



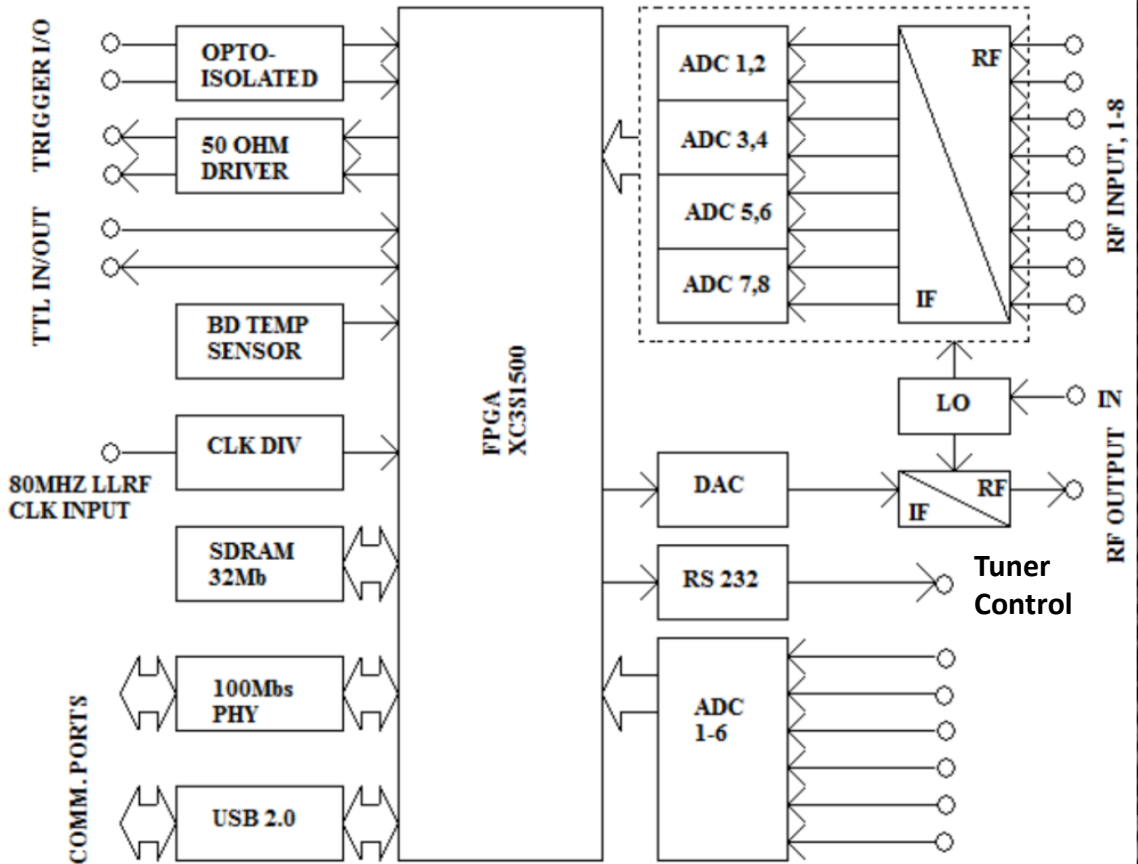
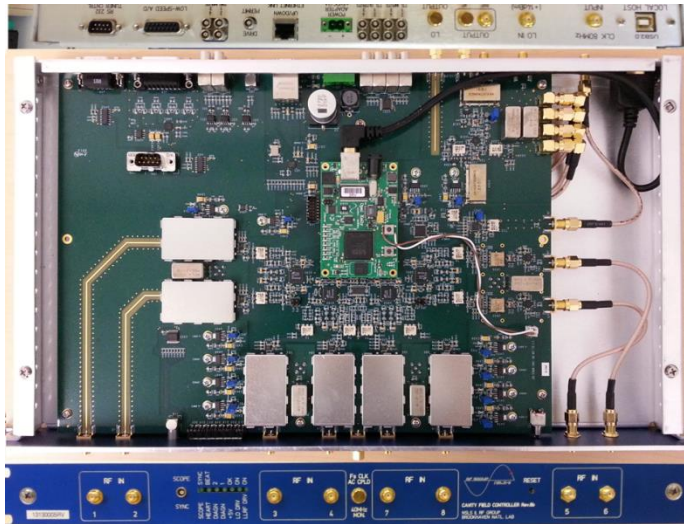
# Status of the NSLS-II LLRF

Carlos Marques, Brian Holub,  
Nathan Towne, James Rose



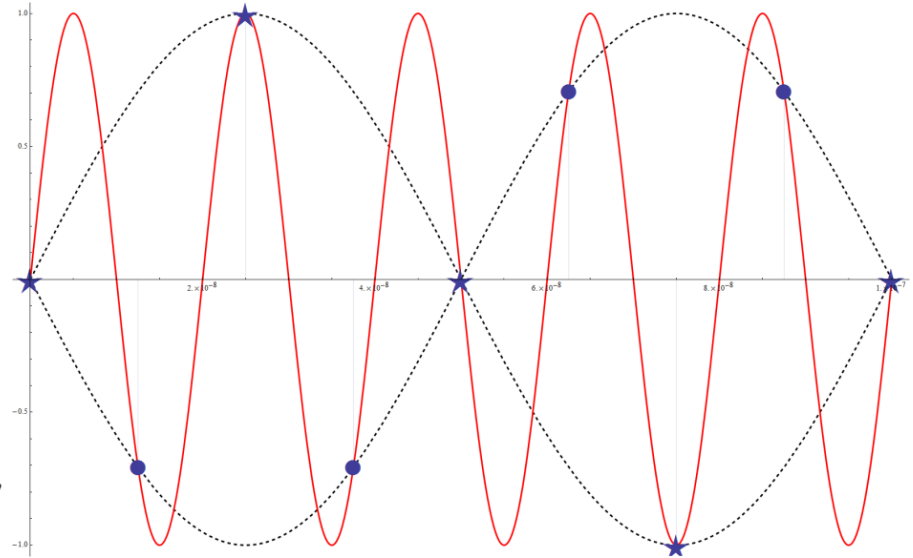
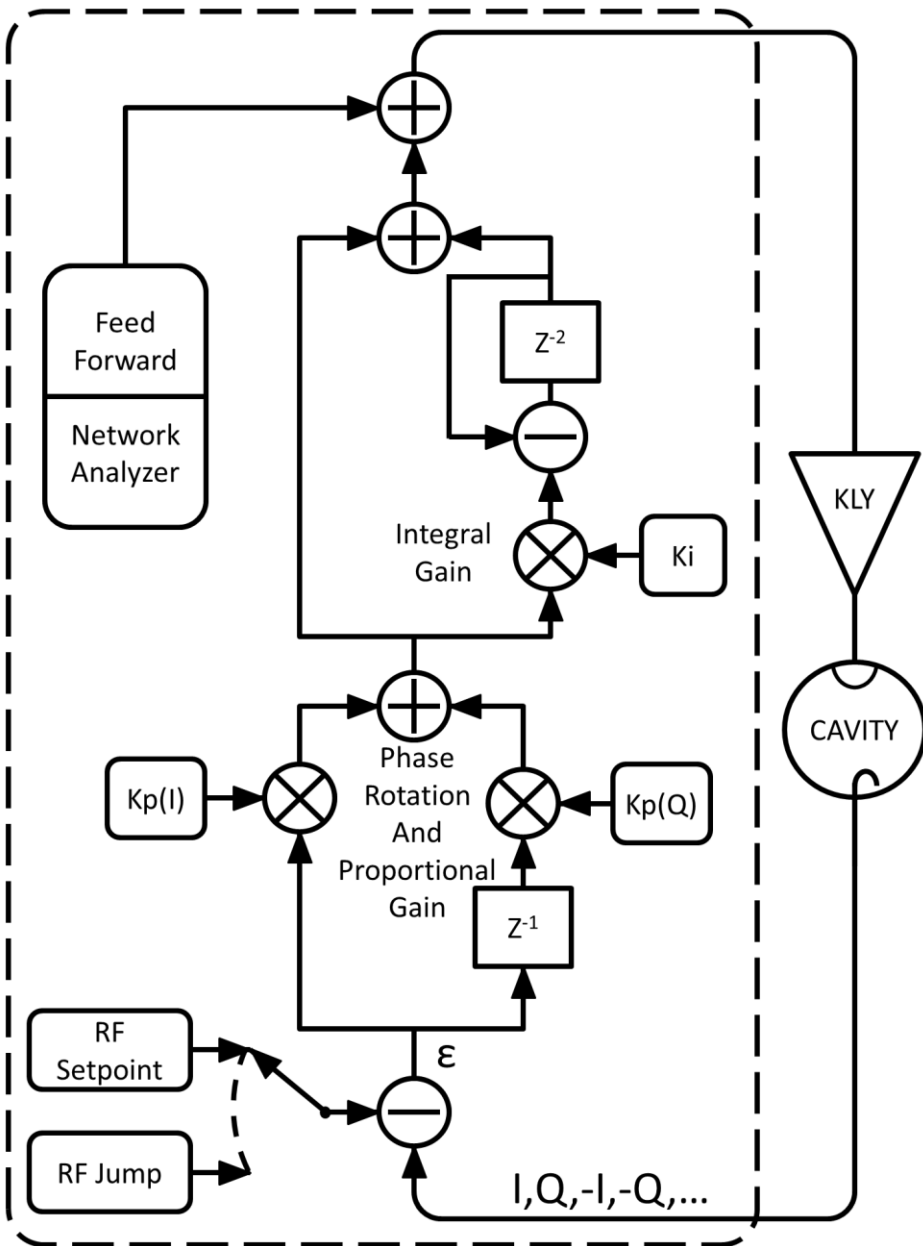
# HARDWARE PLATFORM

