PC&PAC 2016

11th International Workshop on Personal Computers and Particle Accelerator Controls

October 25th – 28th, 2016
Campinas, Brazil

Status of the NSLS-II LLRF

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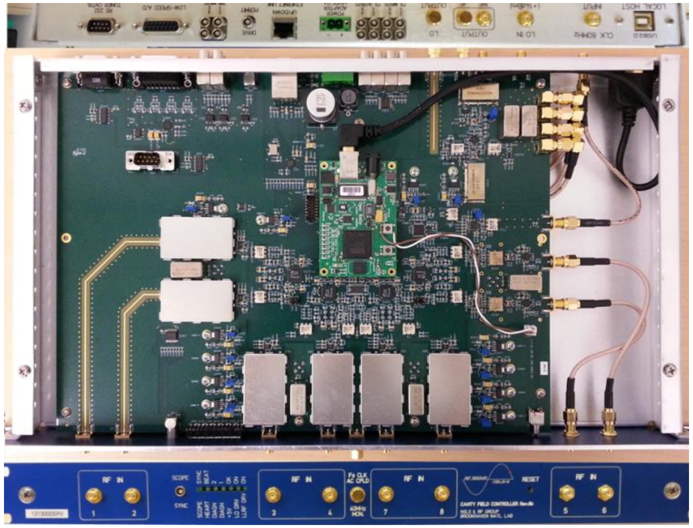
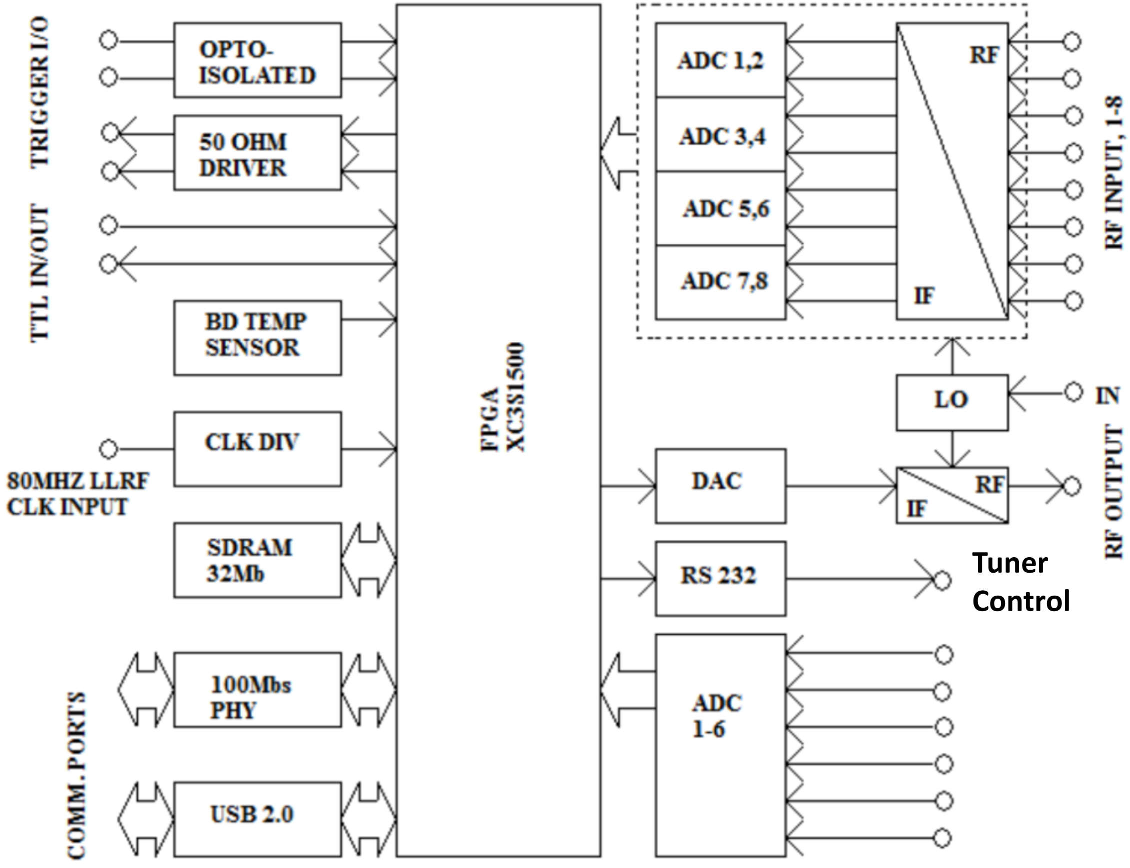
BROOKHAVEN NATIONAL LABORATORY

