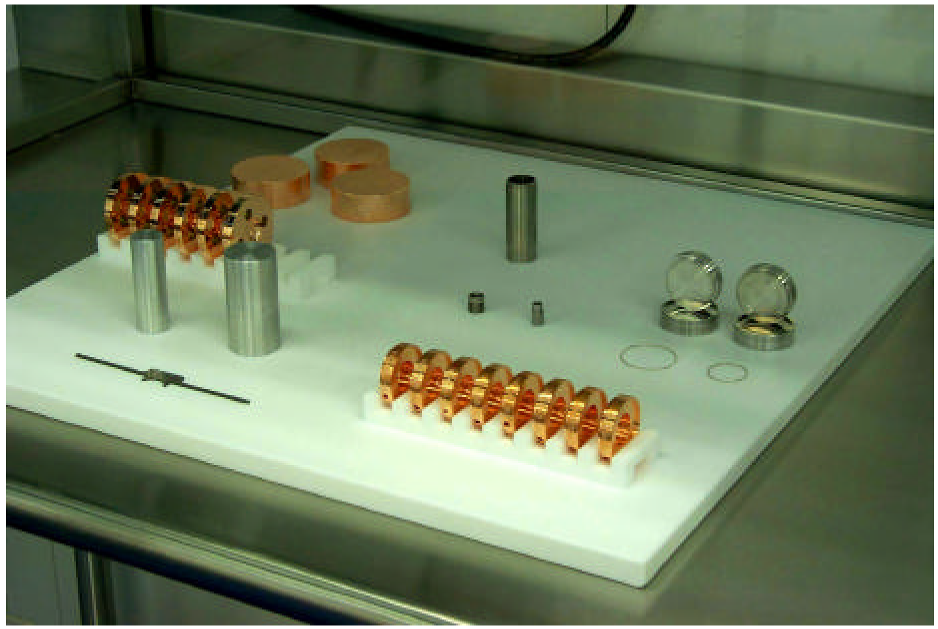
From David Finley's Presentation at the May 31, 2000 NLC Collaboration Meeting at Fermilab

- Seven Elements of the RF Factory
  - RF Design
  - Produce Copper / Machine Copper
  - RF Measurements & Development / Low Power
  - Structure and Vacuum
  - Mechanical Measurements of Straightness
  - Brazing / Bonding Facility
  - High Power Processing

Copper Material and Some Copper Parts
(Tug Arkan, SLAC, Gregg Kobliska & Co.)

Ordered enough bars for ~10K disks (~100 meters total).

Parts machined in US industries.



Have made both RDDS diamond turned disks, and conventional machined high gradient test disks.

9 copper bars ~10 feet long each.

ETF needed ~5K disks.

Eight Pack Test needs ~1K disks.

NLC needs ~1M disks (for 500 GeV center of mass.)

Mechanical Measurements of RDDS Profiles
(Tug Arkan, Ted Beale, Rob Riley)

Measured four profiles (see below) along the tear-drop shaped iris of the rf surfaces of six RDDS disks.

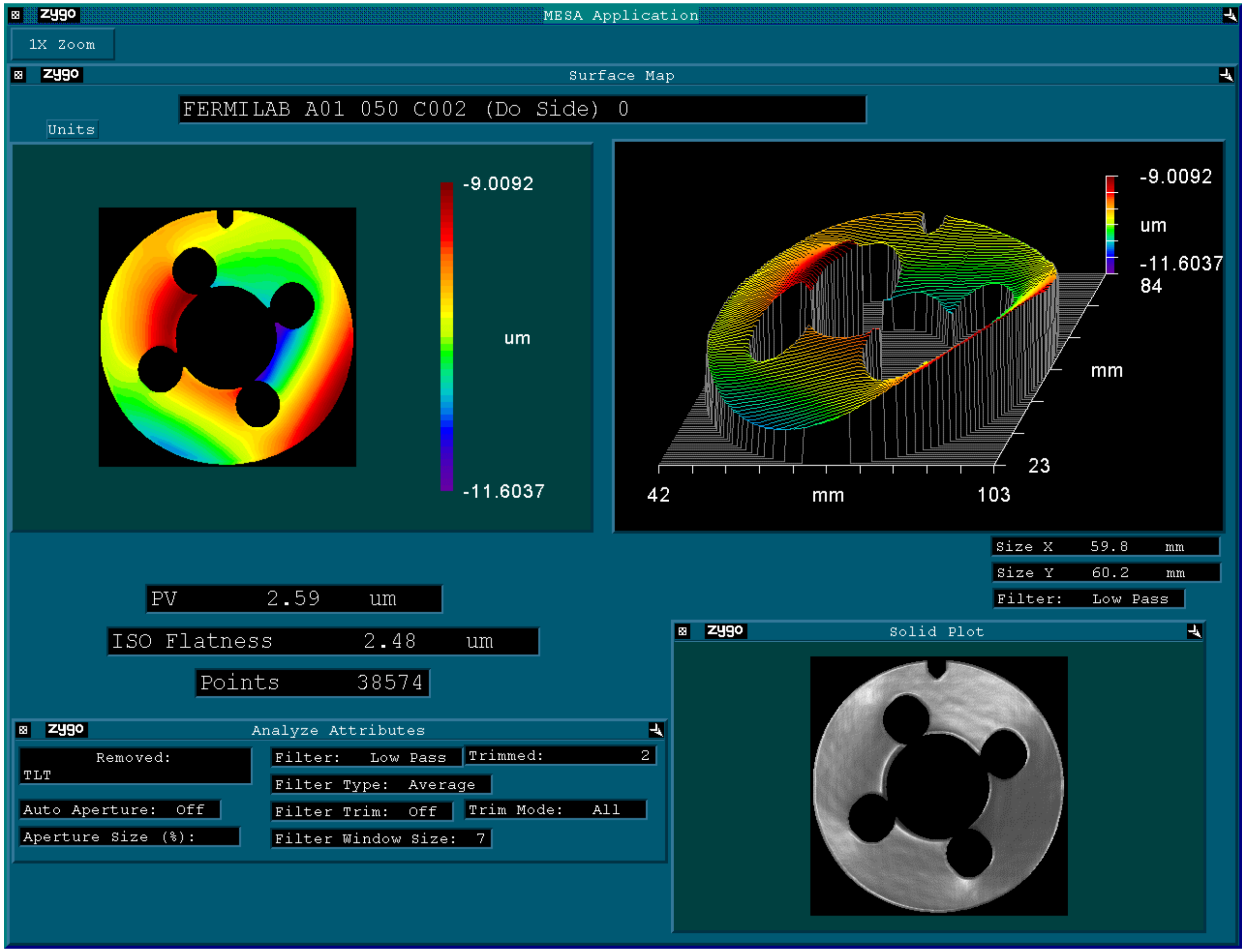
Contours of RDDS disk # C001 taken from D. Sun et al PAC01.
green: measured, blue: design, red: tolerance

Zeiss machine costs ~$500K.

Might (or might not) buy Zeiss machine because it is a general purpose light touch 3D coordinate measuring machine.

Mechanical Measurements of Flatness of RDDS Disks
(Tug Arkan, Ted Beale, Rob Riley)

Zygo machine measures flatness well enough.

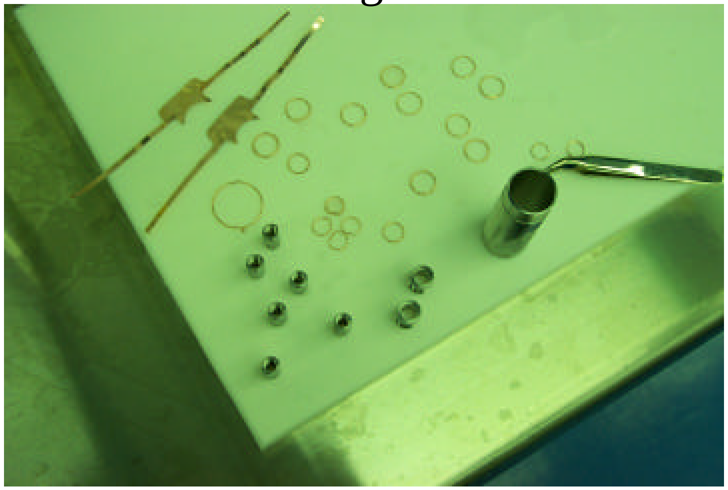


Zygo machine costs ~$400K.

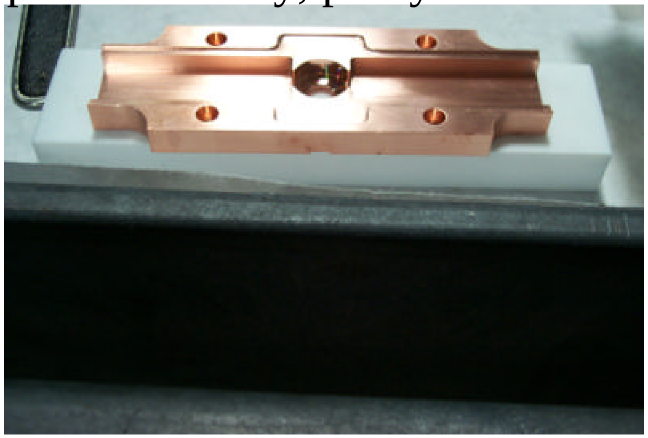
Not going to buy Zygo machine until we know we are doing diffusion bonding rather than brazing.

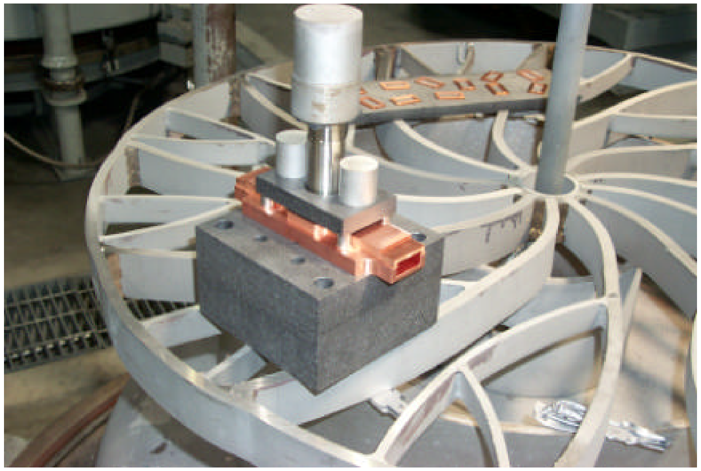
Couplers, Disks, Brazing Materials for FXA-001
(Tug Arkan, Gregg Kobliska & Co., Brian Smith, Danny Snee.)

Some brazing materials etc.