Designed by Hengjie Ma using a derivative of Lawrence R. Doolittle's SNS project.



- Relatively standard digital controller hardware (managed by a small group)
- MATLAB and EPICS interfaces can be run by any standard laptop
- With the proper up/down conversions this hardware can be implemented into any system

# DIGITAL FEEDBACK LOOP



$$|Kp| = \sqrt{Kp_i^2 + Kp_q^2}$$

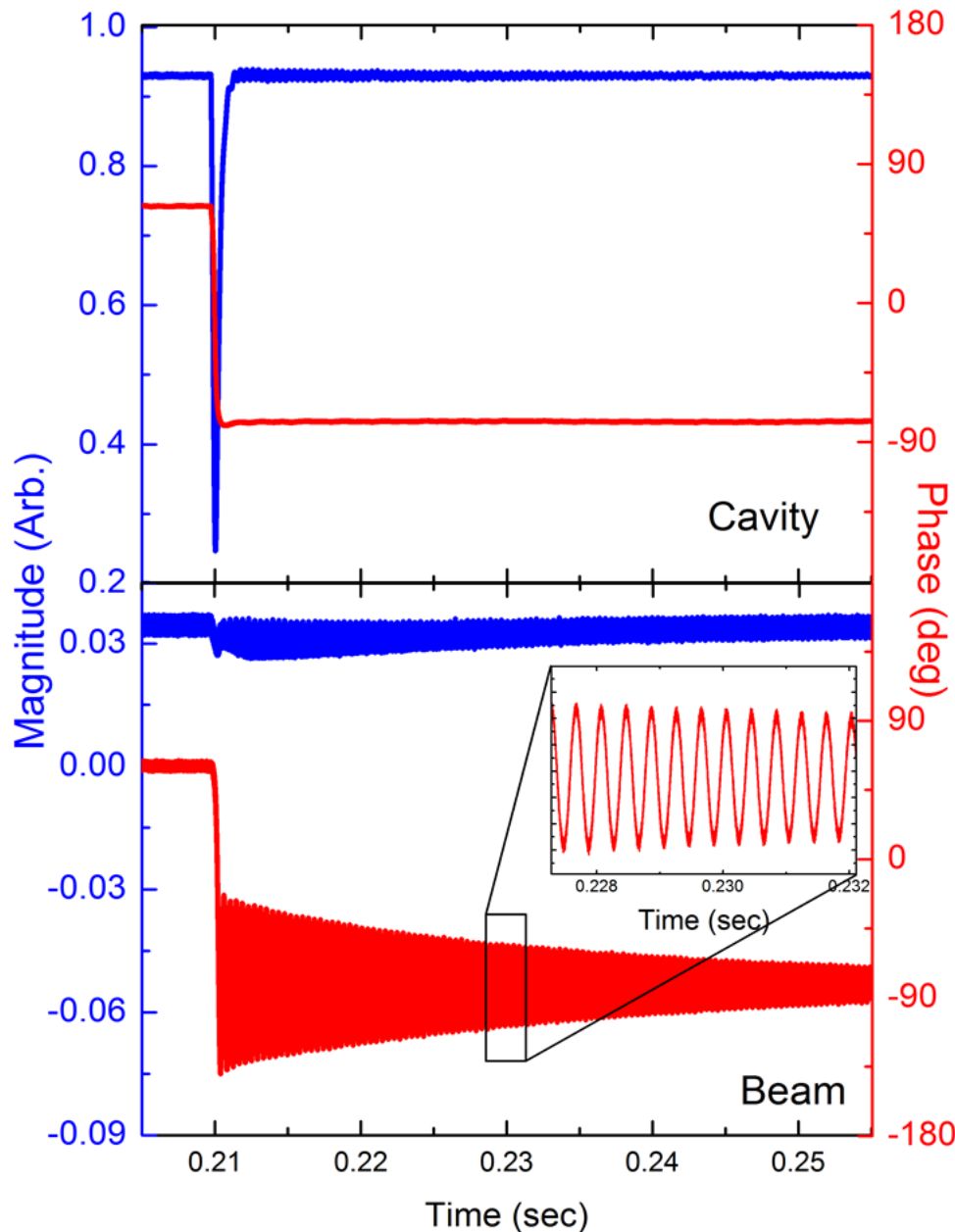
$$I' = I(Kp_i) - Q(Kp_q)$$

$$Q' = Q(Kp_i) + I(Kp_q)$$

$$-I' = -I(Kp_i) + Q(Kp_q)$$

$$-Q' = -Q(Kp_i) - I(Kp_q)$$

