

# Non- Invasive Bunch Length Monitor, Fast Kicker, Bunch Shaper, and Photogun.

**Electrodynamic**, DOE SBIR DE-SC0009509 SBIR Phase II, end of year 1

**PI:** Brock F. Roberts

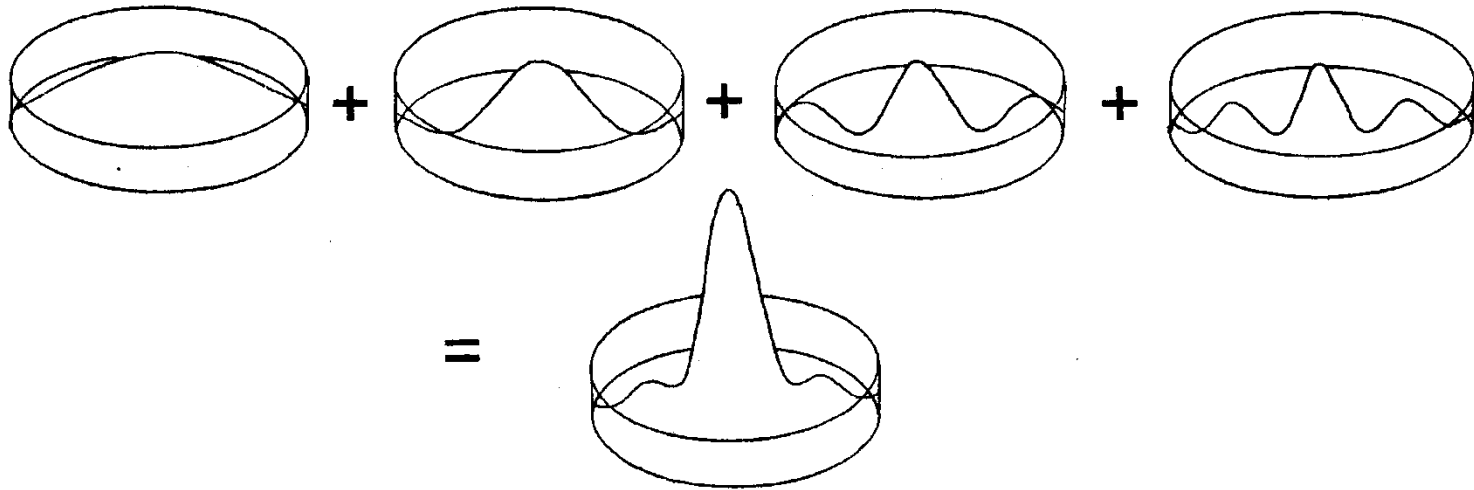
**DOE Phase II SBIR Topic: 41G**, Nuclear Physics Accelerator Technology, Accelerator Control and Diagnostics.

**Collaborator:** Thomas Jefferson National Accelerator Facility (TJNAF). Continuous Beam Electron Accelerator Facility, (CBAF). Center for Injectors and Sources (CIS)

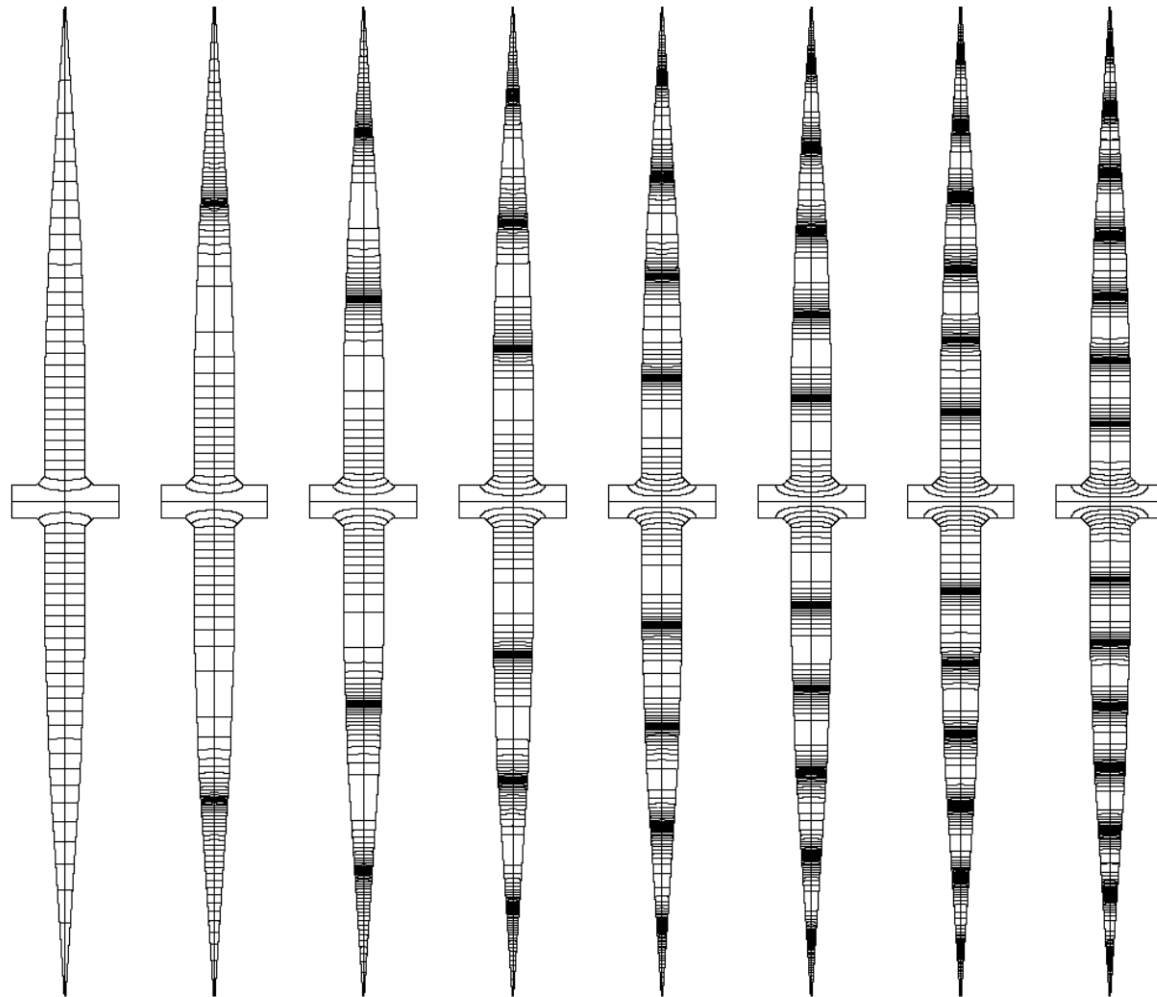
**Contractor:** University of New Mexico, Electrical Engineering Dept. Applied Electromagnetics group.

**Electrodynamic** : 4909 Paseo Del Norte suite D, Albuquerque, NM 87113 (505)-225-9729

Can several harmonic  $TM_{0N0}$  modes be simultaneously superimposed?