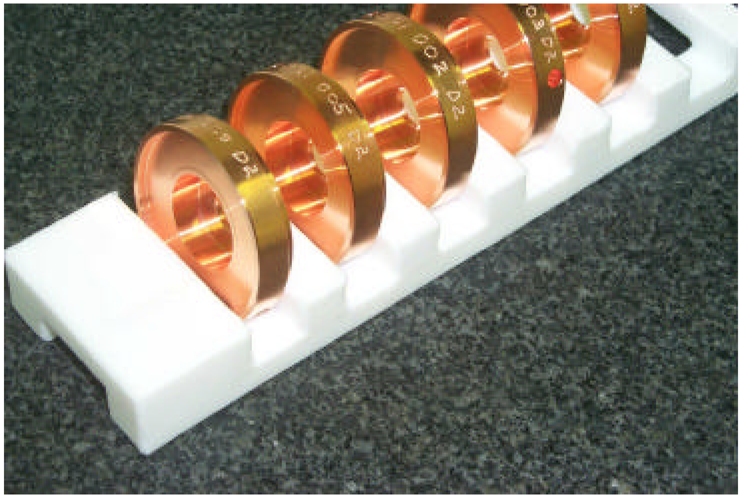


Coupler main body, partly diamond turned.





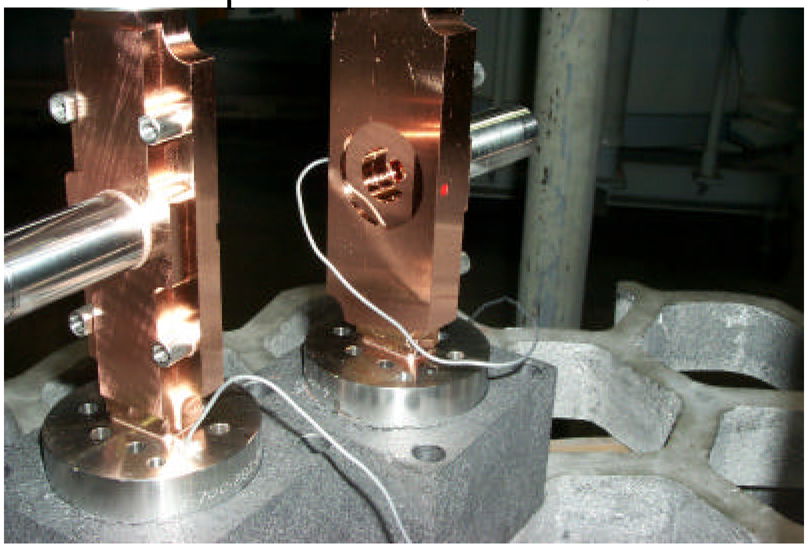
Coupler and beam tube subassembly.



45 mm OD disks for high gradient tests

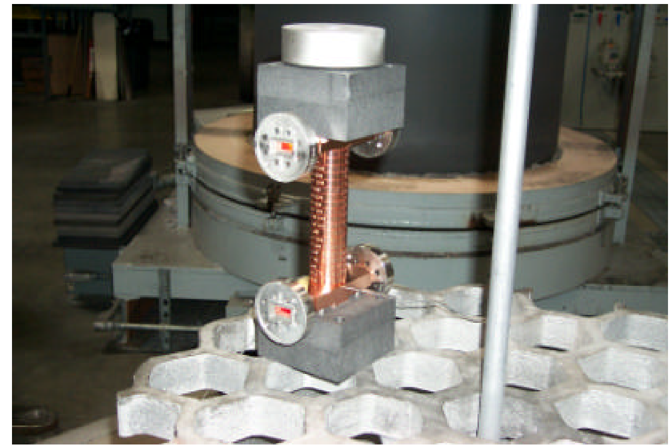
Sub-Assemblies at Alpha Braze (Fresno, CA)
(Tug Arkan, Brian Smith, Danny Snee)

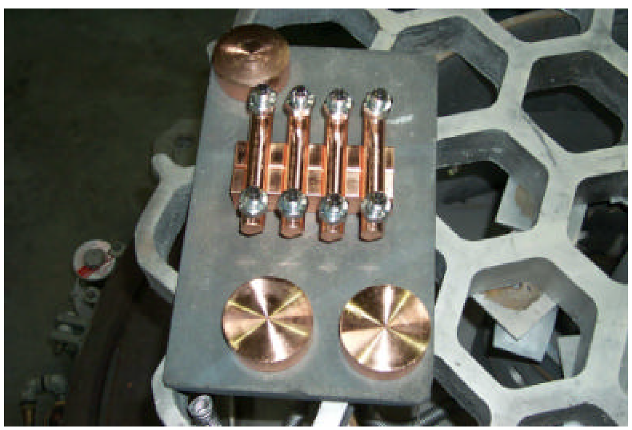
Both Couplers with beam tubes.



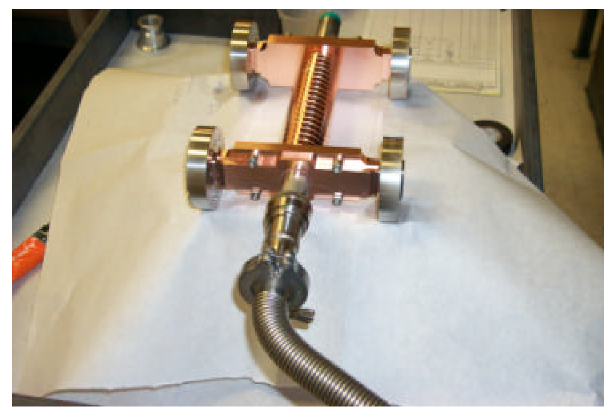
<<< Note mirror quality rf surfaces provided by diamond turning machining.

Couplers and disks.



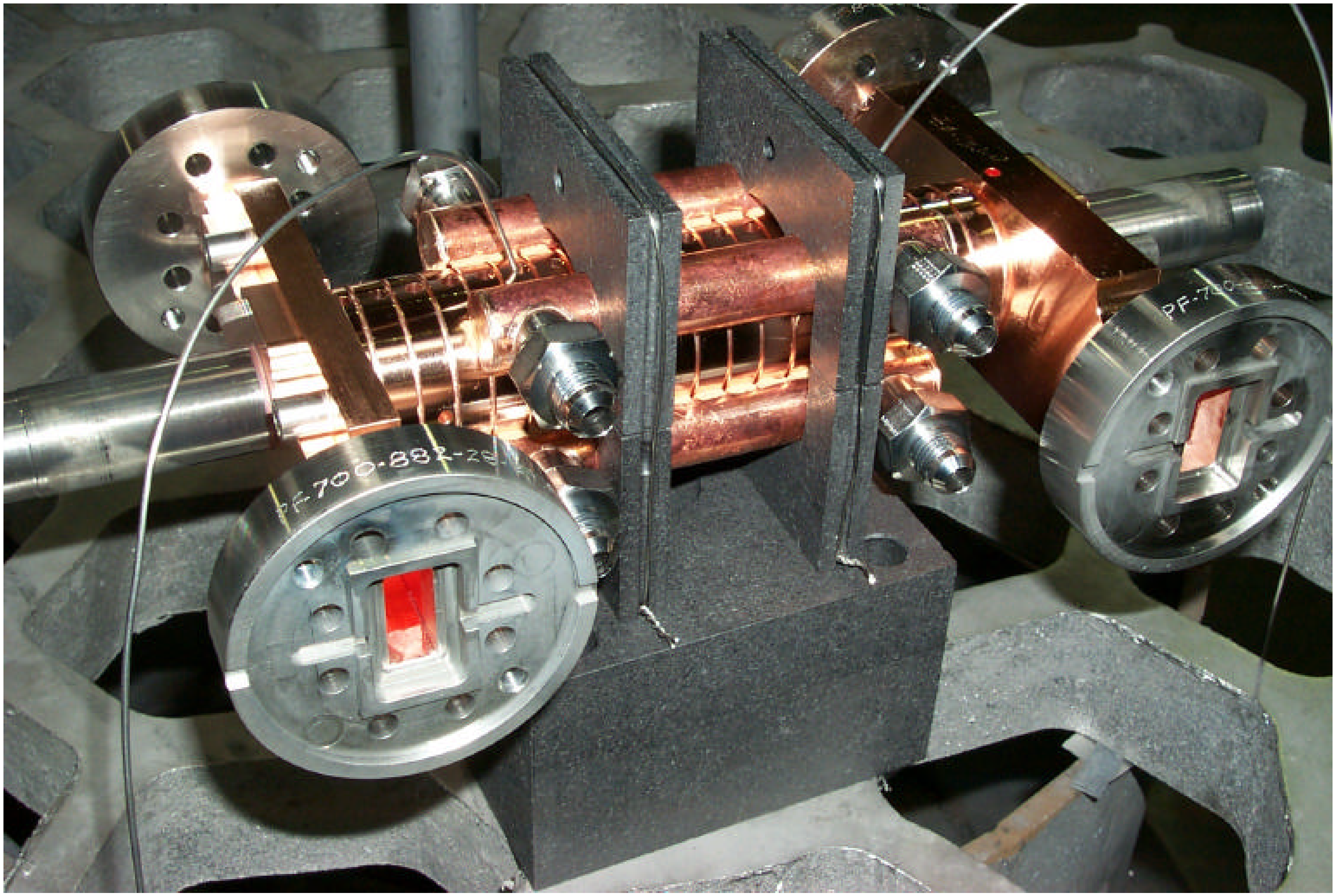


Cooling water tubes and test blocks.



Leak Check.

Final Assembly at Alpha Braze (Fresno, CA)
(Tug Arkan, Brian Smith, Danny Snee)



NICADD Furnaces

(Jerry Blazey, Steve Holmes, Tug Arkan, Gregg Kobliska & Co.)