HARDWARE PLATFORM

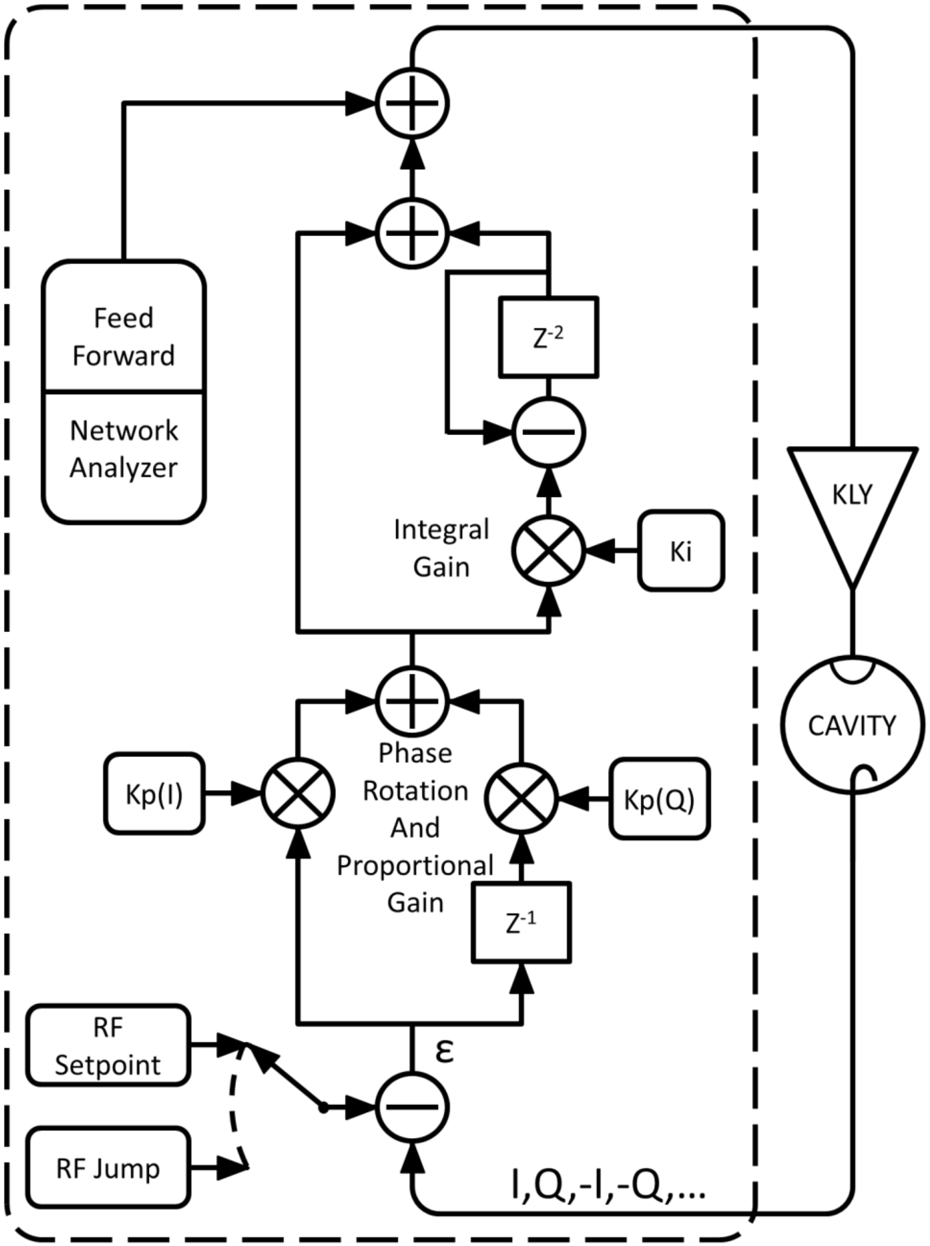
Designed by Hengjie Ma using a derivative of Lawrence R. Doolittle's SNS project.