Yes, the cavities shape tunes the  $TM_{0NO}$  modes to be Harmonic



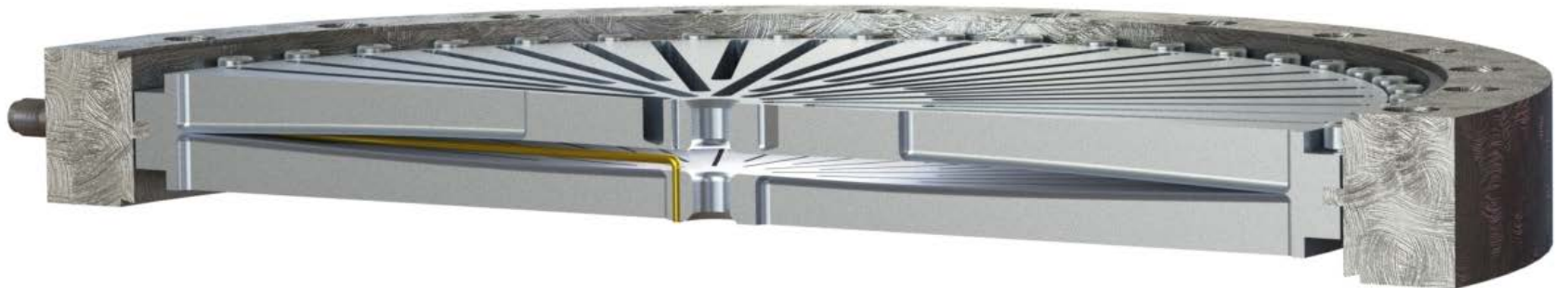
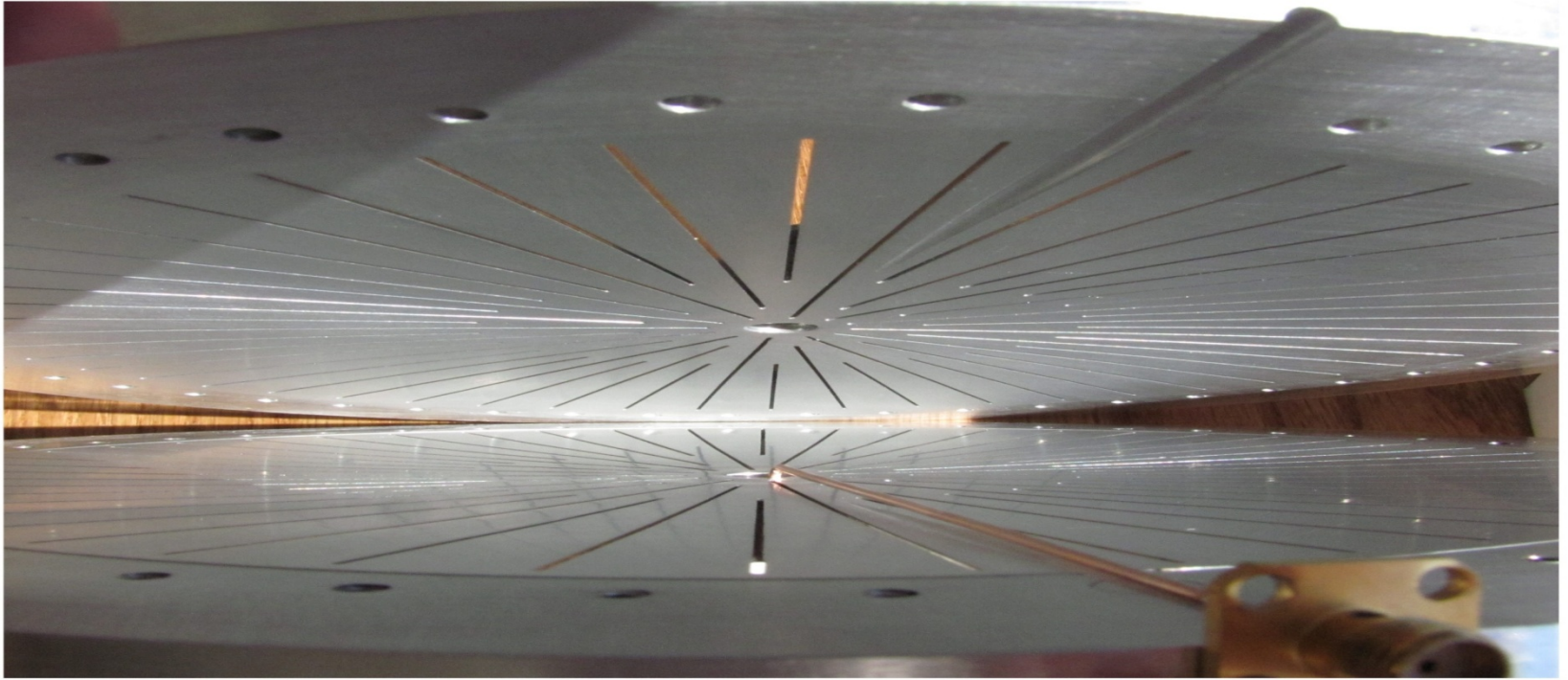
There are many harmonic geometries!

Efficiency



Bandwidth

# Wideband Antenna

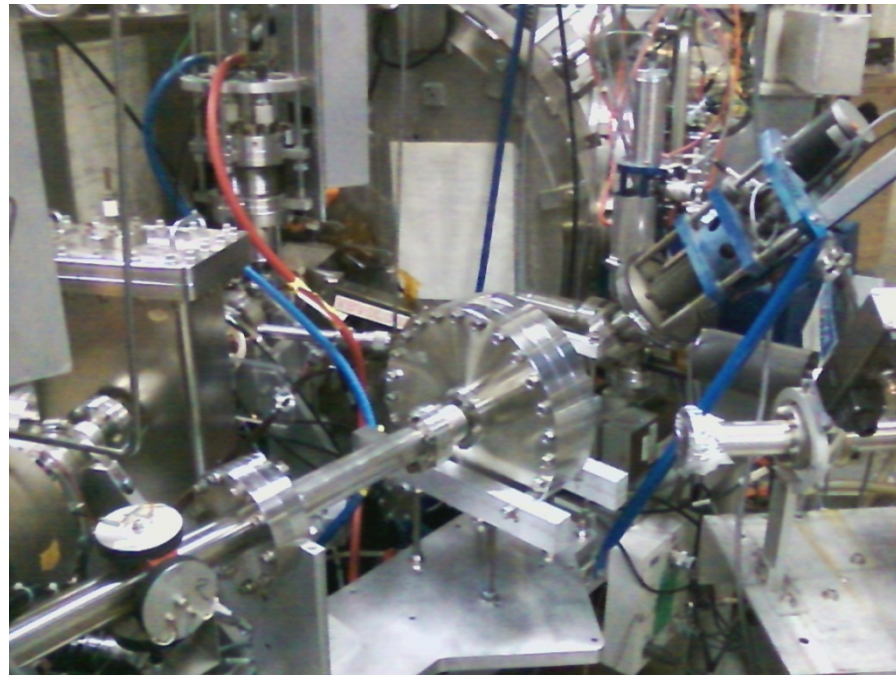
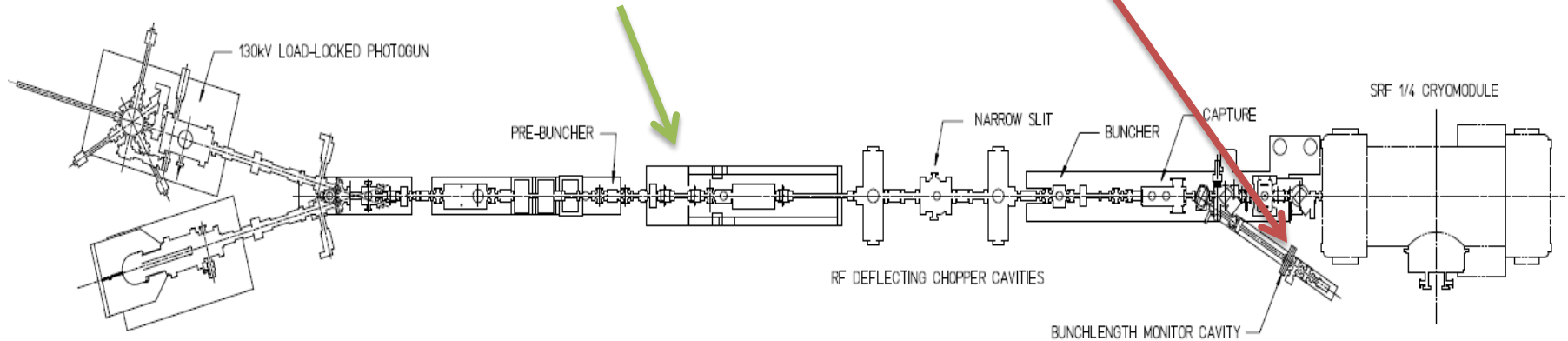