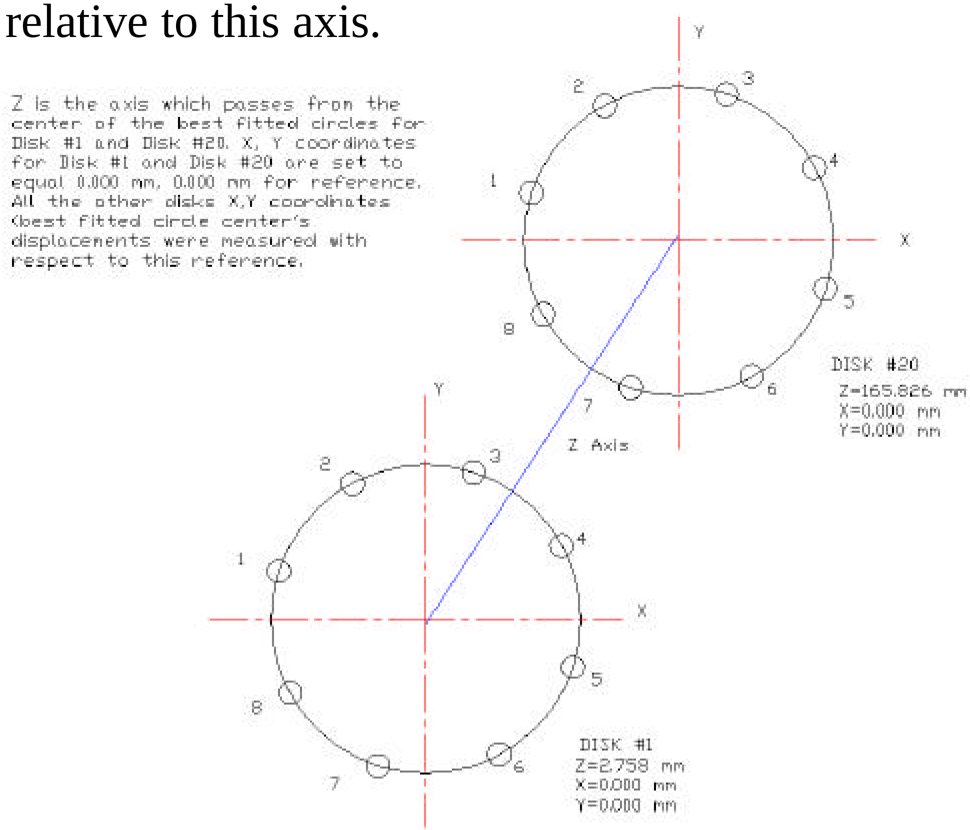
- The small furnace in place in IB4.

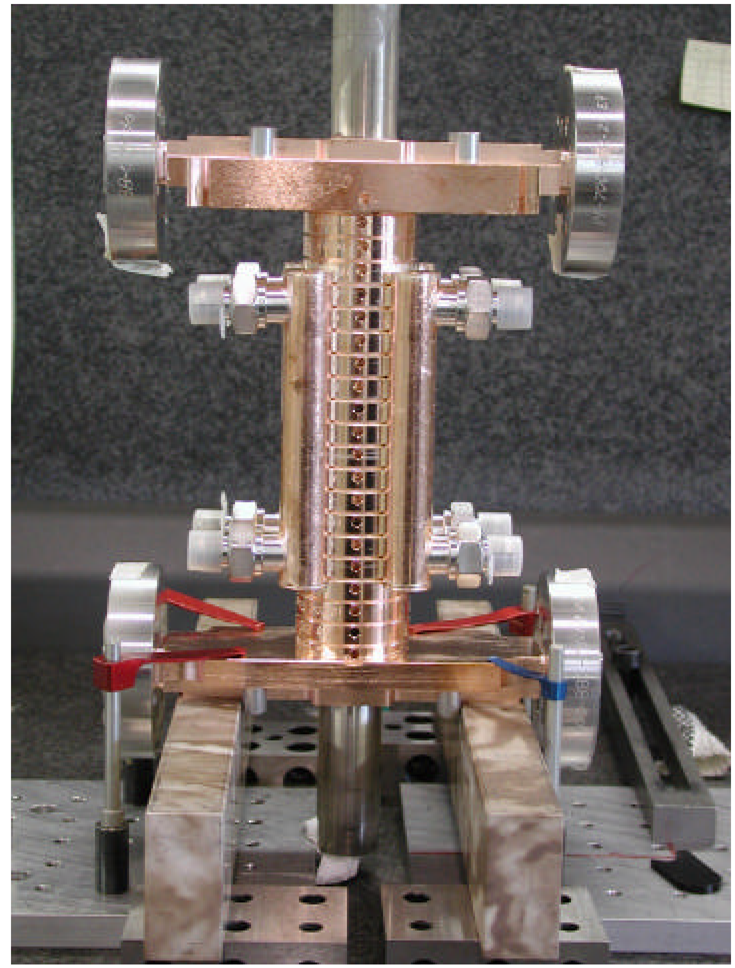
- First use will be for bonding and brazing studies.
- Then it will be used to make sub-assemblies.
- Will likely also be used for electron cooling and maybe scrf.
- Need full sized furnace for final assembly.

Straightness QC on FXA-001 in IB4
(Tug Arkan, Ted Beale, Rob Riley)

Define the z axis based on disks #1 and #20.

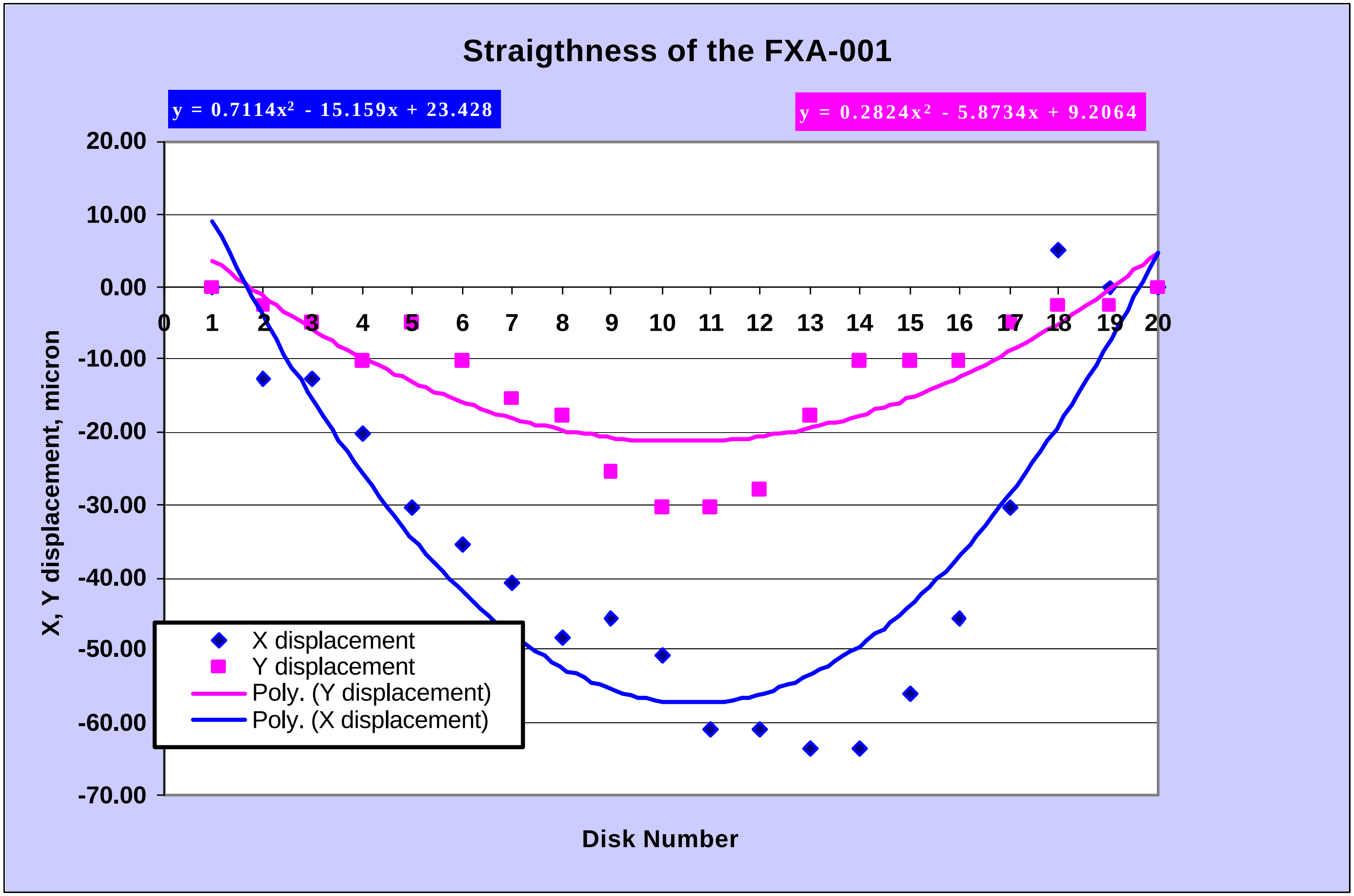
Measure the centers of the other 18 disks relative to this axis.





FXA-001 Setup for Mechanical QC at Fermilab Technical Division, 08/01/01

Straightness QC on FXA-001 in IB4
(Tug Arkan, Ted Beale, Rob Riley)



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RF Measurements on FXA-001

(Gennady Romanov, Ding Sun, Ivan Gonin, Timergali Khabiboulline)

Bead Pull Principle

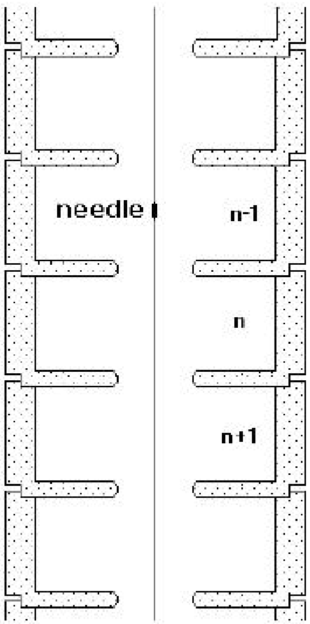


Figure 2.1. Bead-pull measurement.

With the bead-pull method we can measure and calculate amplitudes and phases of the field in the centers of the cells: $A_1 e^{j\varphi_1}$, $A_2 e^{j\varphi_2}$, $A_3 e^{j\varphi_3}$, ... For two neighboring cells with number n-1 and n, let us consider this values as a super-position of forward and backward waves: $a_n e^{j(-2\pi/3(i-n)+\psi_n)}$ and $b_n e^{j(2\pi/3(i-n)+\phi_n)}$, which has passed through n-th disc (between cells n-1 and n).

$$A_{n-1} e^{j\varphi_{n-1}} = a_n e^{j(2\pi/3+\psi_n)} + b_n e^{j(-2\pi/3+\phi_n)} \qquad 3.1$$

$$A_n e^{j\varphi_n} = a_n e^{j\psi_n} + b_n e^{j\phi_n}. \qquad 3.2$$

The solutions of these two complex equations are:

$$a_n e^{j\psi_n} = (A_{n-1} e^{j(\varphi_{n-1}-\pi/2)} + A_n e^{j(\varphi_n-\pi/6)})/\sqrt{3} \qquad 3.3$$

$$b_n e^{j\phi_n} = (A_{n-1} e^{j(\varphi_{n-1}+\pi/2)} + A_n e^{j(\varphi_n+\pi/6)})/\sqrt{3} \qquad 3.4$$

From formula (3.4) we can find the amplitude b_n and phase ϕ_n of the backward wave which passed the n-th disc (between cells n-1 and n). For the next (n+1) disc we can use the formula (3.4) to calculate the backward wave:

$$c_n e^{j\eta_n} = (A_n e^{j(\varphi_n+\pi/2)} + A_{n+1} e^{j(\varphi_{n+1}+\pi/6)})/\sqrt{3} \qquad 3.5$$