# AMPLITUDE/PHASE JUMP

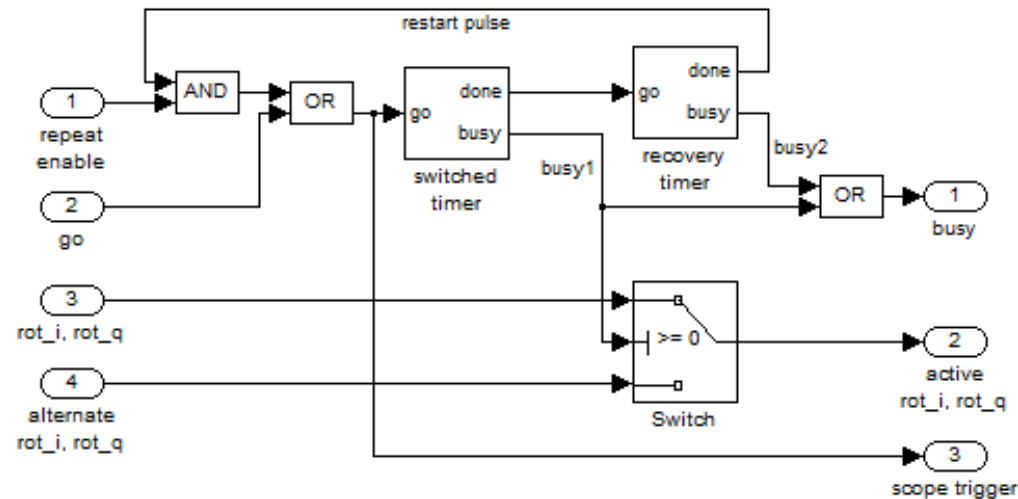
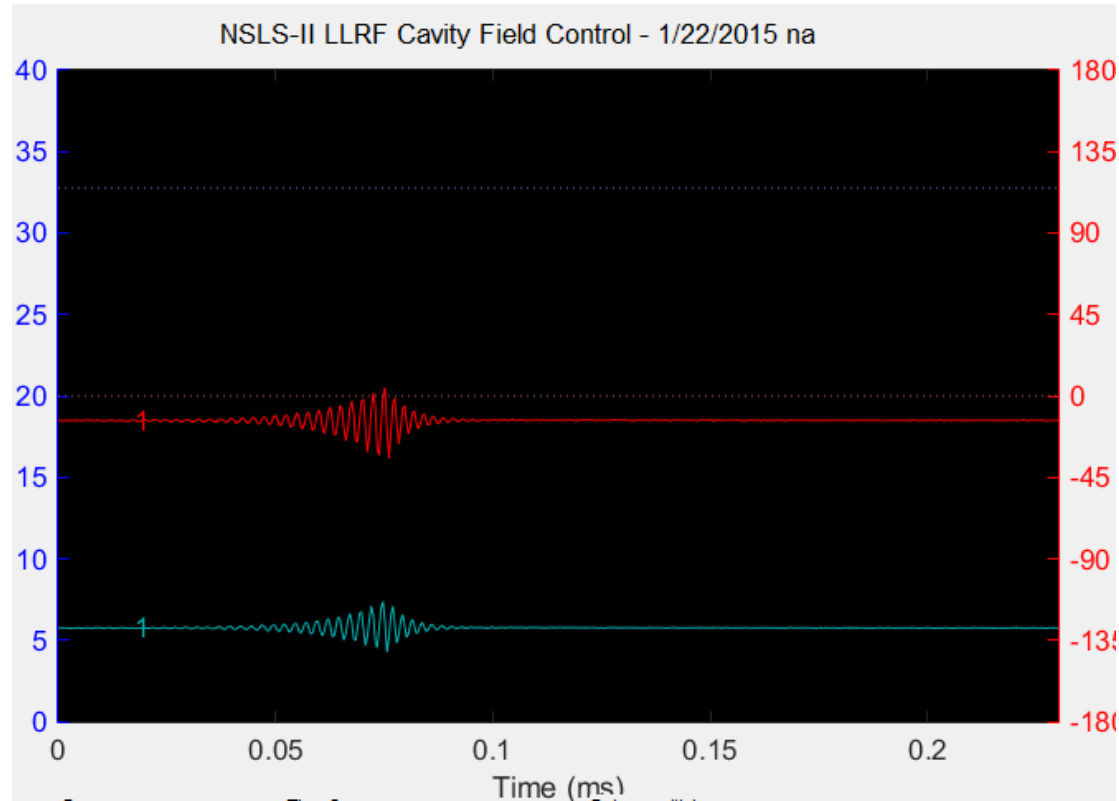


Phase or amplitude jump triggered by timing event is synchronized with turn by turn bpm data for measuring dynamic aperture, field non-linearities, etc. More information can be found in literature [1].

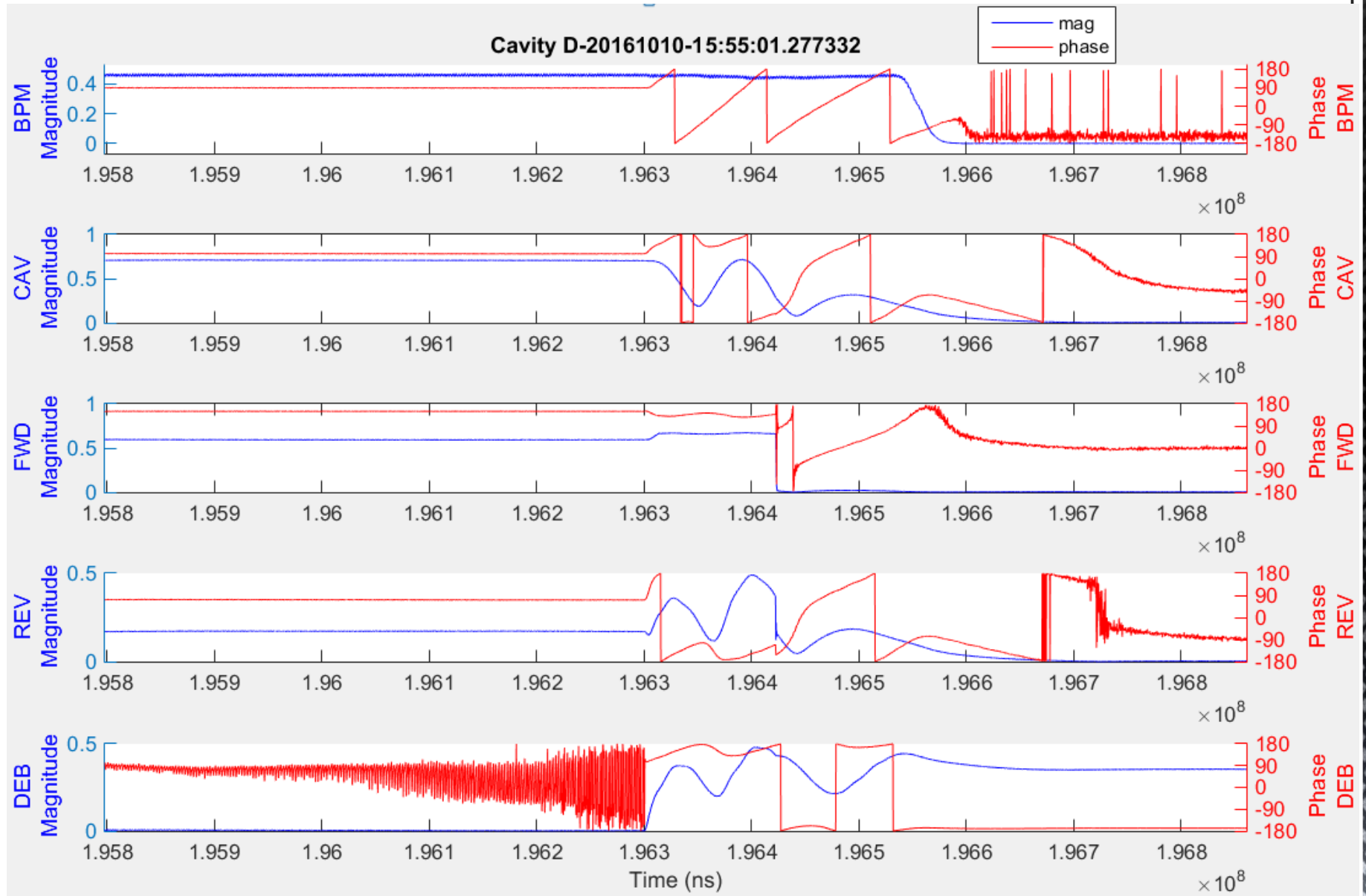
Figure to the left shows a phase jump of 120 degrees shown with beam response.

[1] G. M. Wang, et al. , "RF PINGER COMMISSIONING AND BEAM DYNAMICS STUDIES AT NSLS-II" IPAC2016, THOBA01.