Beam Monitor

# Beam Monitor Evaluation and Integration into CEBAF's injector



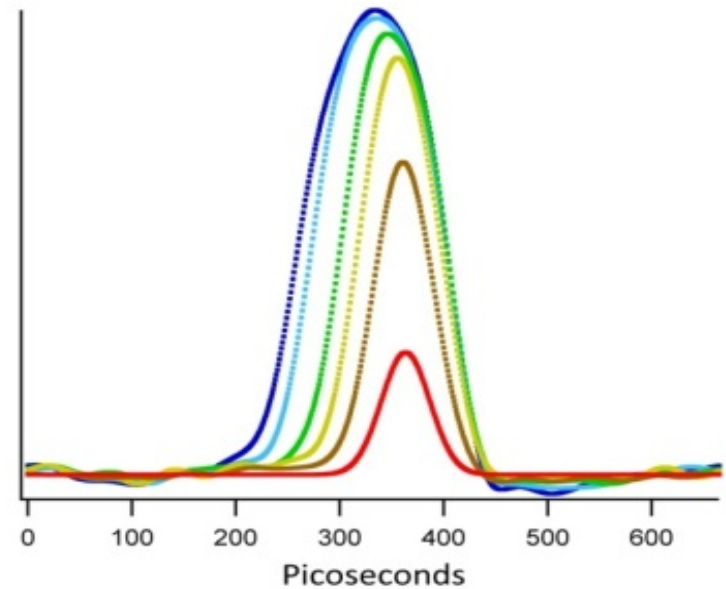
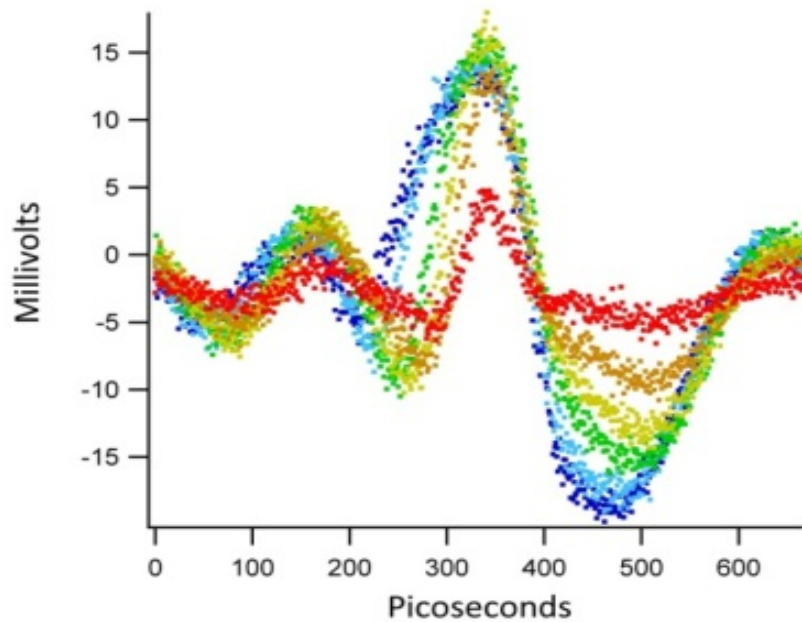
The detected waveform is the superposition of the cavity modes excited by the beam. The beam can be described in the same format; the compact trigonometric form of their Fourier series

$$F(v_{detected}(t)) = a_{TM_{010}} \cos(\omega_0 t + \theta_{010}) + a_{TM_{020}} \cos(2\omega_0 t + \theta_{020}) \dots + a_{TM_{0n0}} \cos(n\omega_0 t + \theta_{0n0}).$$

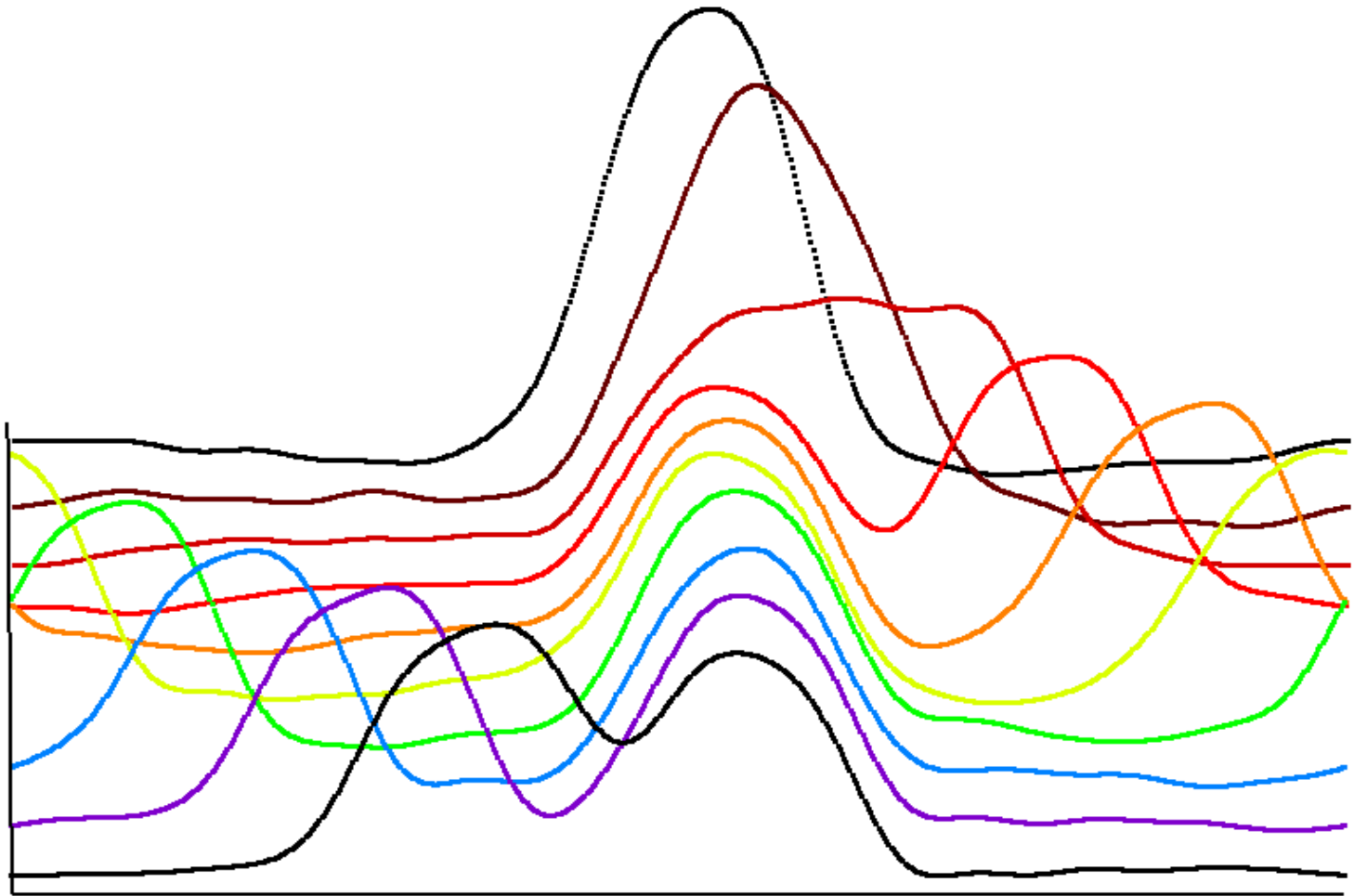
$$F(i_{beam}(t)) = a_1 \cos(\omega_0 t + \theta_1) + a_2 \cos(2\omega_0 t + \theta_2) \dots + a_n \cos(n\omega_0 t + \theta_n).$$