Let us calculate the difference of these two backward waves in the plane of the n-th diaphragm. The phase shift per cell is about $2\pi/3$ and if attenuation can be neglected we can write:

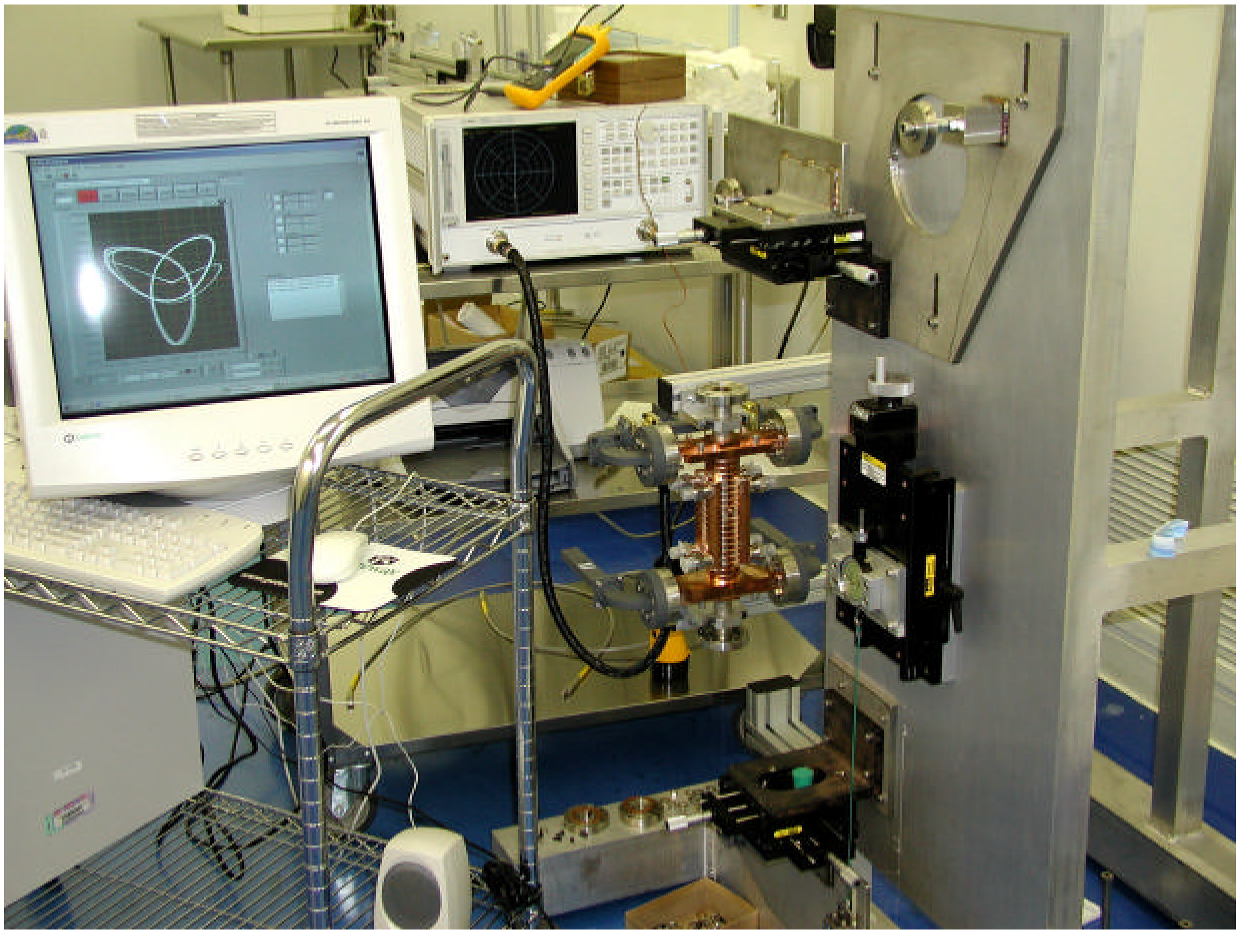
$$S_n e^{j\theta_n} = b_n e^{j\phi_n} - c_n e^{j(\eta_n-2\pi/3)}. \qquad 3.6$$

From PAC95 paper on DESY S-Band setup

- A network analyzer puts an rf wave into the structure composed of cells and couplers. Some of the wave is transmitted, some is reflected, and the reflected power measured and analyzed.
- A metal "bead" (shown as "needle" in the figure) is pulled along the length of the structure and disturbs the rf wave.
- The analysis yields the amplitude and phase of the wave.

RF Measurements on FXA-001
(Gennady Romanov, Ding Sun, Ivan Gonin, Timergali Khabiboulline)

- Bead pull setup in RF Factory Clean Room A.



- Note network analyzer (from Beams Division), bead pull support, pulley, data on computer screen, and FXA-001.

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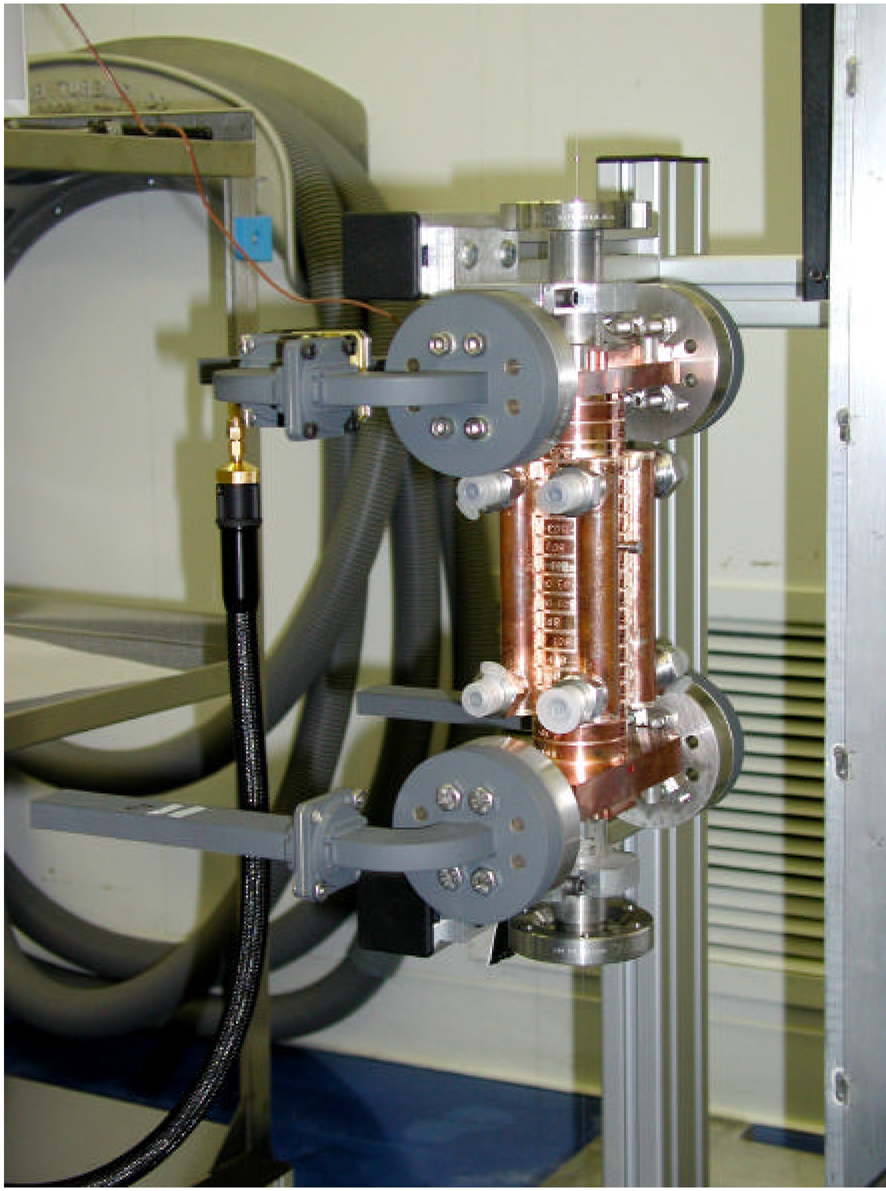
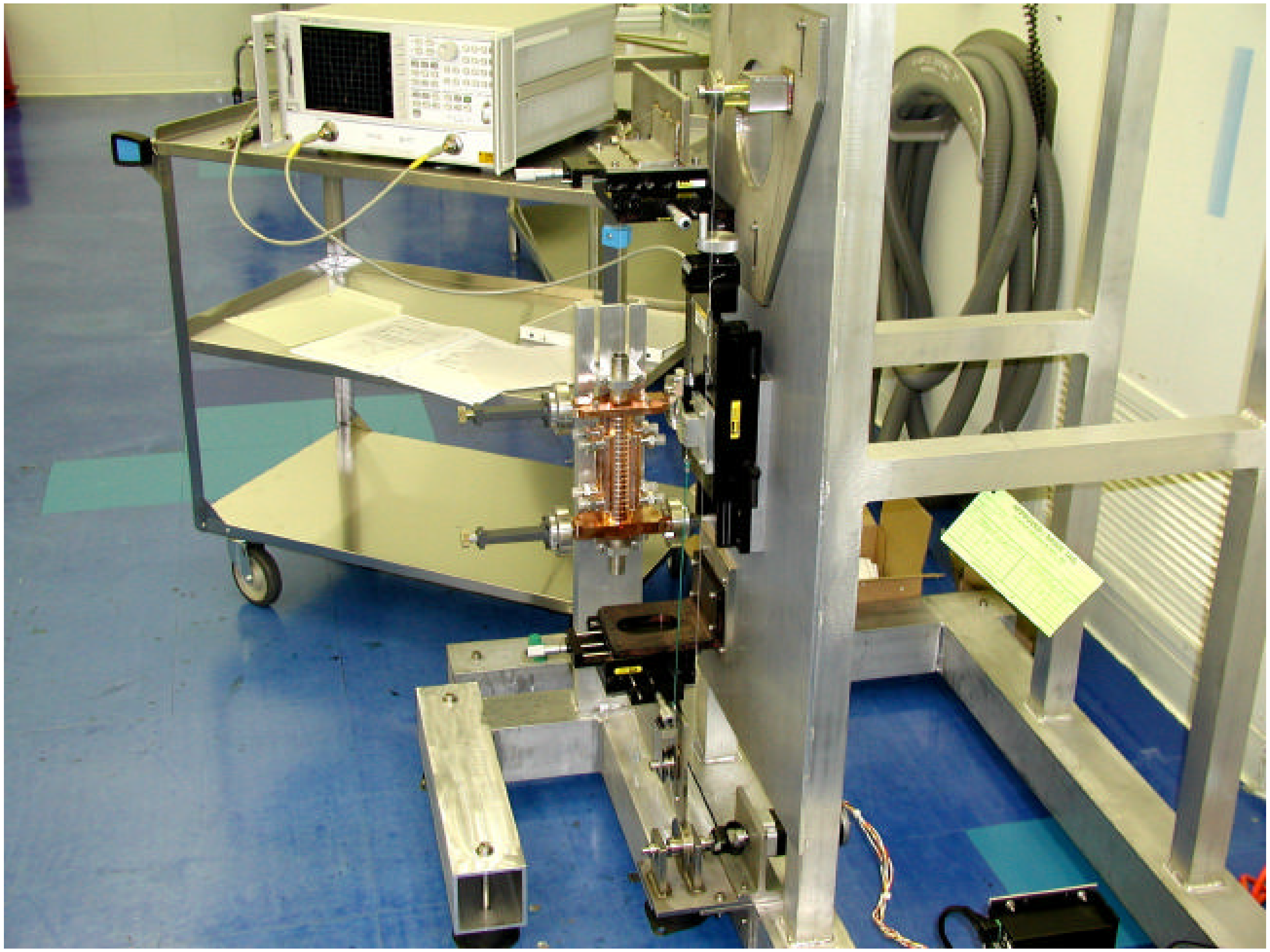
RF Measurements on FXA-001



- Here, the bead is (barely) visible against the shadow just above the beam pipe.