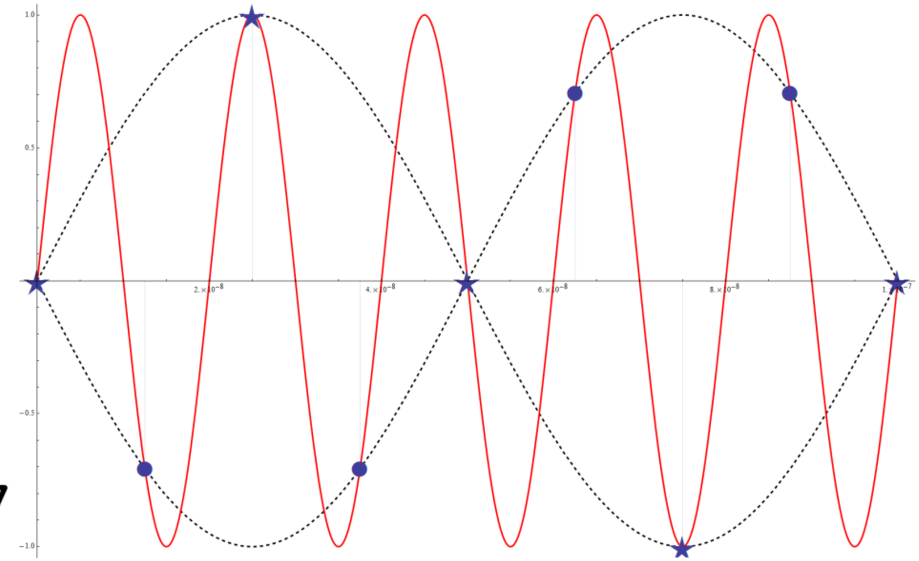




- Relatively standard digital controller hardware (managed by a small group)
- MATLAB and EPICS interfaces can be run by any standard laptop
- With the proper up/down conversions this hardware can be implemented into any system