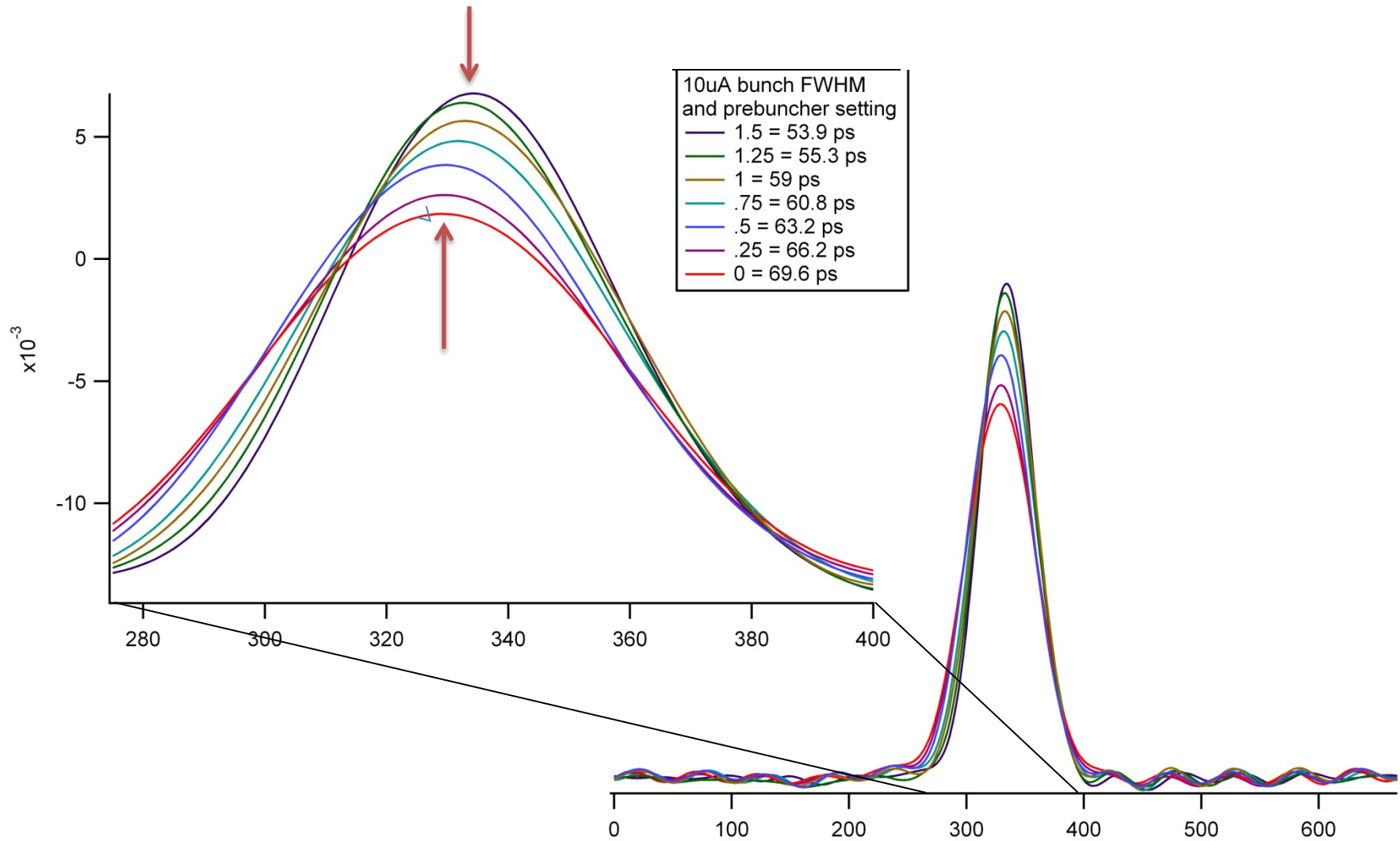
The ratio of these two series is the harmonic cavities transfer function. Once determined, the cavities transfer function can be used to un-distort subsequent data independent of new bunch shapes.



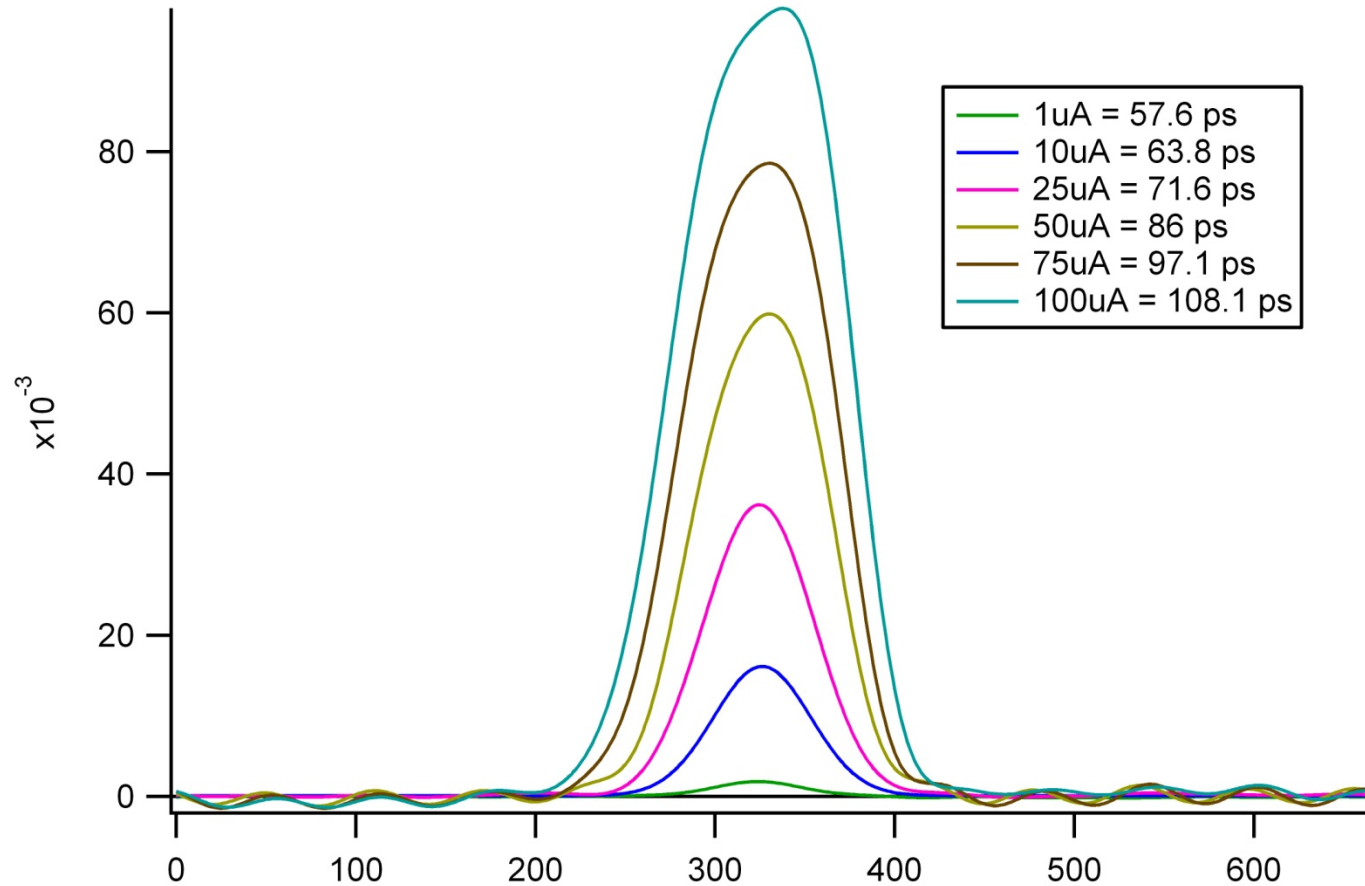
# Measurement of Two Interleaved 499 MHz beams.