RF Measurements on FXA-001

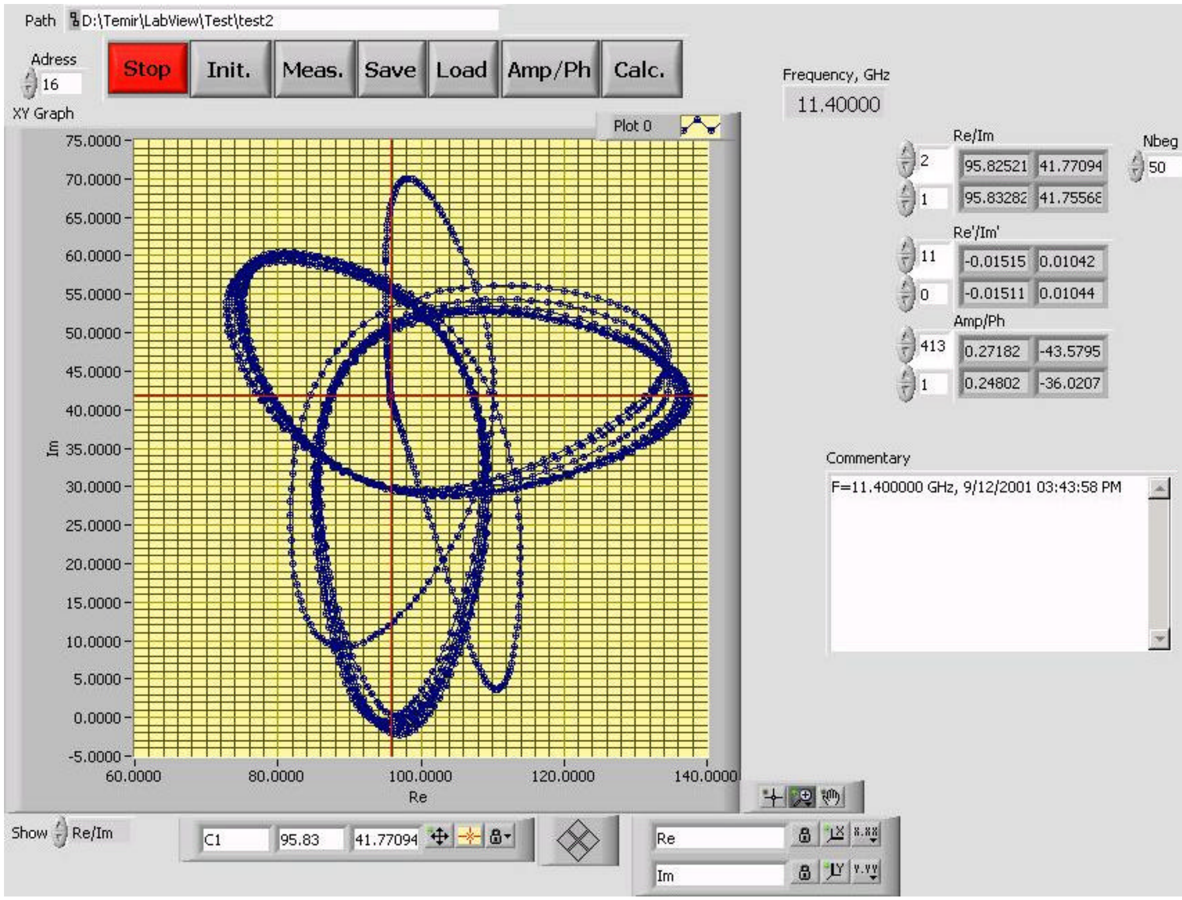
- A better view of just the bead pull apparatus with FXA-001.



RF Measurements on FXA-001

Im vs. Re part of reflected rf wave at 11.400 GHz before tuning.

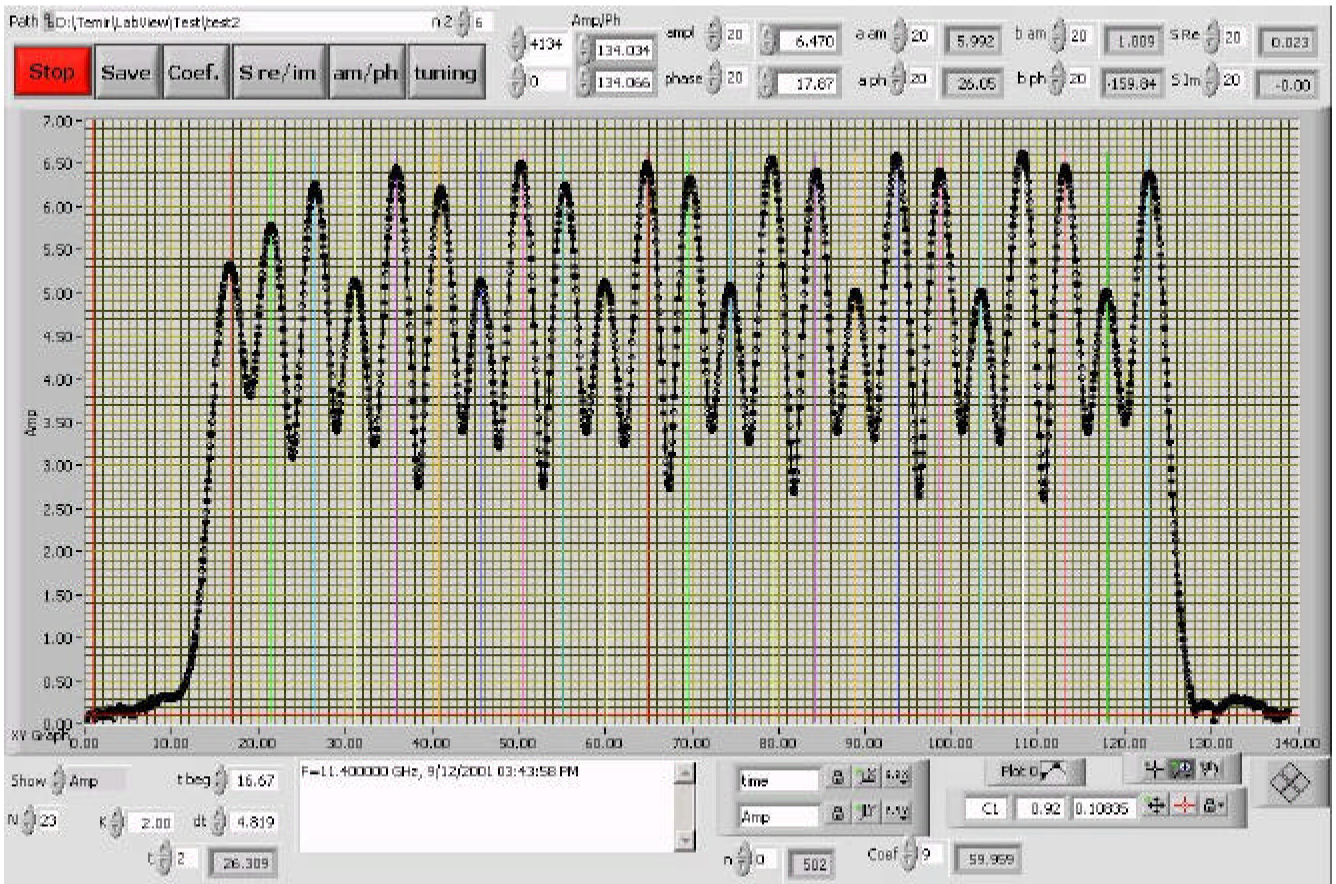
Note: You want 11.424 GHz; thus the cells are about 24 MHz low.



- The bead is pulled through the structure at a constant speed over about 140 seconds.
- Data is taken at constant time intervals.
- The data taking window is about 10 msec.

RF Measurements on FXA-001

Amplitude of reflected rf wave at 11.400 GHz before tuning as a function of time.

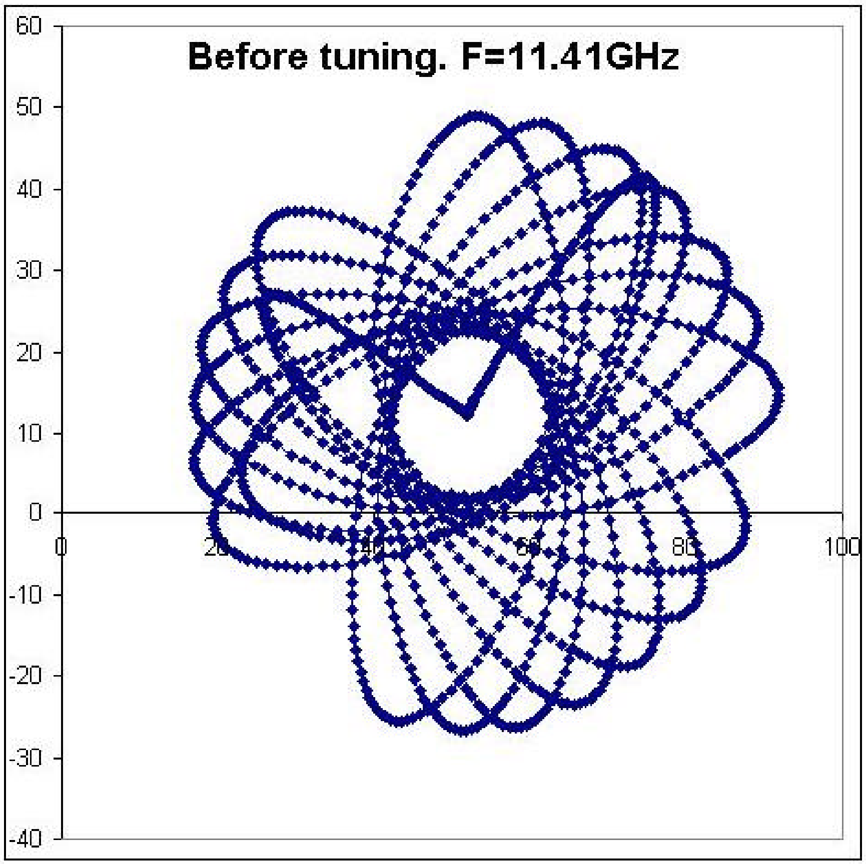


- You want this to be flat - which it isn’t.
- This is the same measurement as the previous slide but it is easier to see that every third peak is smaller than the other two.