# PULSED FEEDBACK GAINS

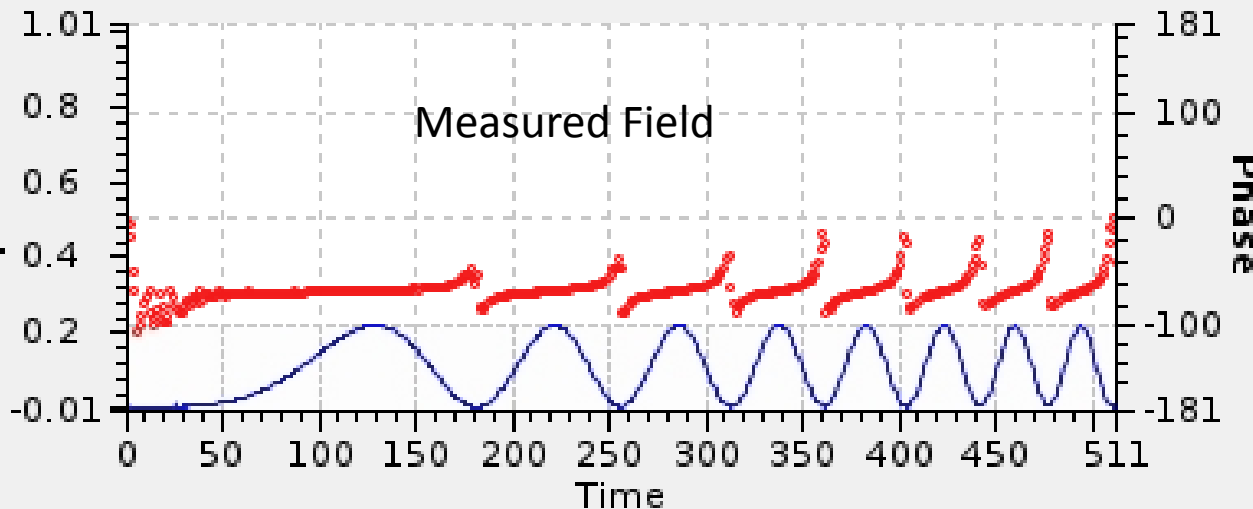
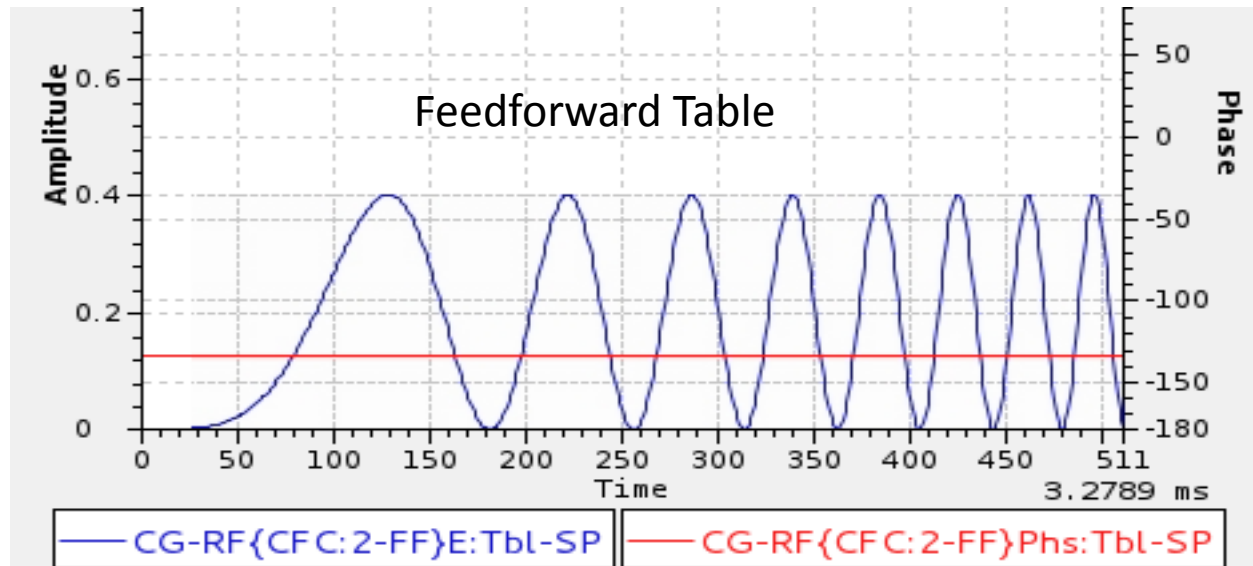


# CIRCULAR BUFFER





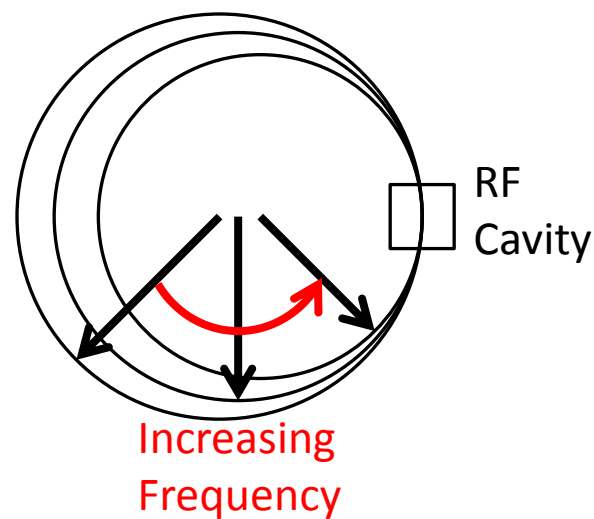
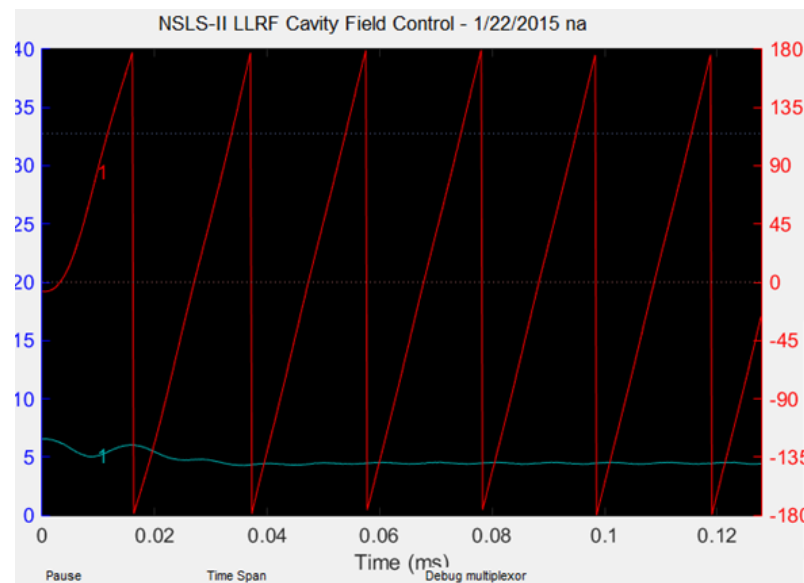
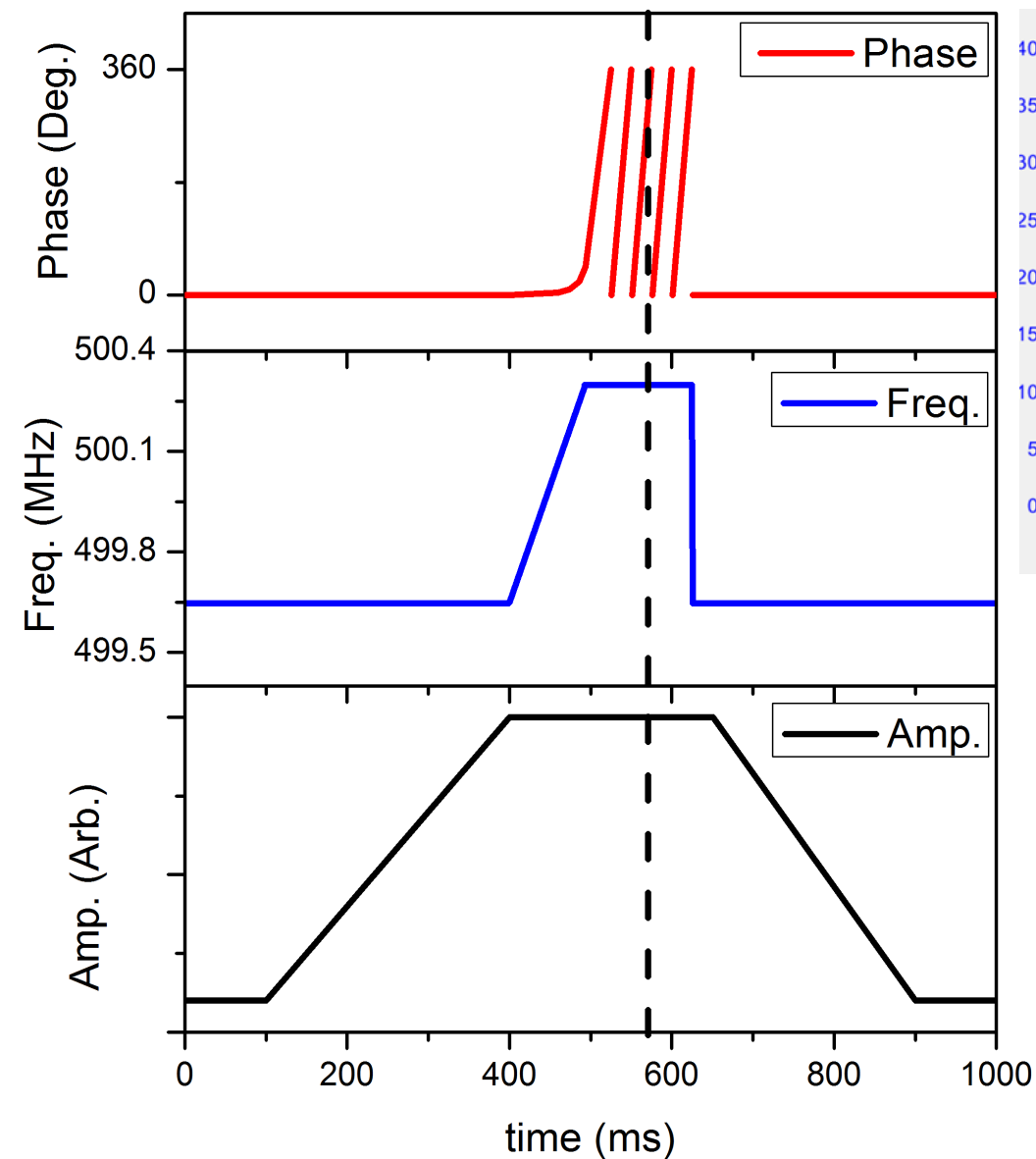
# FEEDFORWARD TABLE