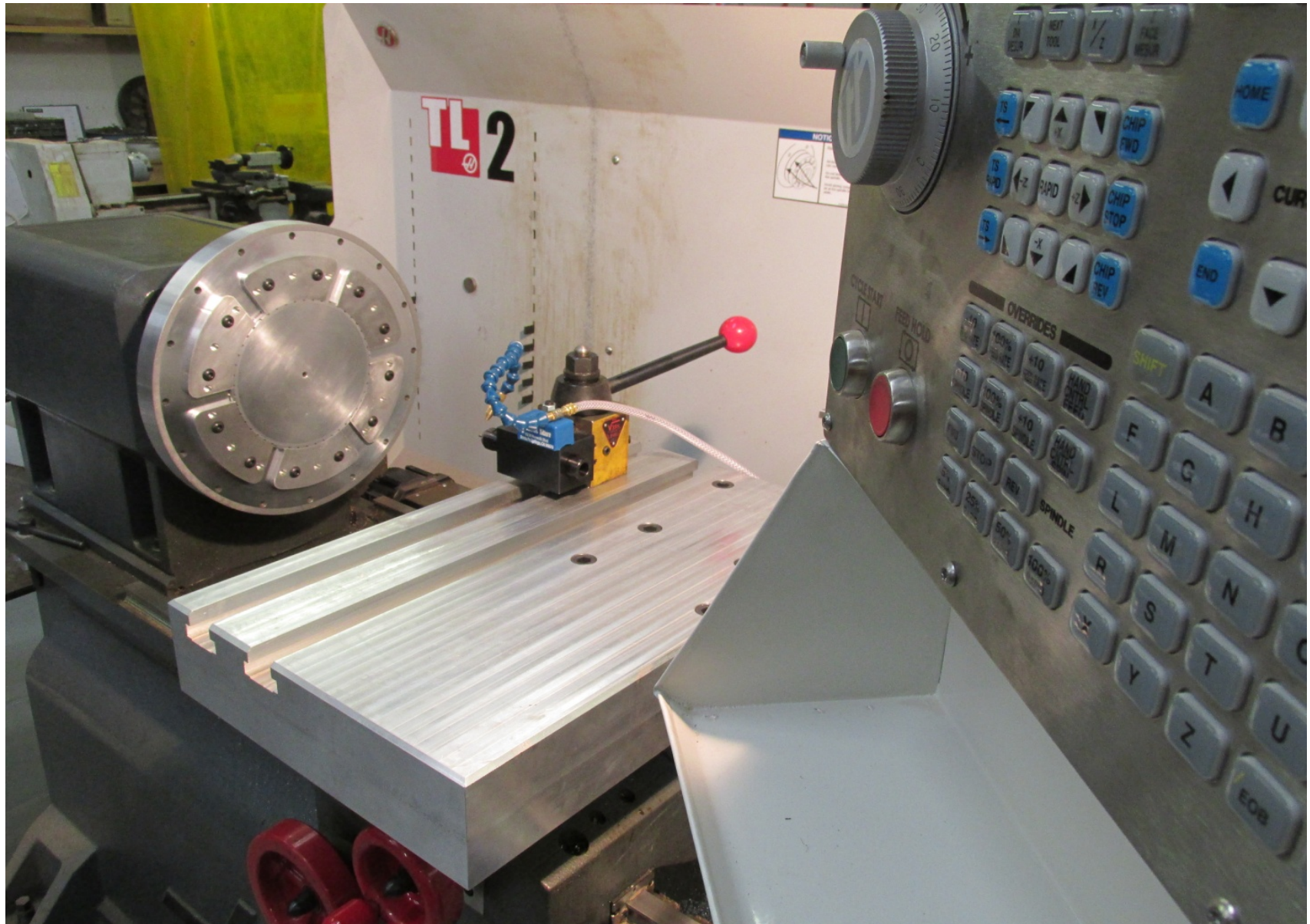
# Setting the Buncher Phase



# Bunch Width Measurement



# CNC Lathe and Vacuum Chuck

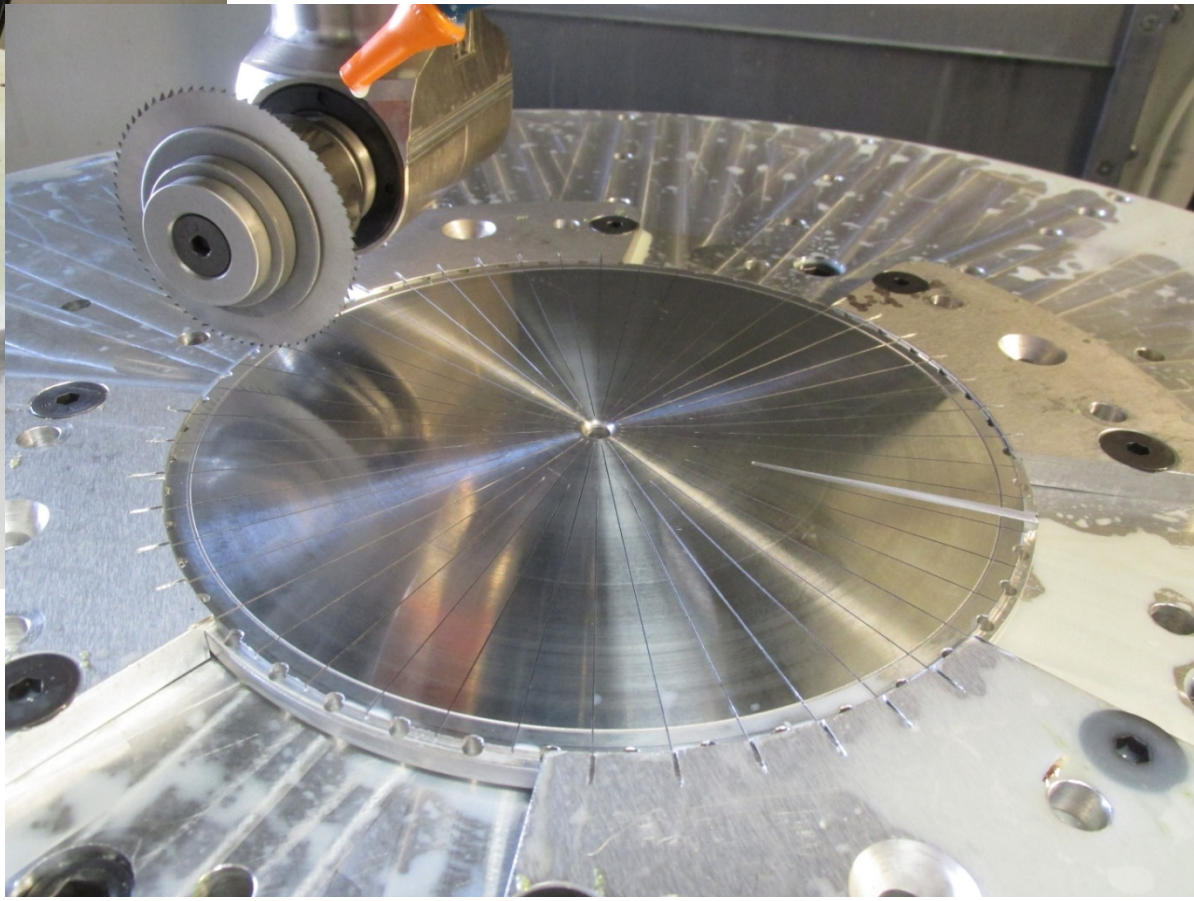
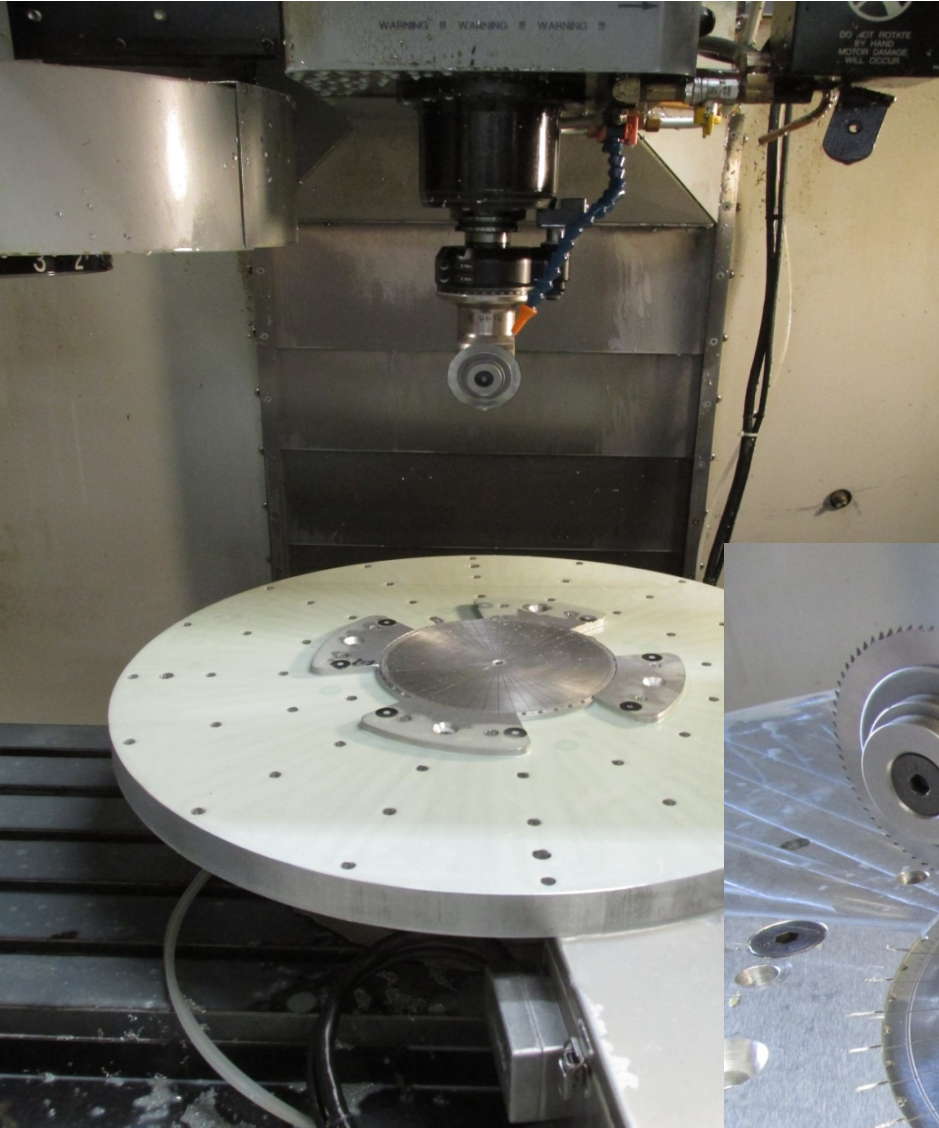