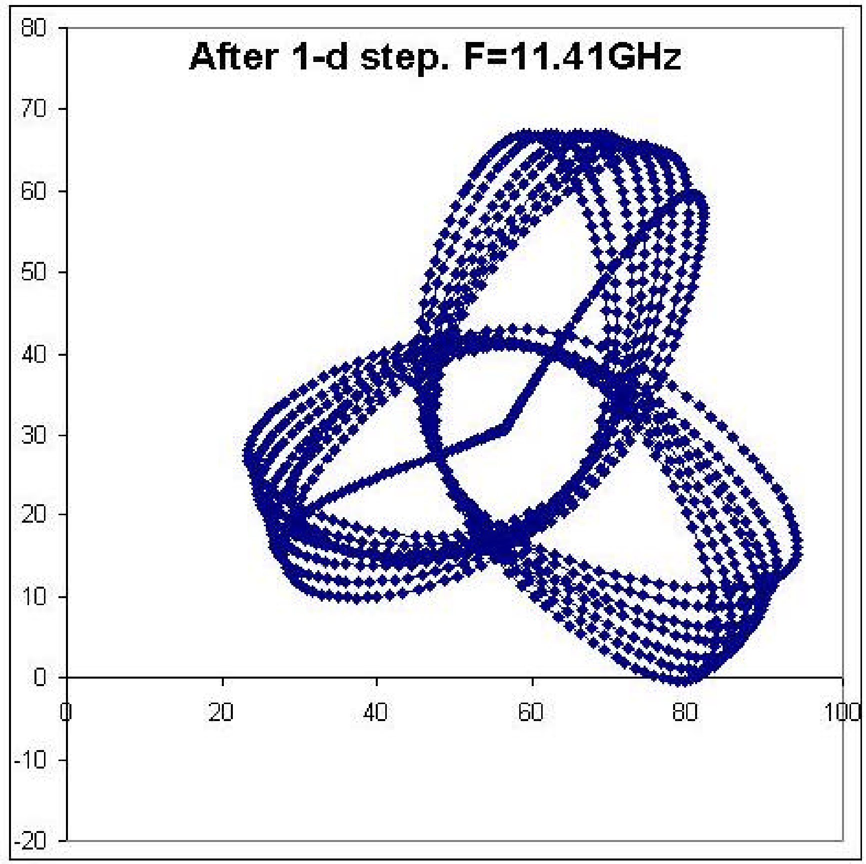
RF Measurements on FXA-001

First Tuning Step: Set analyzer at 11.410 GHz, a 10 MHz step.

Before



After



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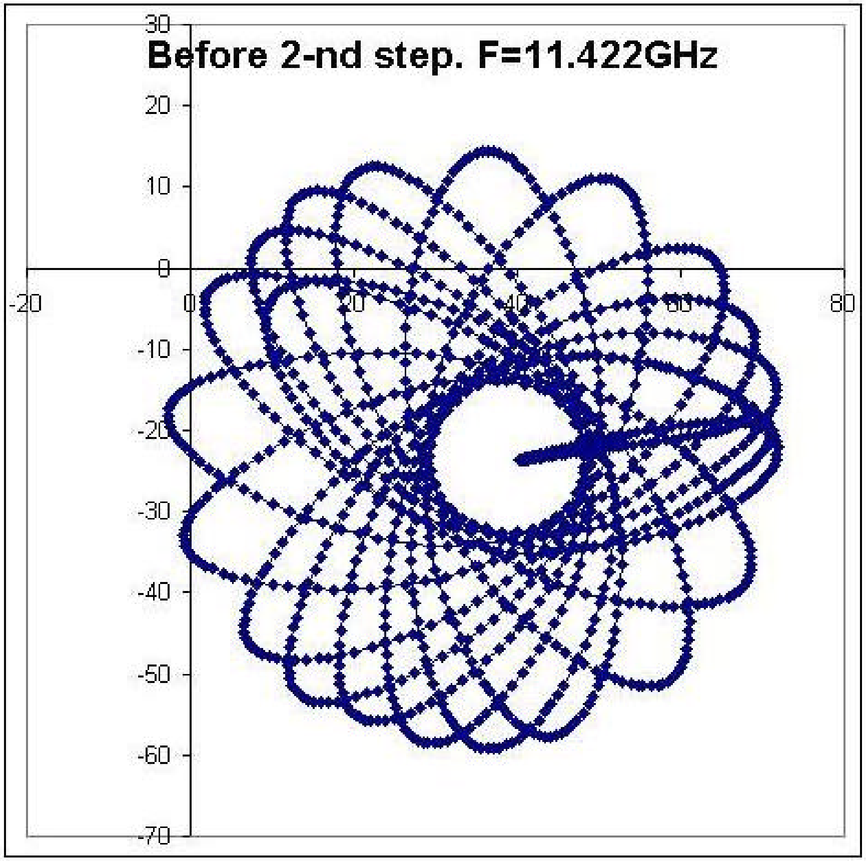
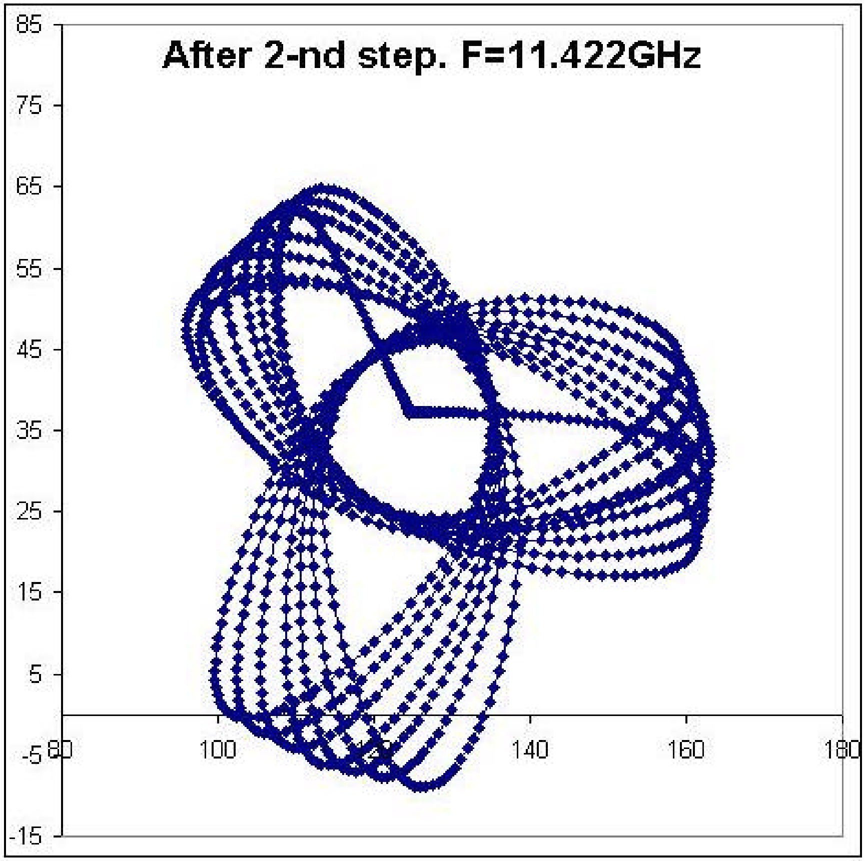
RF Measurements on FXA-001

2nd Tuning Step: Set analyzer at 11.422 GHz, an additional 12 MHz step.