Scope span and ff-table output duration as a function of zoom. The numbers apply to a sample frequency of 40 MHz.

zoom	scope span	ff-table duration
0	25.6 $\mu$ s	51.2 $\mu$ s
1	128 $\mu$ s	102 $\mu$ s
2	230 $\mu$ s	205 $\mu$ s
3	435 $\mu$ s	410 $\mu$ s
4	845 $\mu$ s	819 $\mu$ s
5	1.66 ms	1.64 ms
6	3.30 ms	3.28 ms
7	6.58 ms	6.55 ms
8	13.13 ms	13.11 ms
9	26.24 ms	26.21 ms
10	52.5 ms	52.4 ms
11	105 ms	105 ms
12	210 ms	210 ms
13	419 ms	419 ms
14	839 ms	839 ms
15	1.68 s	1.68 s
16	3.36 s	3.36 s
17	6.71 s	6.71 s
18	13.4 s	13.4 s
19	26.8 s	26.8 s

# FEEDBACK SETPOINT TABLE





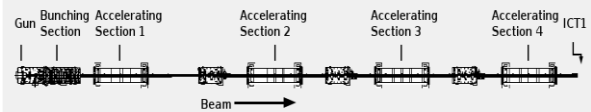
# LLRF ACCELERATOR SUITE



## NSLS-II Linac Status

NATIONAL SYNCHROTRON LIGHT SOURCE II

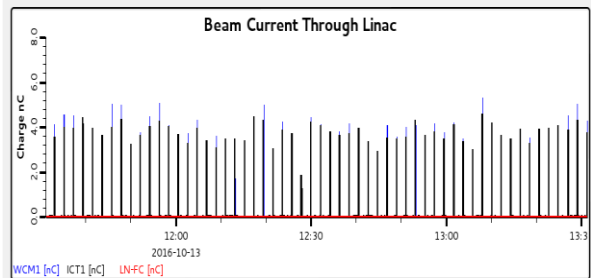
10/13/2016 13:31:15



**Beam Current**  
**WCM1** 0.00 nC  
**ICT1** -0.00 nC  
**% Efficiency** 0.0  
**FC out** 0.00 nC  
**Gun State**  
 HV On  
 Mode Multi Bunch 0  
 Rate Single Divider: 3  
**Gun Trigger**  
 Request Enable  
 Status Enable

**Rad Mons** No Alarm  
**LN Tunnel** Secured  
**ACMI Status** Interlocked  
**WCM-1 Norm. Fill Pattern**

**Diagnostics Status**  
 FC Out  
 Flags All Out  
**Vacuum Status**  
 Valves All Open  
**Power Supply Status**  
 Sol All On  
 Quad All On  
 Corr All On  
**RF Mod Status**  
 Mod HV 1 & 2 On  
 #1 30 #2 31 #3 0 MW



## NSLS-II Booster Status

NATIONAL SYNCHROTRON LIGHT SOURCE II

10/14/2016 10:31:22



**Beam Current - DCCT**  

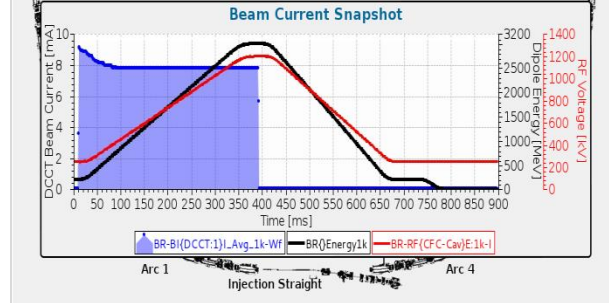
	Current	Charge	Energy
Injection	9.16 mA	4.83 nC	201 MeV
Extraction	7.81 mA	4.12 nC	2995 MeV
Injection Efficiency	93.3 %	Inj/LB-IT2	
Acceler. Efficiency	85.3 %	Ext/Inj	

**Rad Monitors** OK  
**PPS Status**  
 Berm Secured Secured  
 BR Secured Secured  
 RF Permit Enabled  
 BF Permit Enabled  
 BS-B2 Permit Enabled

**Power Supply Status**  

	Injection	Extraction
Kicker 1	Kicker 1	Kicker 1
Kicker 2	Kicker 2	Kicker 2
Kicker 3	ACSeptum	
Kicker 4	DCSeptum	
Septum	Bump	
Correctors	Tune Kickers On	

**Vacuum Valves**  
 Open  
**Flag Status**  
 All Out  
**RF State**  
 RF On



## NSLS-II Storage Ring Status

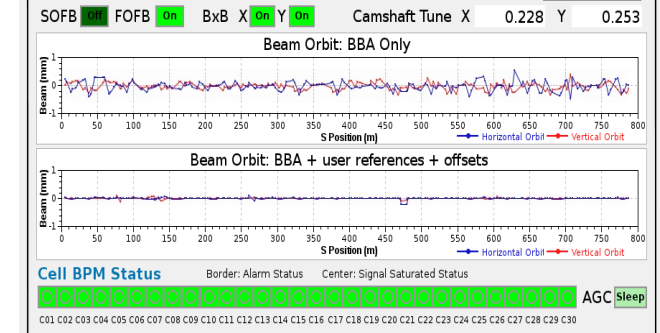
NATIONAL SYNCHROTRON LIGHT SOURCE II

10/13/2016 13:32:16

**Diagnostics**

**Current** 250.08 mA  
 Beam Charge 660.22 nC  
 Lifetime (DCCT) 8.32 hour  
 Daily Amp Hours 3321.9 mAh  
 Injection Effic 90.54 %  
 Injected Beam I 0.00 mA  
 Injected Beam Q 0.00 nC  
 Number Bunches 1004  
 Scrapers All Out