DIGITAL FEEDBACK LOOP

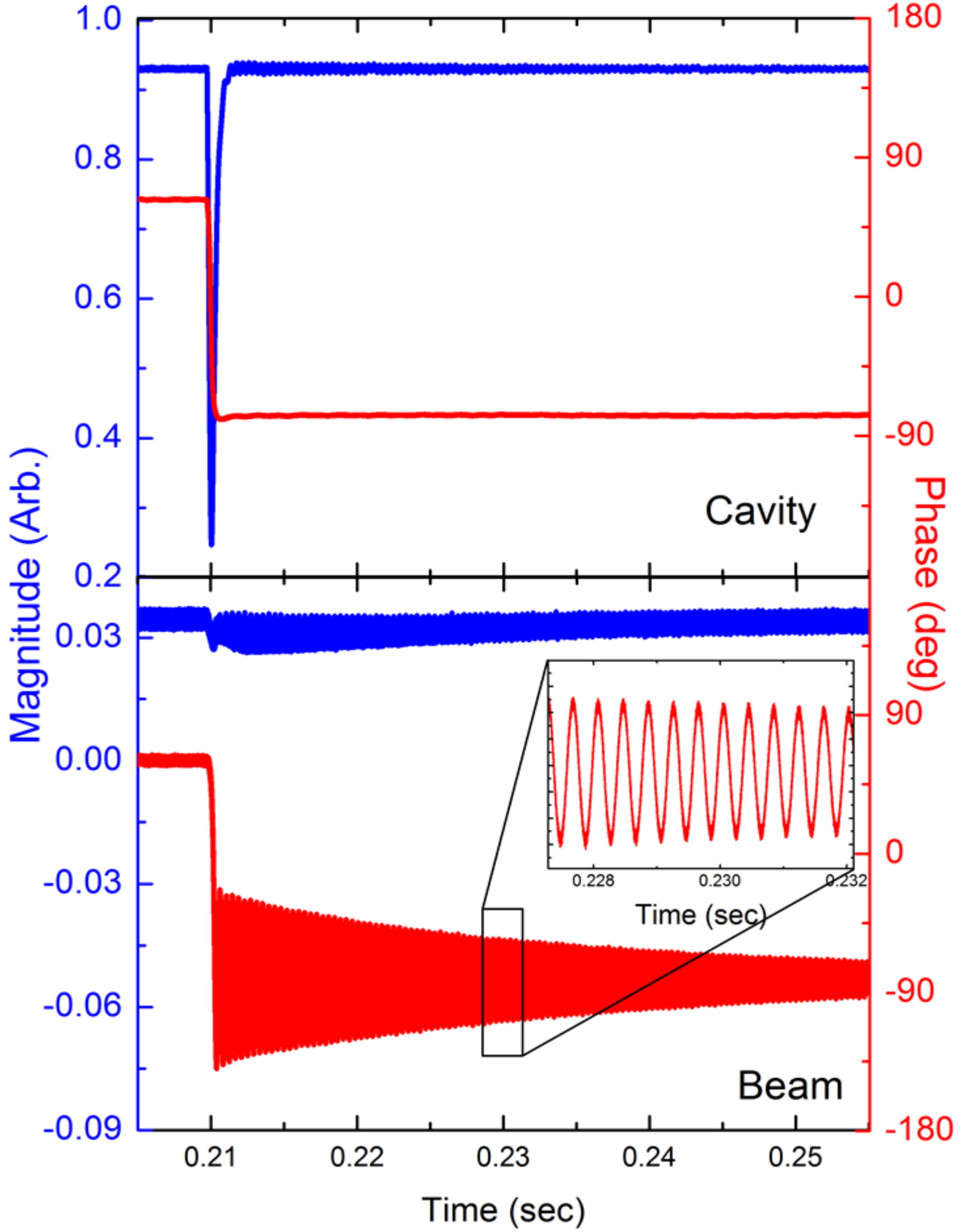




$$|Kp| = \sqrt{Kp_i^2 + Kp_q^2}$$

$$\begin{aligned}
\mathrm{I}' &= I(Kp_i) - Q(Kp_q) \\
\mathrm{Q}' &= Q(Kp_i) + I(Kp_q) \\
\text{-}\mathrm{I}' &= -I(Kp_i) + Q(Kp_q) \\
\text{-}\mathrm{Q}' &= -Q(Kp_i) - I(Kp_q)
\end{aligned}$$