Before



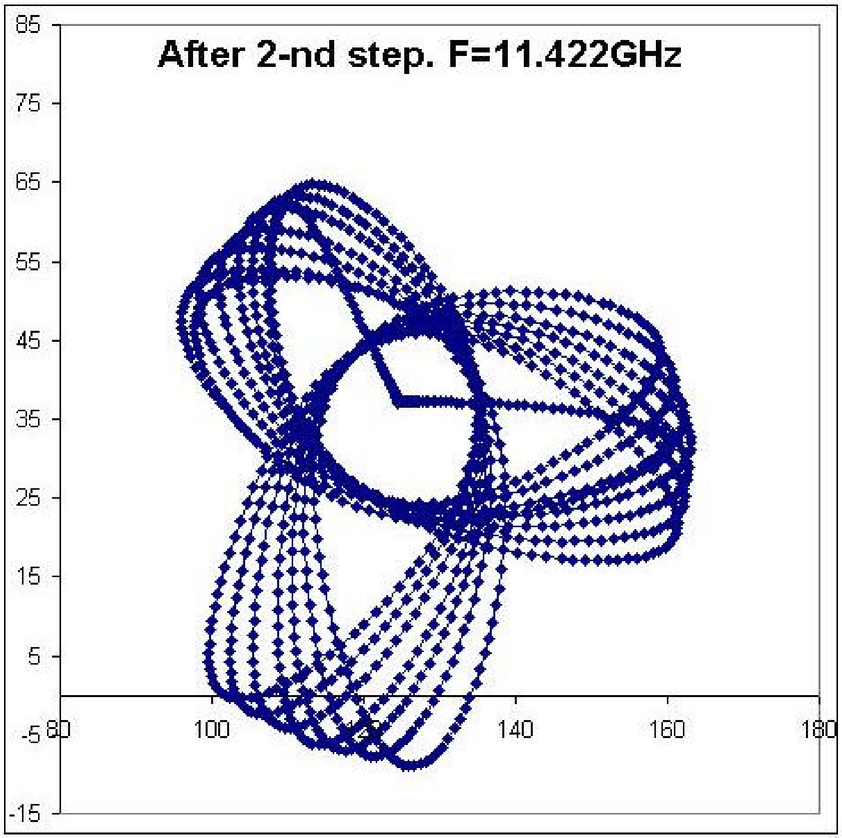
After



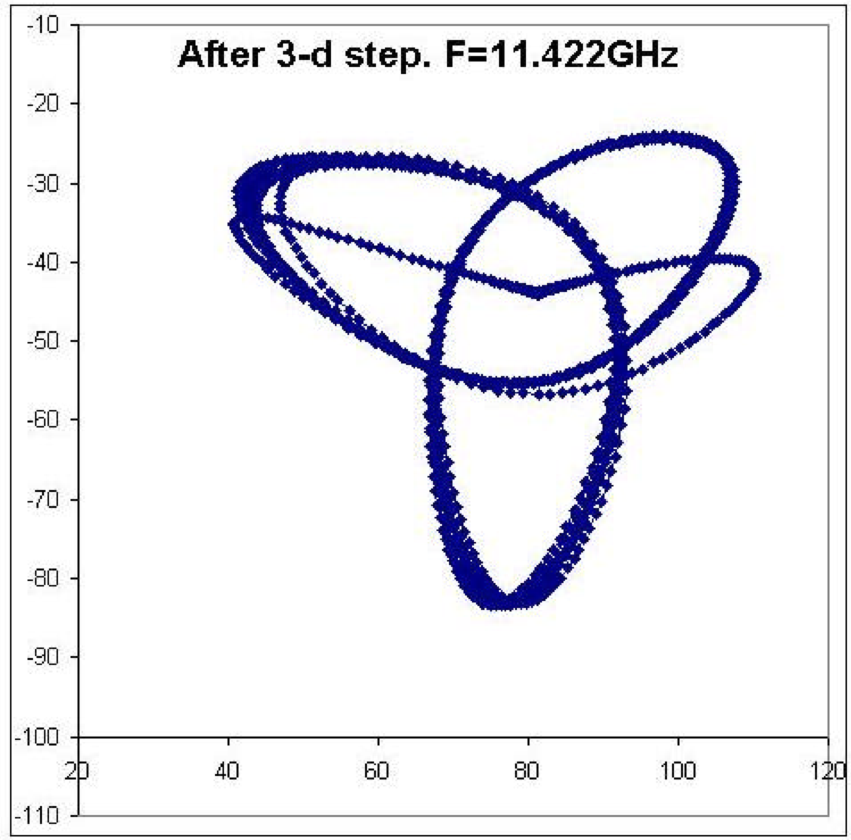
RF Measurements on FXA-001

3rd Tuning Step: Stay at 11.422 GHz, and tweak cells again.

Before
(same as "After" on previous slide)



After

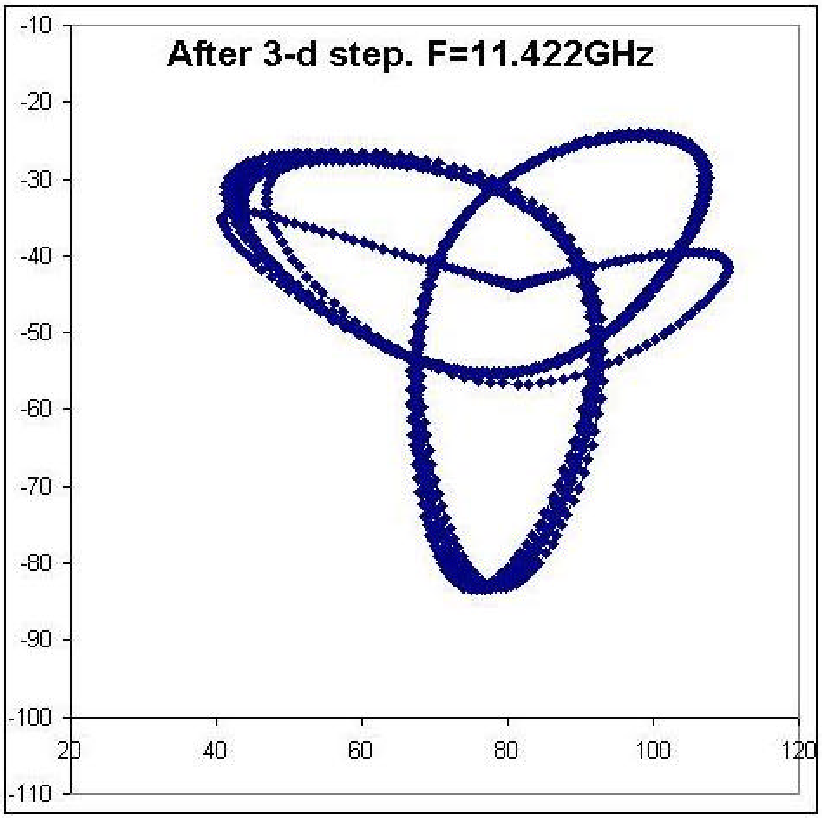


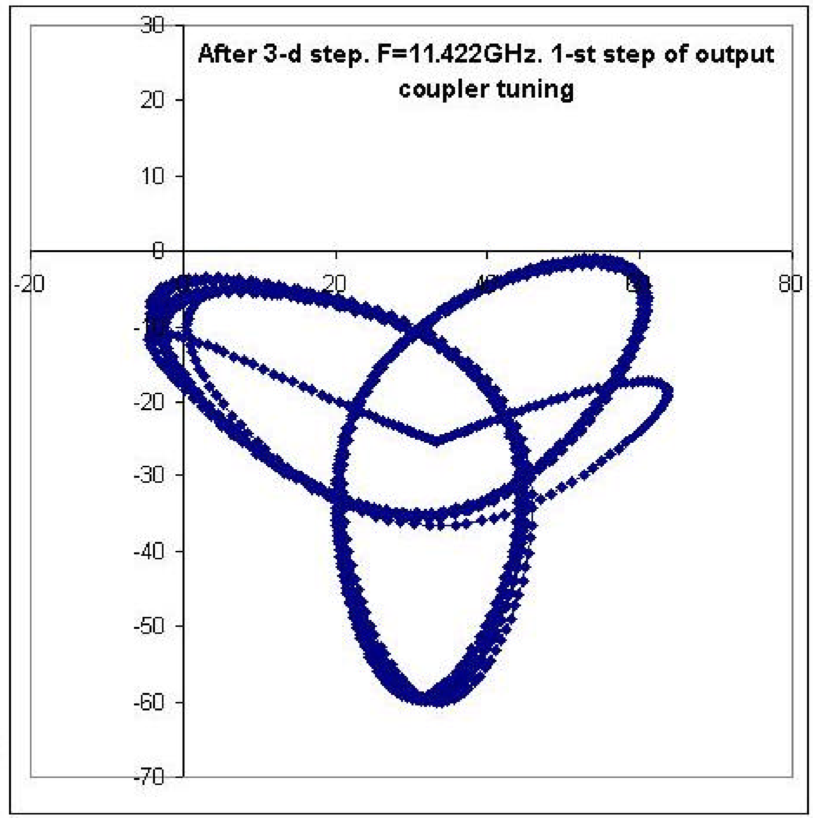
Another Tuning Step: Stay at 11.422 GHz, and tune couplers.

Before

(same as "After" on previous slide)

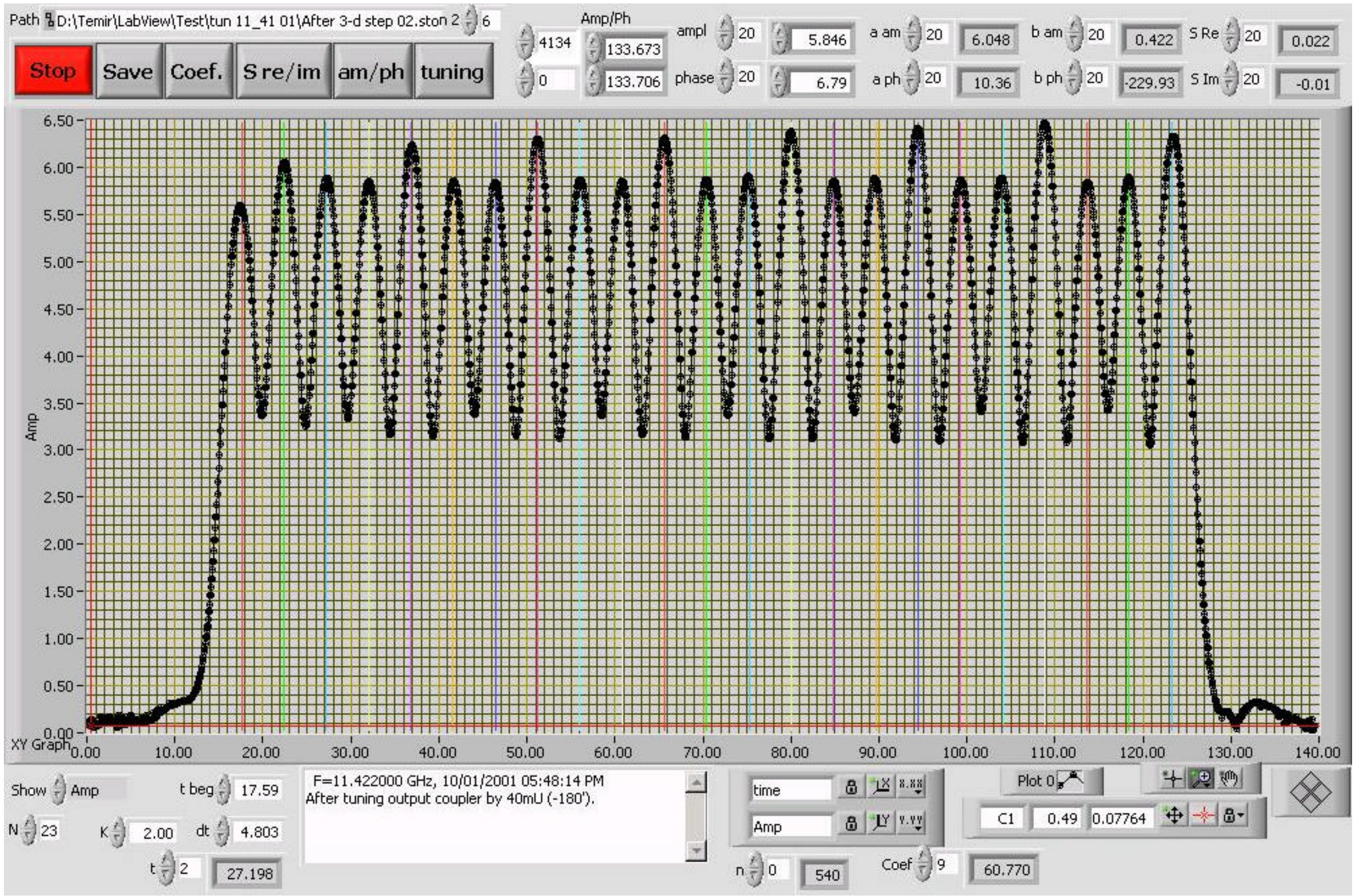
After





RF Measurements on FXA-001

Amplitude vs. time after coupler tuning at 11.422 GHz.