SOFB On FOFB On Bx B Y On Camshaft Tune X 0.228 Y 0.253

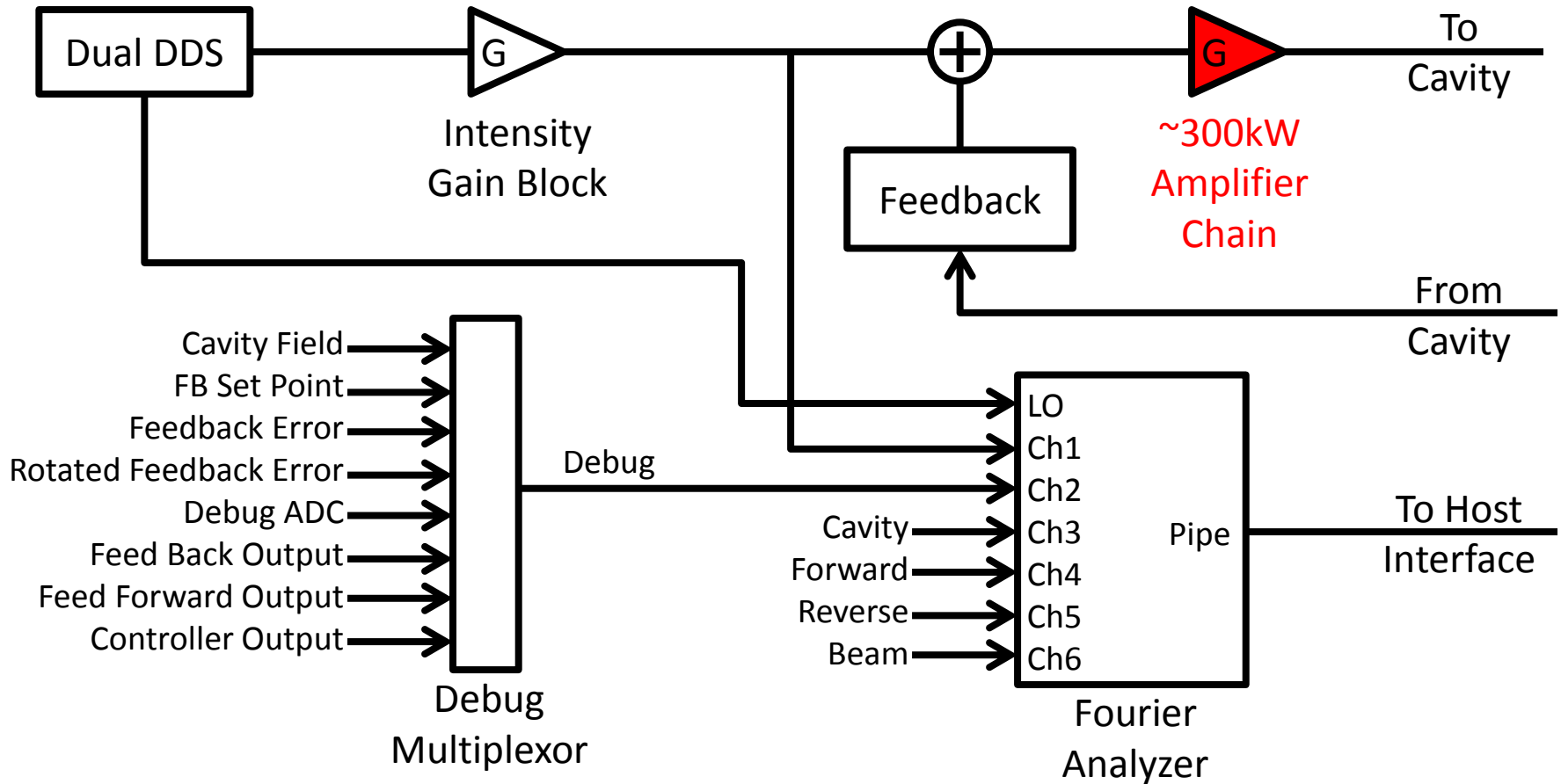


**Vacuum**  
 Ave Pressure (Torr) 3.80E-9  
 Gate Valve Pentant Summary  
 P1 P2 P3 P4 P5 RF FE

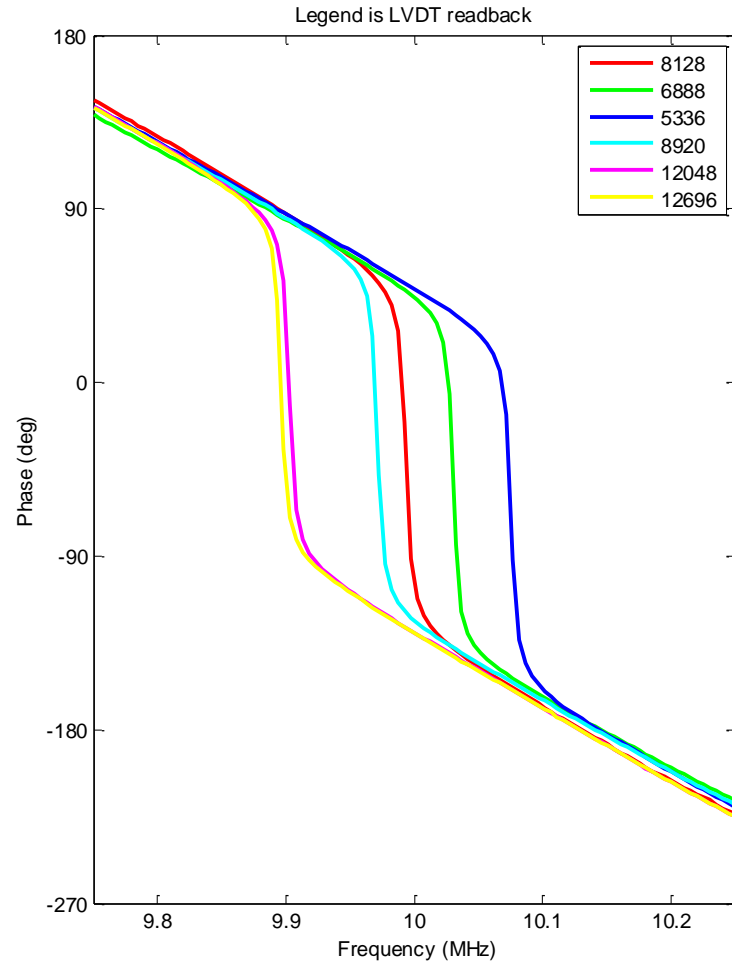
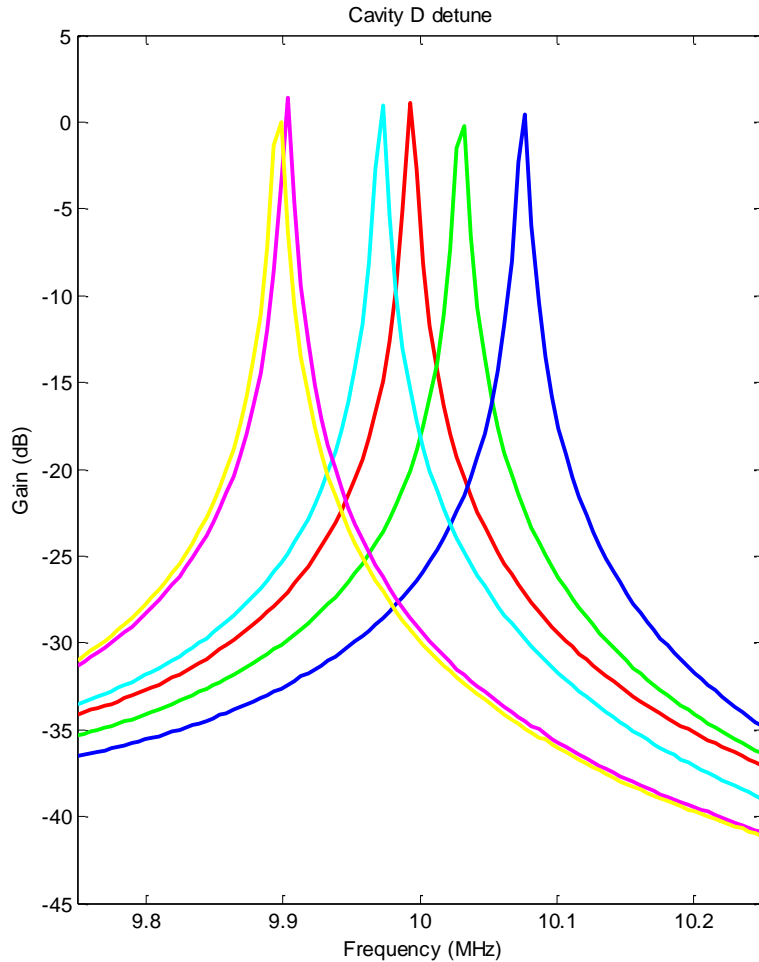
**Power Supply**  
 Border: Alarm Status Center: Power Status  
 Main Dipole  
 PS1 -364.0 A ON  
 PS2 -363.9 A ON  
 Kickers AC Septum  
 Trigger Enable  
 Pinger H V