AMPLITUDE/PHASE JUMP

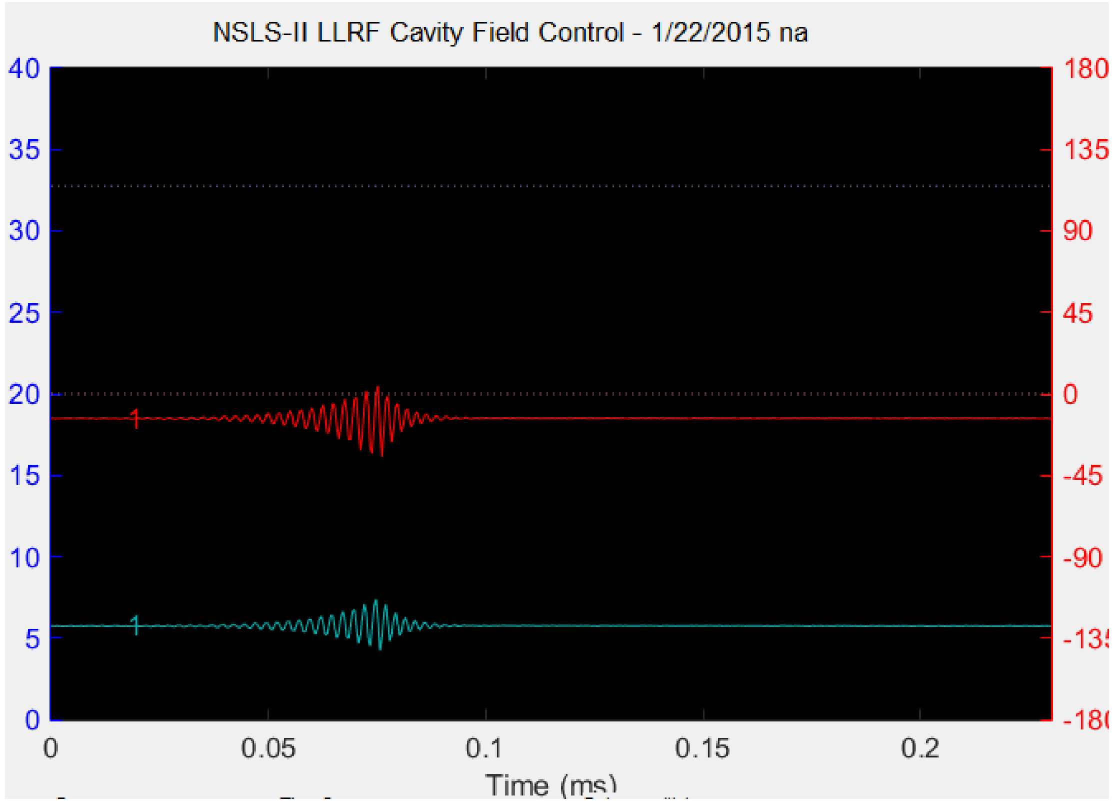


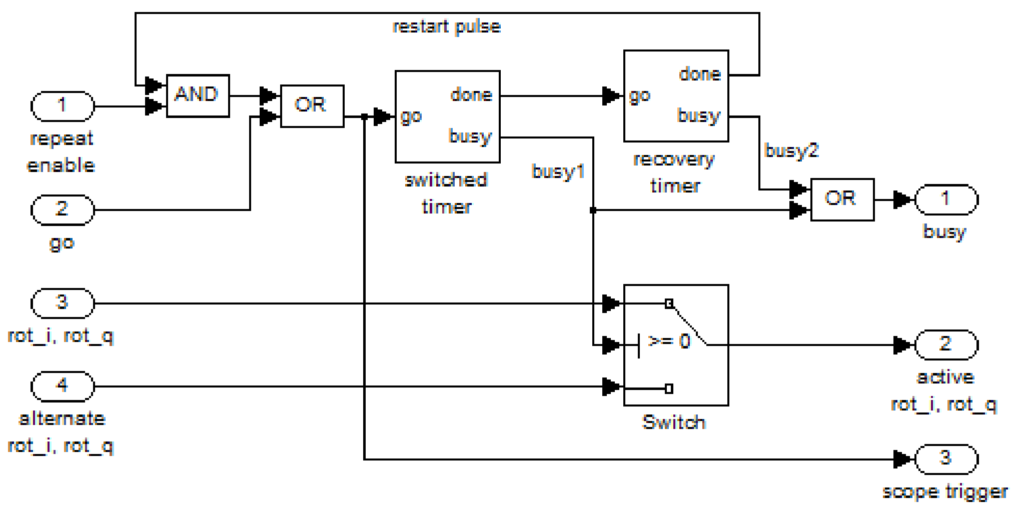
Phase or amplitude jump triggered by timing event is synchronized with turn by turn bpm data for measuring dynamic aperture, field non-linearities, etc. More information can be found in literature [1].