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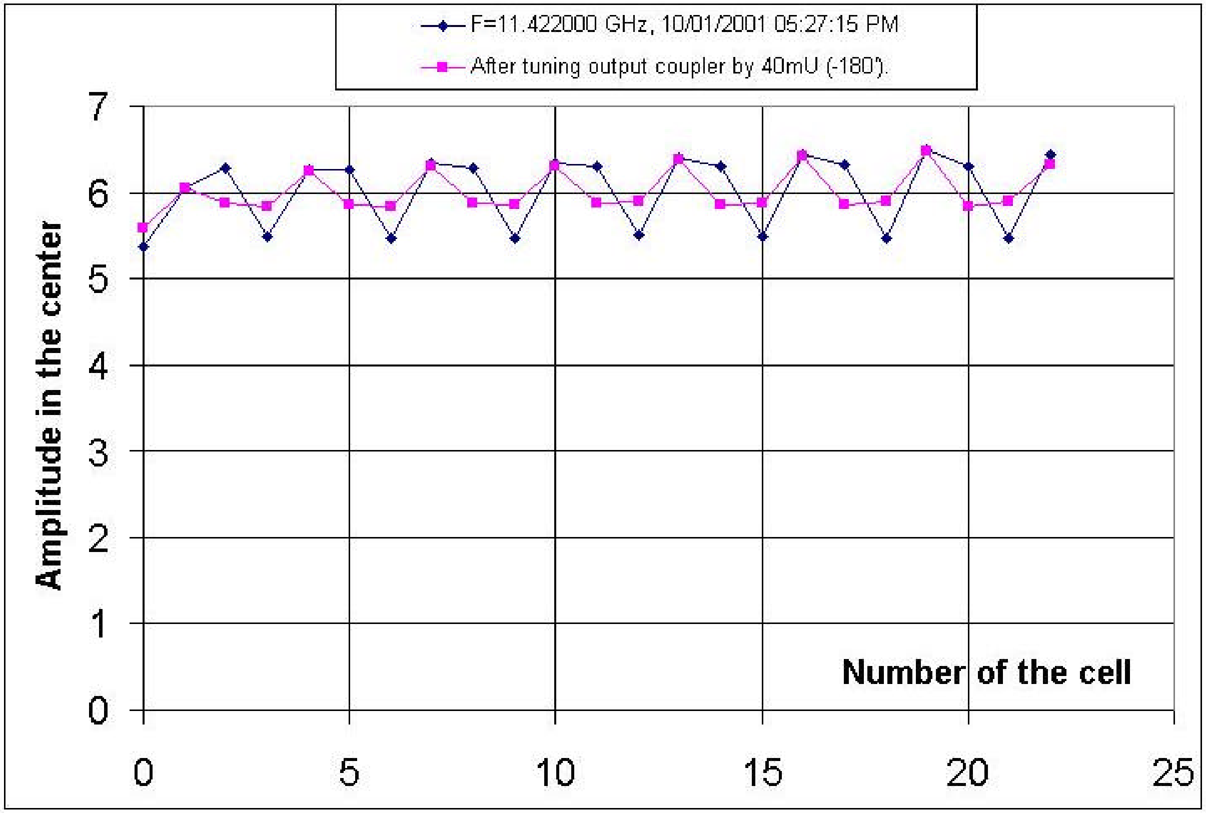
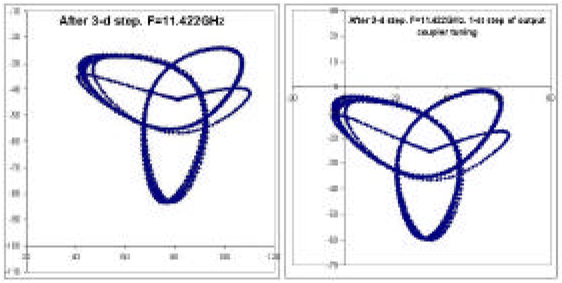
RF Measurements on FXA-001

- Amplitude vs. cell number at 11.422 GHz before and after tuning output coupler.



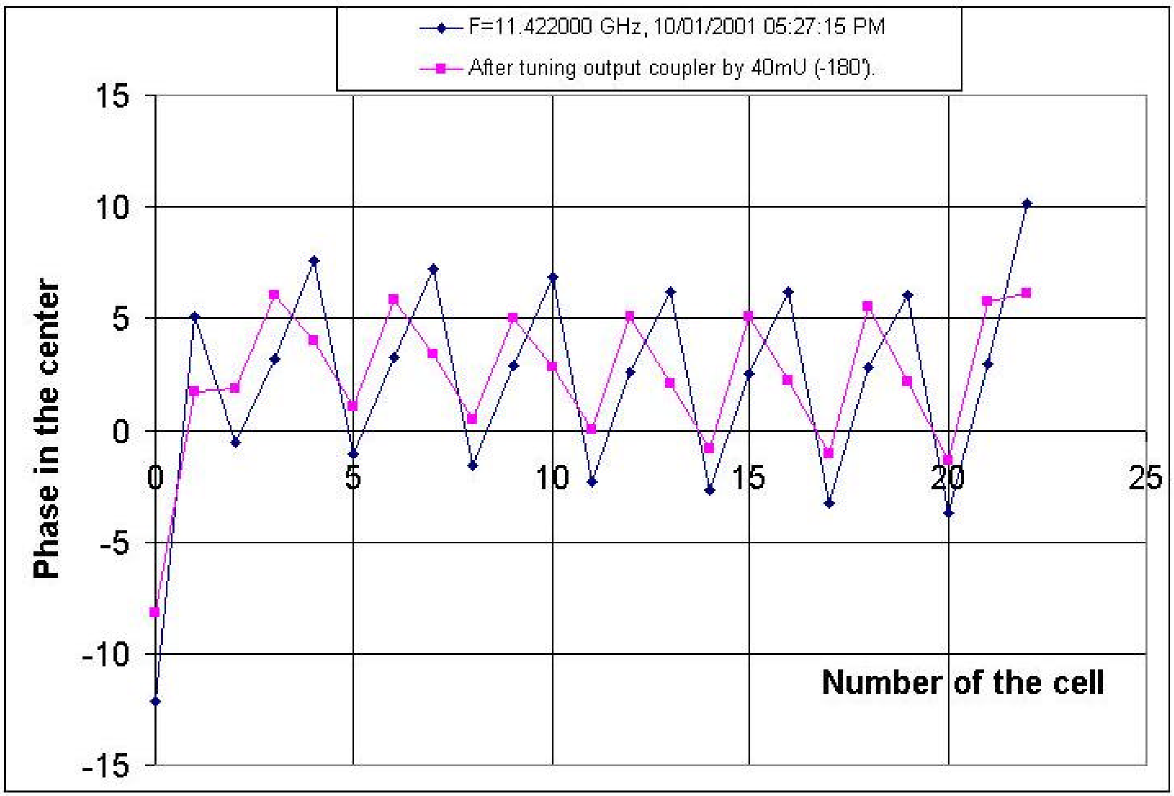
- Same data as:



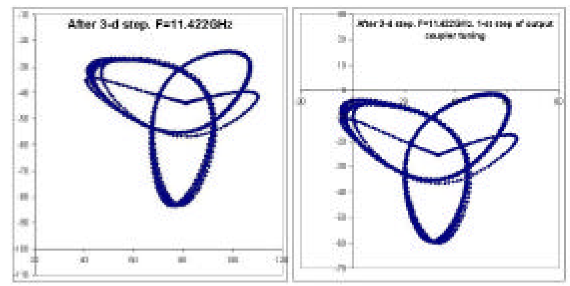
from two slides ago … but the differences are shown more clearly in this plot.

RF Measurements on FXA-001

- Phase vs. cell number at 11.422 GHz before and after tuning output coupler.



- Same data as:



from two slides ago … but the differences are shown more clearly in this plot.

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Summary of FXA-001
(David Finley's Observations and Tactics)

- It is a learning experience (it is not junk) and it has taught us some of what we need to learn to join copper together.
  - But it is not an accelerating structure, and may or may not be used for "high gradient" structure tests.

- Next we want to
  - see if we can make FXA-002 and FXA-003 "the same but better than" FXA-001,
  - make ~1 / month rather than ~1 / year,
  - make structures for high gradient testing,
  - make structures good enough for the NLC Main Linac,
  - make two girders with six structures on each girder.

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The Next Steps for X-Band Structures at Fermilab (David Finley, Harry Carter et al)

- Engineering Teams (Harry Carter)
  - FY02 Budget includes 180 FTE-days at SLAC
  - Present emphasis is on Technical Division effort
  - Note: Engineering Teams include TESLA
- Make Structures for the Eight Pack Test
  - Note: No longer talking about ETF at Fermilab.
  - But still involve industry as much as possible
    - For example, SBIRs

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Engineering Teams (Harry Carter and David Finley)

Originally created to help focus on Technical Division FY02-03 goals for Linear Collider R&D. But expanded to include more and is a **moving target** at this time.

Recall: Fermilab's Linear Collider R&D Goal:
By the end of 2003, complete the R&D work leading up to CD-1.

For X-Band (NLC)

- **Fermilab RF Factory**
- **Structures (Mechanical)**
- **Structures (Electrical/RF)**
- **Girders**
- **Vacuum System**
- **Cooling Water System**
- **Specifications Development**
- **Quality Assurance Development**
- **8 Pack Integration**

Both TESLA and NLC

- **FNAL Cleaning Facility**
- **SBIRs**
- **Permanent Magnets**
- **Demonstration of Remote Accelerator Operation**
- **Siting LC's near Fermilab**
- **Etc etc**

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Structures for Eight Pack Test

- Eight Pack Test at SLAC (Dave Schultz)
  - In Phase II, a “pack of eight klystrons” will feed
    - 11.424 GHz X-Band power into
    - a modified DLDS system and
    - power two girders worth of structures
    - with the full power and energy required by the NLC design.
  - The (impossible) goal is to be done by the end of FY03
- Girder A: 6 High Gradient Test Structures (FXBs)
- Girder B: 6 NLC Main Linac Structures (FXCs)

The (Fermilab) Plan for X-Band Structures

- In FY02 (with $1.95M)
  - Make FXA-002 and FXA-003
    - 20 cm long, conventional machined, high gradient tests, 45 mm OD
  - Make FXB-001 thru 003
    - 90 cm long, conventional machined, high gradient tests, 61 mm OD
    - Assume same coupler design we had in FY01 (aka "sparky")
  - Start to order parts for FXC
    - Final NLC Main Linac Design >>> The Real Thing
    - 90 cm long, assume diamond turned, real accelerators
    - Note: Need FXC design (including couplers) by July 2002
- In FY03
  - Make FXB-004 thru 006 (plus two extras)
    - Assume better coupler design than we had in FY01.
  - Make FXC-001 thru 006 (plus two extras)
  - See how many we actually have in mid to late FY03 and decide what to do in FY04

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Status of X-Band Structures Fabrication

- Our First X-Band Structure
- Progress of RF Factory at IB4
- Assembly of FXA-001
- Measurements of FXA-001
    - Mechanical and RF (see right)
- The Next Steps and The Plan