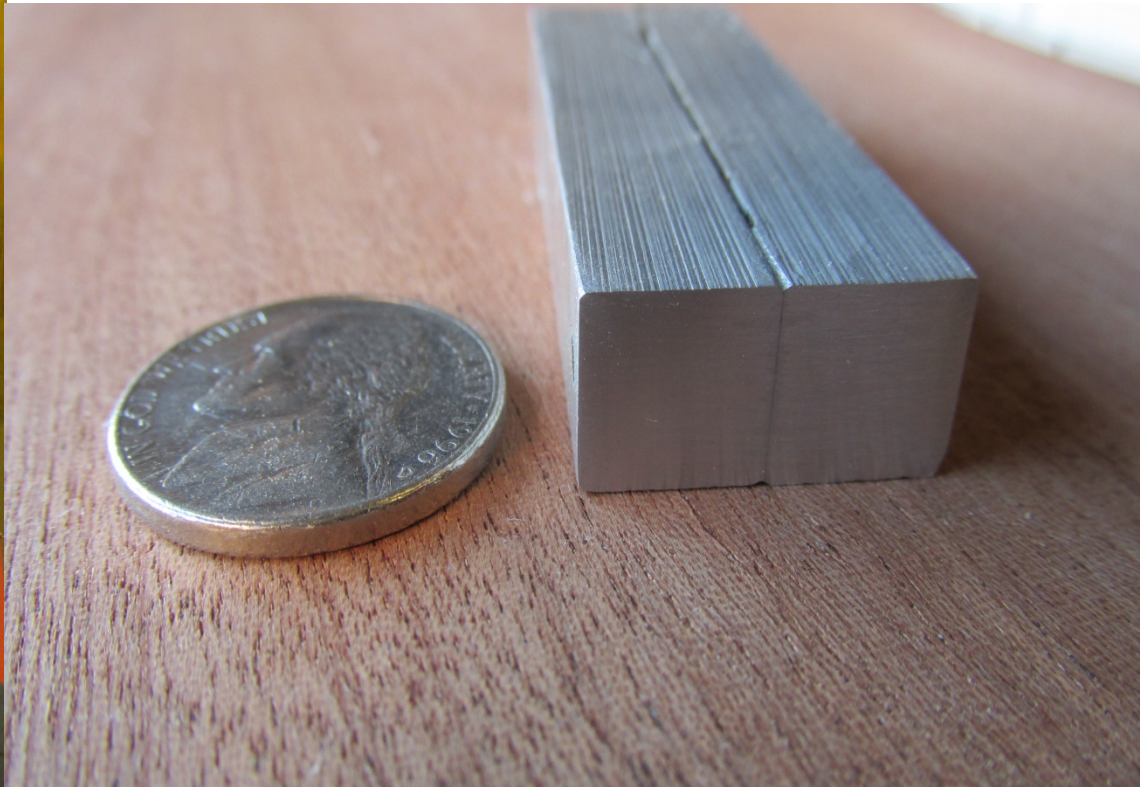


# Slitting Saw on CNC Mill with 26" rotary

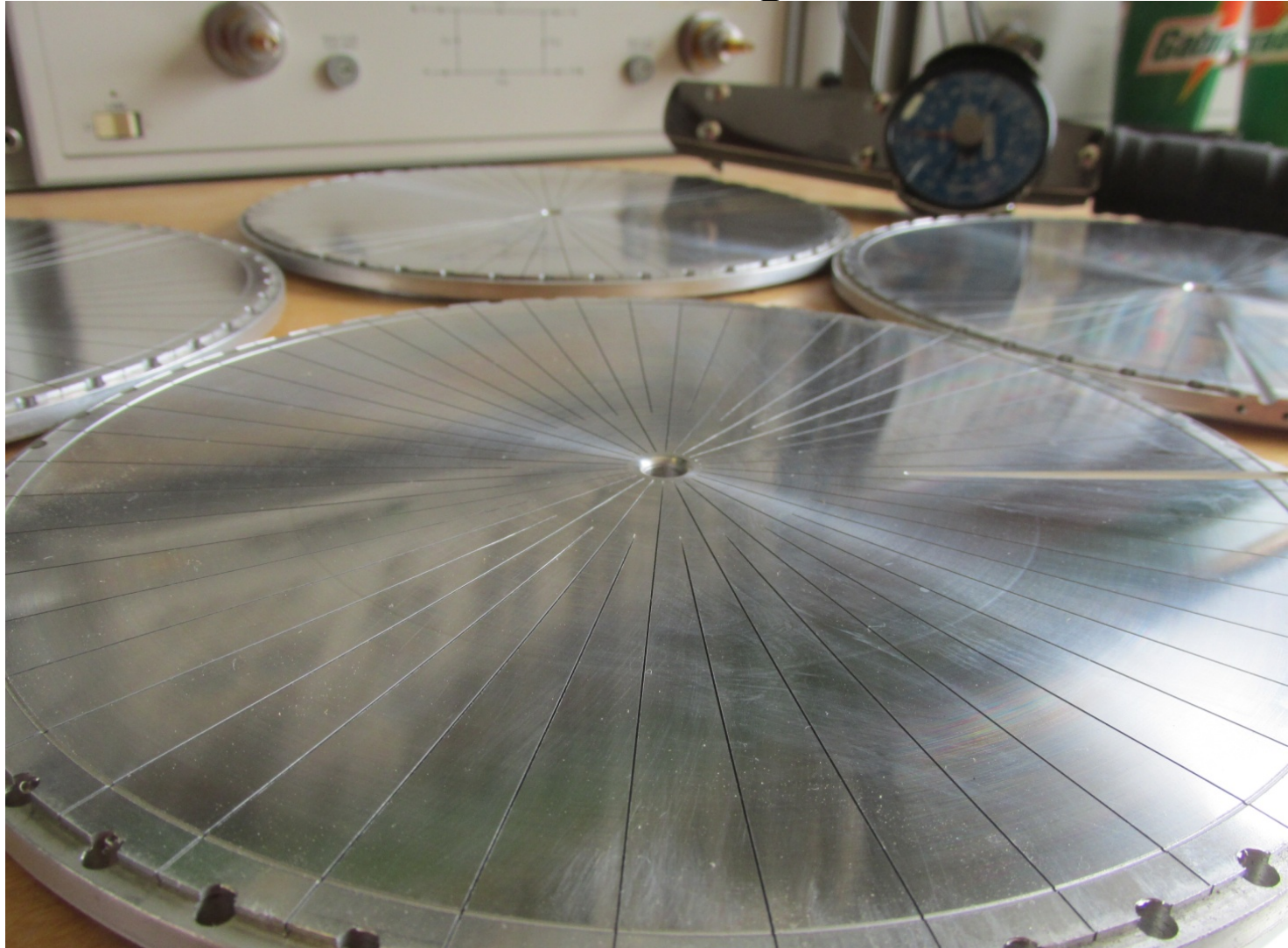




# Brazing in Argon Gas

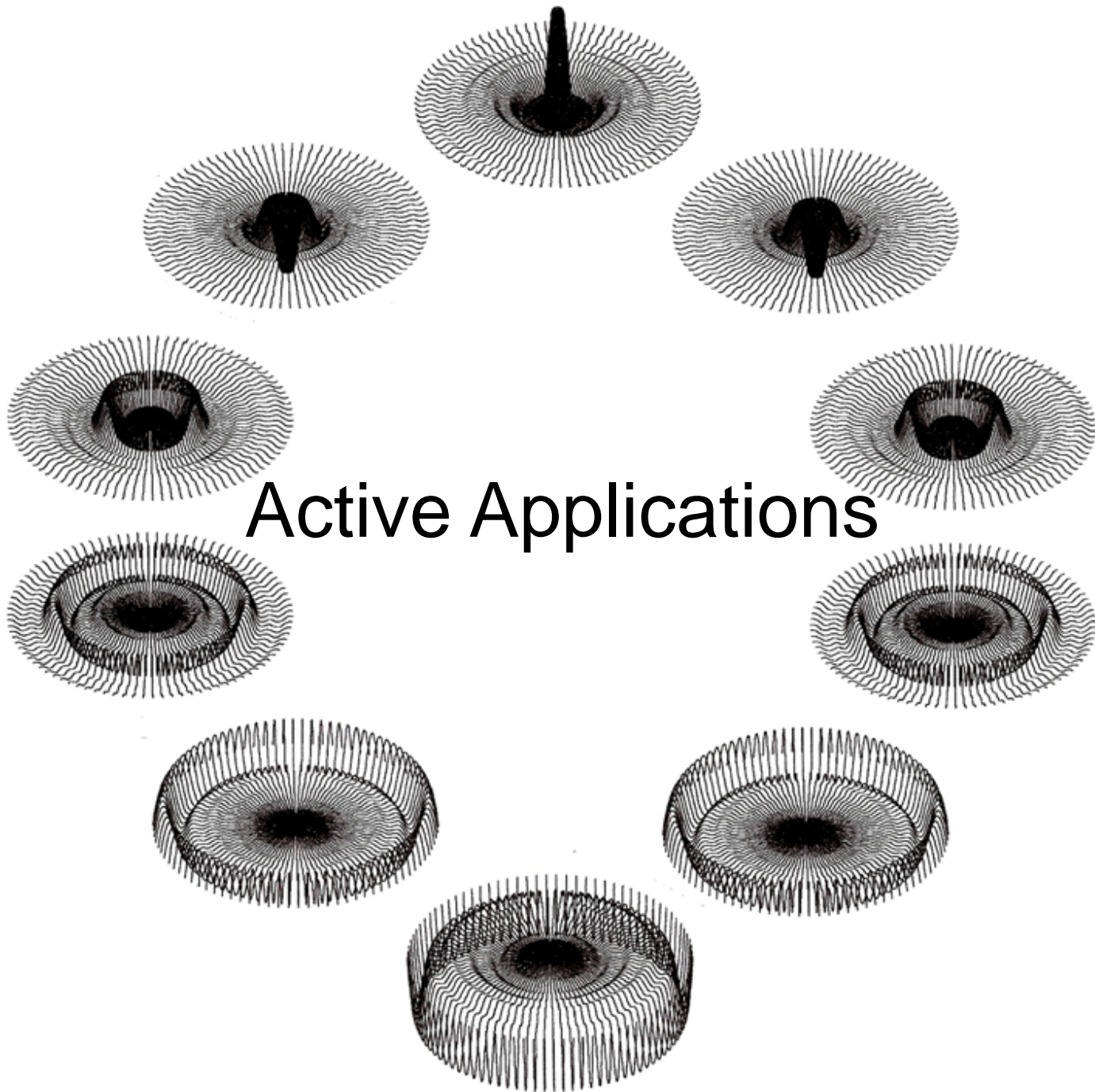


# New Cavities Ready for Bench Testing





# Active Applications





# Harmonic Arbitrary Waveform Generator (HAWG)



# HAWG Graphical User Interface

File Edit Format View Help

```
[GENERAL]
Description=Standard settings for ElectroDynamics
master_offset=0
num_controllers=16

[controller_1]
amplitude=50
phase=291
name=Fundamental
divisor=1
dac1_offset=0
dac2_offset=0
paactive=1

[controller_2]
amplitude=100
phase=189
name=2nd Harmonic
divisor=2
dac1_offset=0
dac2_offset=0
paactive=1

[controller_3]
amplitude=100
phase=27
name=3rd Harmonic
divisor=3
dac1_offset=0
dac2_offset=0
paactive=1

[controller_4]
amplitude=100
phase=339.5
name=4th Harmonic
divisor=4
dac1_offset=0
dac2_offset=0
paactive=1

[controller_5]
amplitude=36
phase=164
name=5th Harmonic
```

File Help

## Standard Settings for ElectroDynamics

Control Channel	Phase	Amplitude	Active
1 Fundamental	20.56	76.90	True
2 2nd Harmonic	194.49	91.92	True
3 3rd Harmonic	30.02	100.00	True
4 4th Harmonic	339.50	100.00	True
5 5th Harmonic	164.00	36.00	True
6 6th Harmonic	326.40	75.00	True
7 7th Harmonic	261.00	79.00	True
8 8th Harmonic	353.70	55.00	True
9 9th Harmonic	51.44	88.24	True
10 10th Harmonic		123.91 73.50	False
11 11th Harmonic		64.27 92.14	False
12 12th Harmonic		0.00 100.00	False
13 13th Harmonic		0.00 100.00	False
14 14th Harmonic		0.00 100.00	False
15 15th Harmonic		0.00 100.00	False
16 16th Harmonic		0.00 100.00	False