**RF:C** State RF Cav Voltage 1492.8 kV Amplitude 0.242 Phase 170.0 deg  
**RF:D** State RF Cav Voltage 1500.0 kV Amplitude 0.706 Phase -149.0 deg

# NETWORK ANALYZER



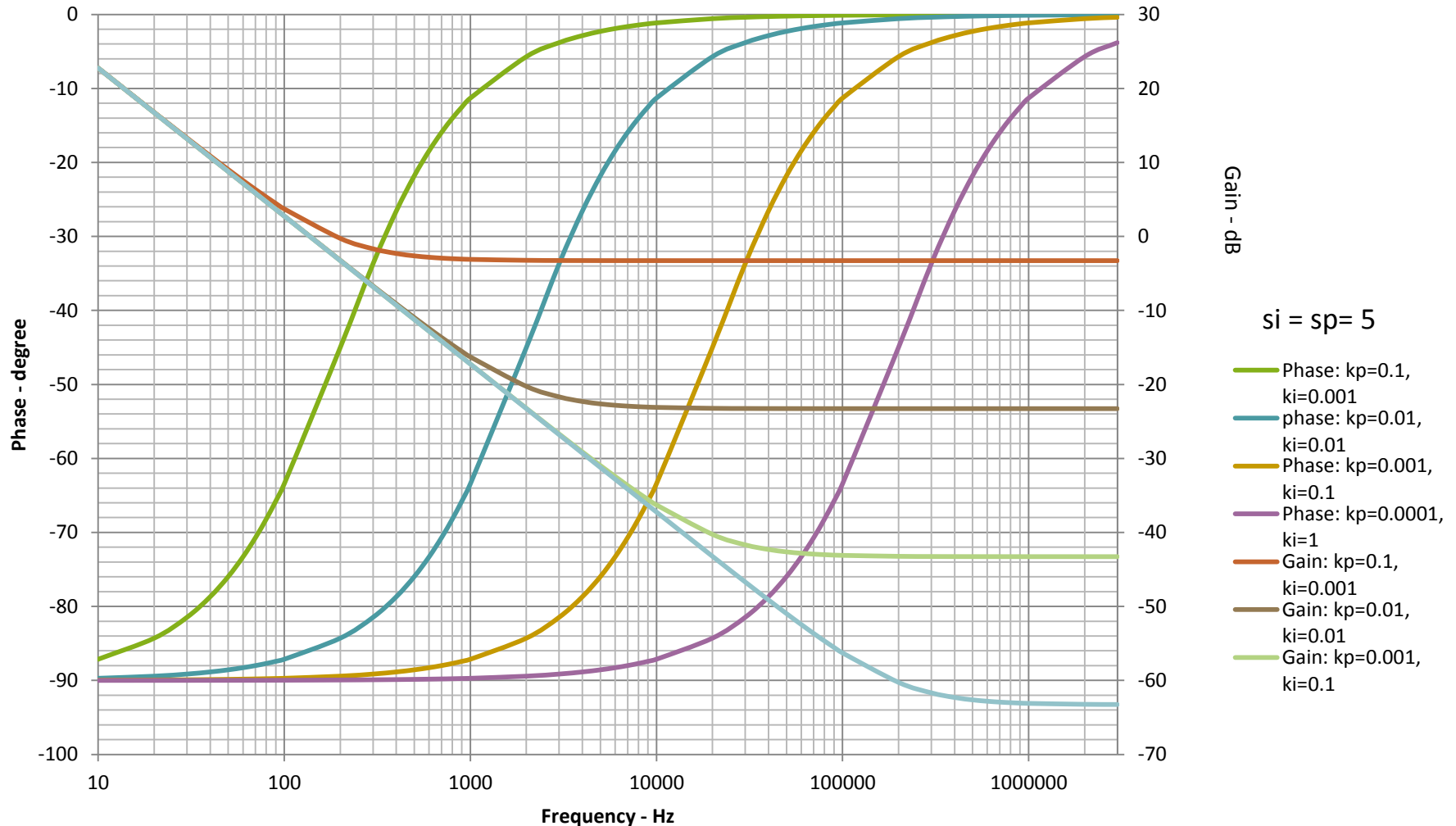
# NETWORK ANALYZER



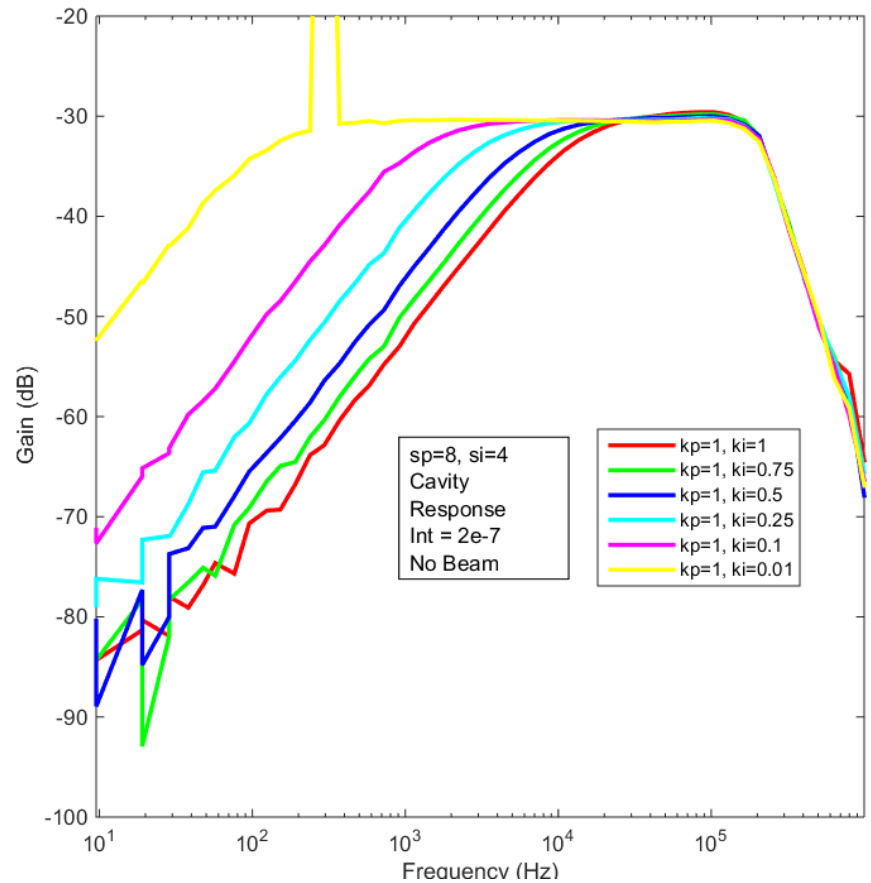
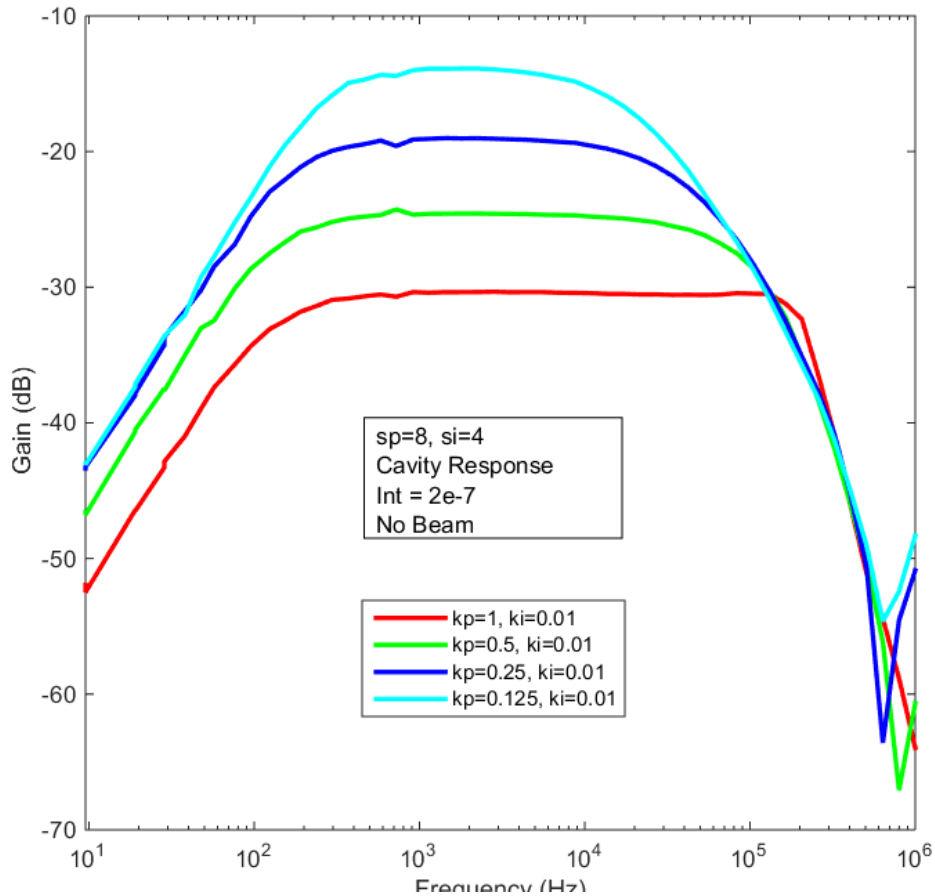
Cavity S21 Frequency sweep vs. Tuner Position measured at **100kW!**  
Frequency axis is in the digital IF Frequency of ~10MHz which corresponds to the 500MHz RF Frequency

# NETWORK ANALYZER

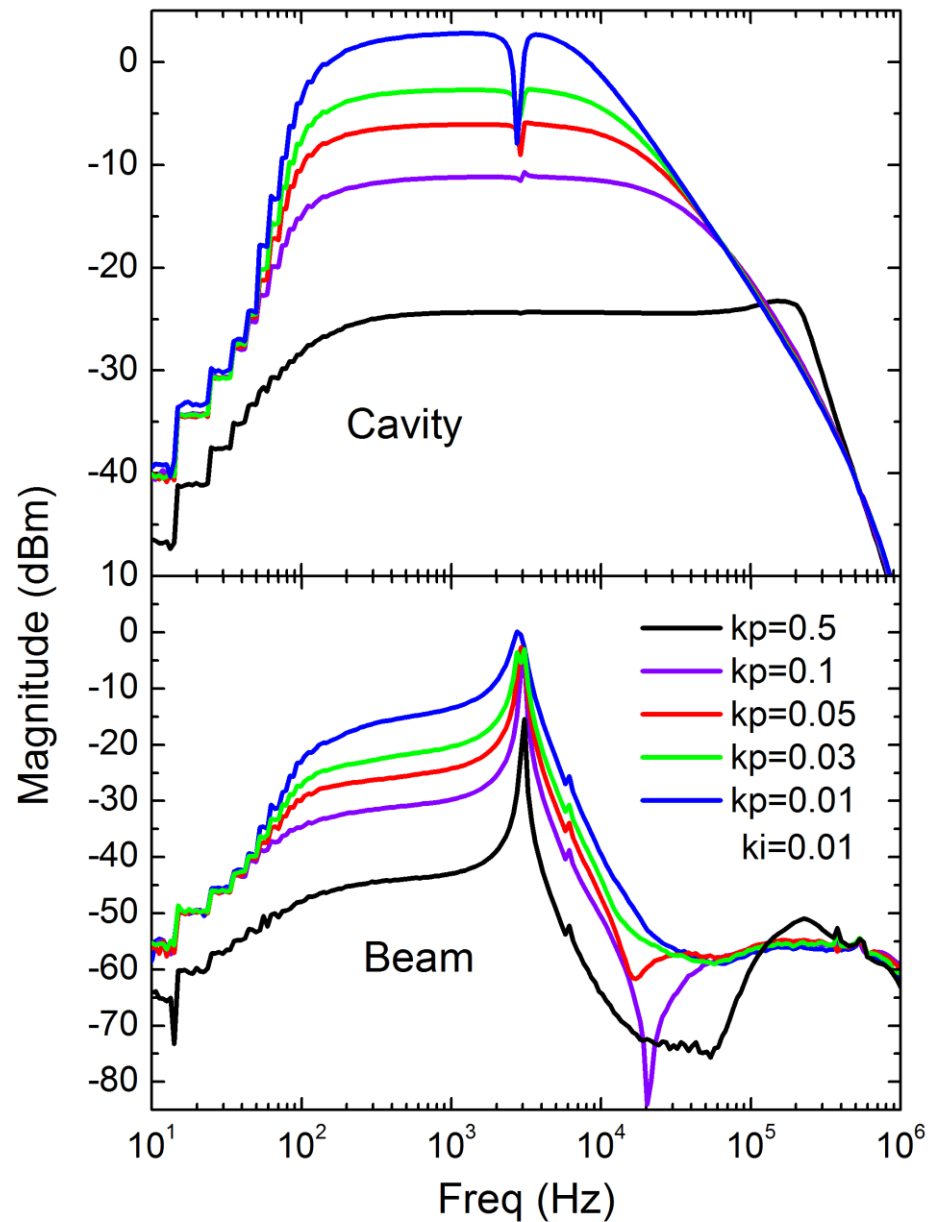
$$\phi = \arctan \left( \frac{-6250 \cdot 2^{s_i} \cdot k_i}{f} \right) \quad \text{gain} = 20 \log \left( 0.214375 \cdot 2^{s_p} \cdot k_p \sqrt{\left( 1 + \frac{6250 \cdot 2^{s_i} \cdot k_i}{f} \right)^2} \right)$$



# NETWORK ANALYZER



# NETWORK ANALYZER





# CONCLUSION

- Relatively standard digital controller hardware includes many unique tools for beam gymnastics and measurements embedded into logic and can be run using any standard laptop running MATLAB or EPICS
- Digitized RF waveforms with digitized beam signal allows accurate post-mortems, beam studies and machine studies
- “Network analyzer” with frequency sweeps up to  $\pm 1$  MHz measure cavity and beam response in real time with full beam current, feedback loops open or closed.
- Future options
  - Currently uses proportional-integral feedback but have untested state-space variable feedback to minimize the error in both cavity field and beam phase.