UNKNOWN CMD5007FFFFE  
SET CHANNEL SUCCESS

P001  
RFSTATE=ON

### 2nd Harmonic

Phase 194.490 Ampl 92 Active

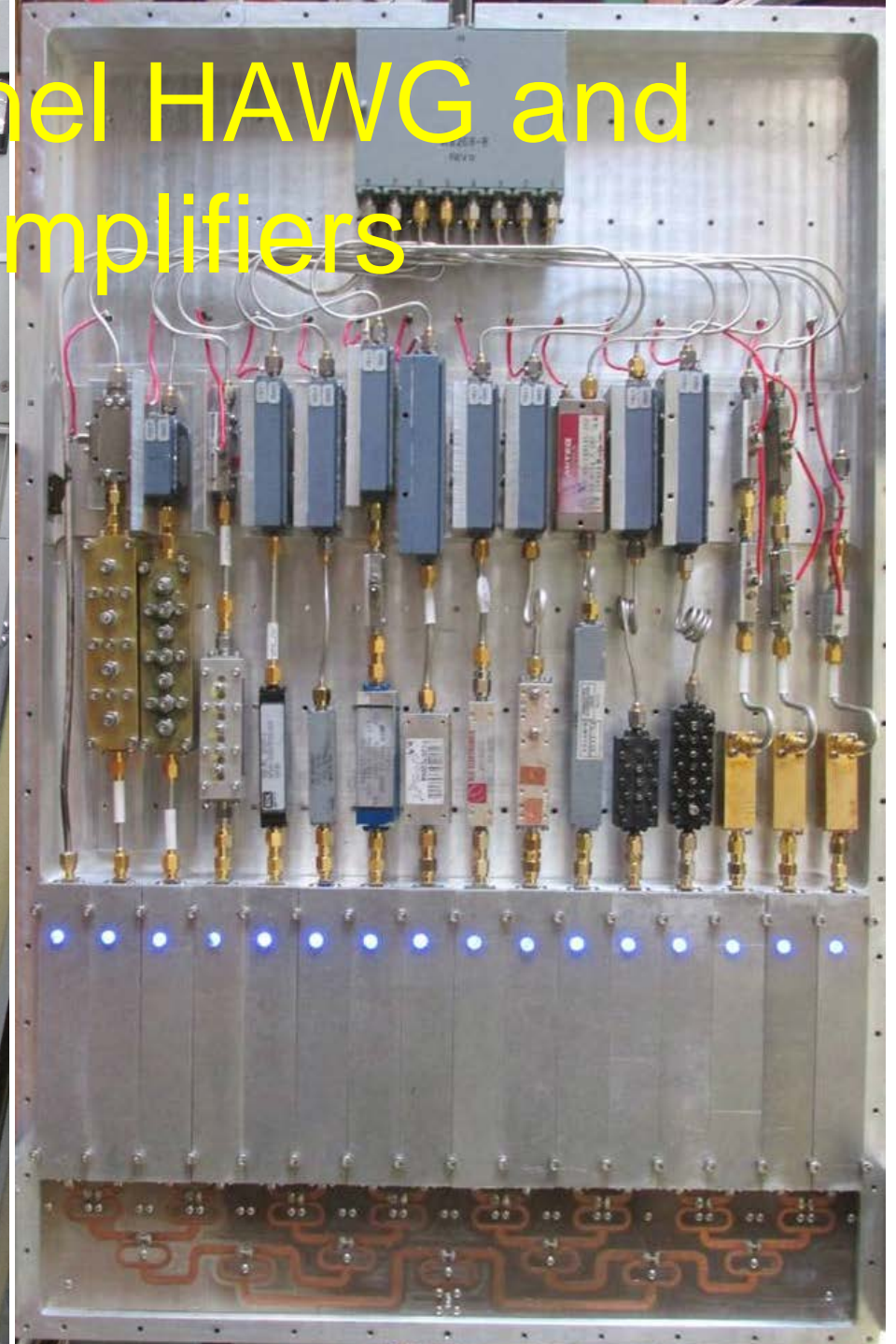
X: -88.99998 0E1 Y: -23.00008 628

Master Phase Offset 0.000

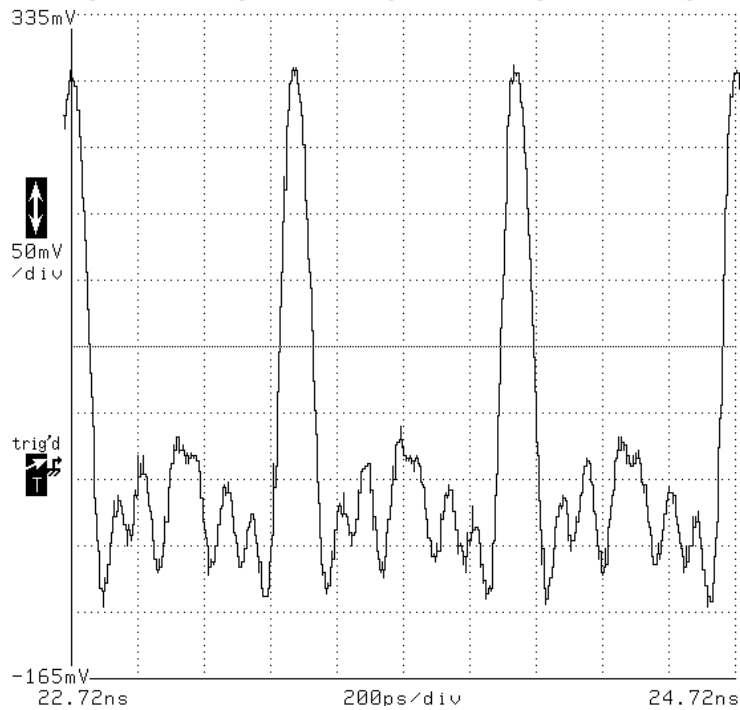
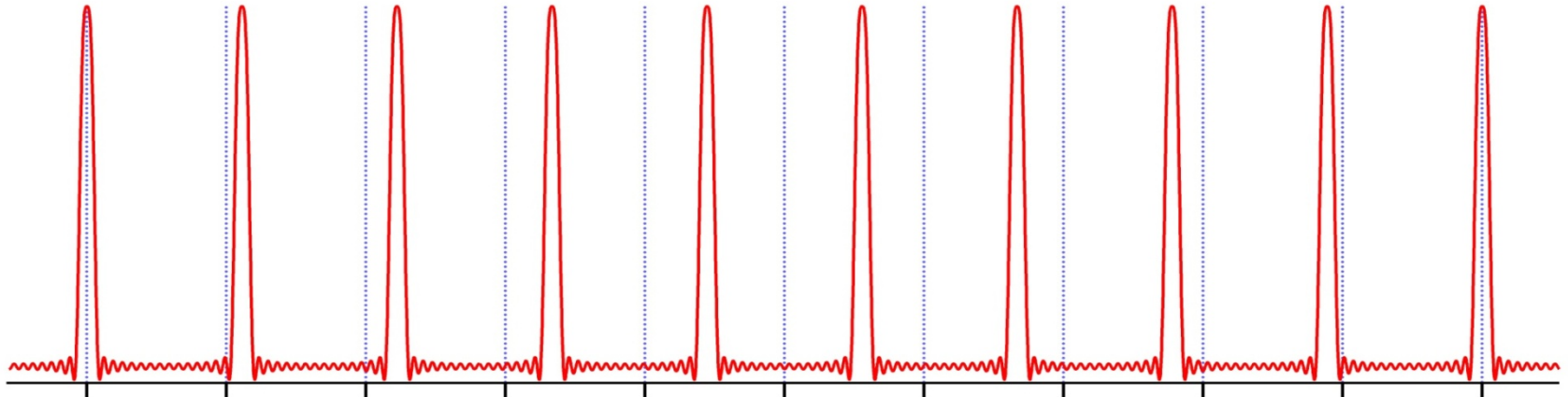
Reset Phases Reset Amplitudes



# Sixteen Channel HAWG and Power Amplifiers

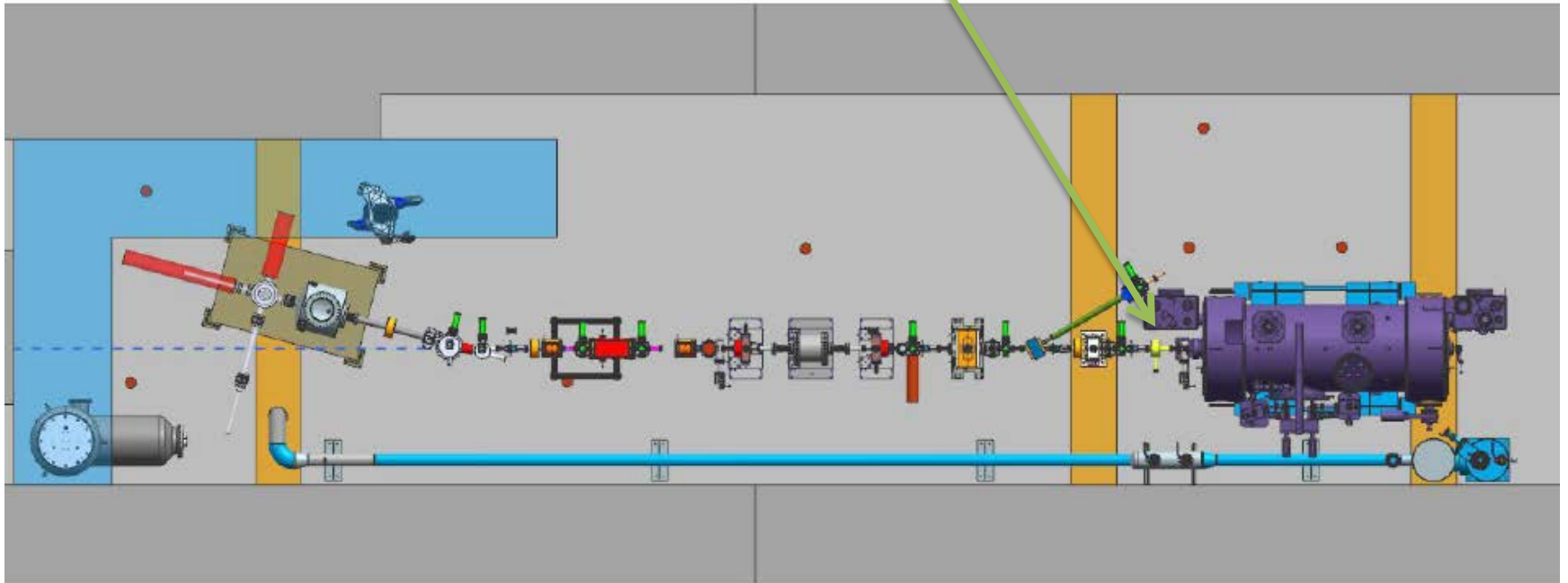


# Fractionally Interleaved Kicking





Harmonic cavities are here to stay!  
New injector plans include a  
harmonic cavity.





# Thank you for supporting the SBIR Program

- Stay tuned for this years activities.
- Better harmonic cavities will produce better beam monitors.
- Kicking and bunch shaping experiments will evaluate the feasibility of fractionally interleaved kicking and a bunch shaping photogun.
- Challenges: high power microwave re-combination.