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

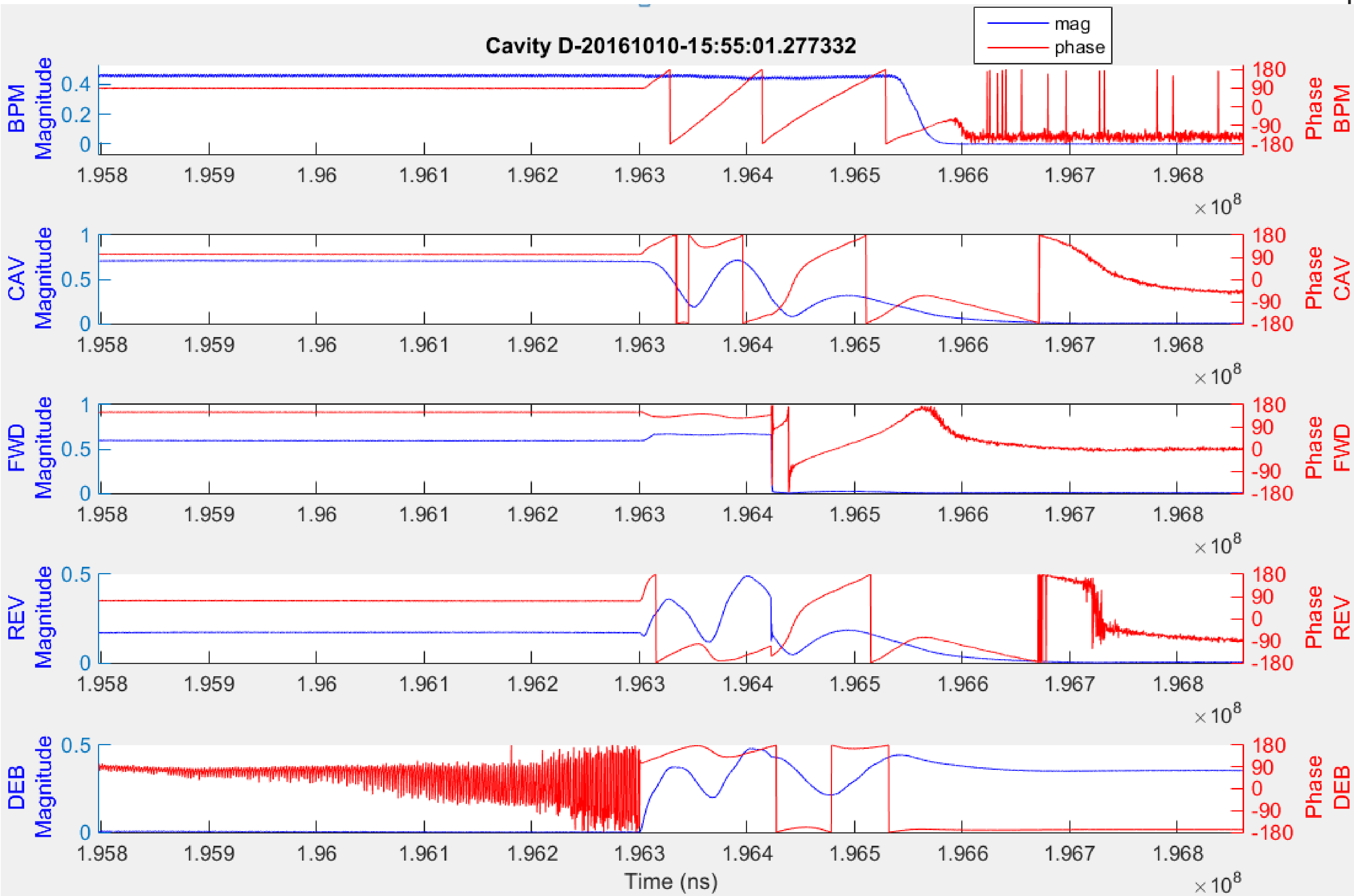
[1] G. M. Wang, et al. , "RF PINGER COMMISSIONING AND BEAM DYNAMICS STUDIES AT NSLS-II" IPAC2016, THOBA01.

PULSED FEEDBACK GAINS

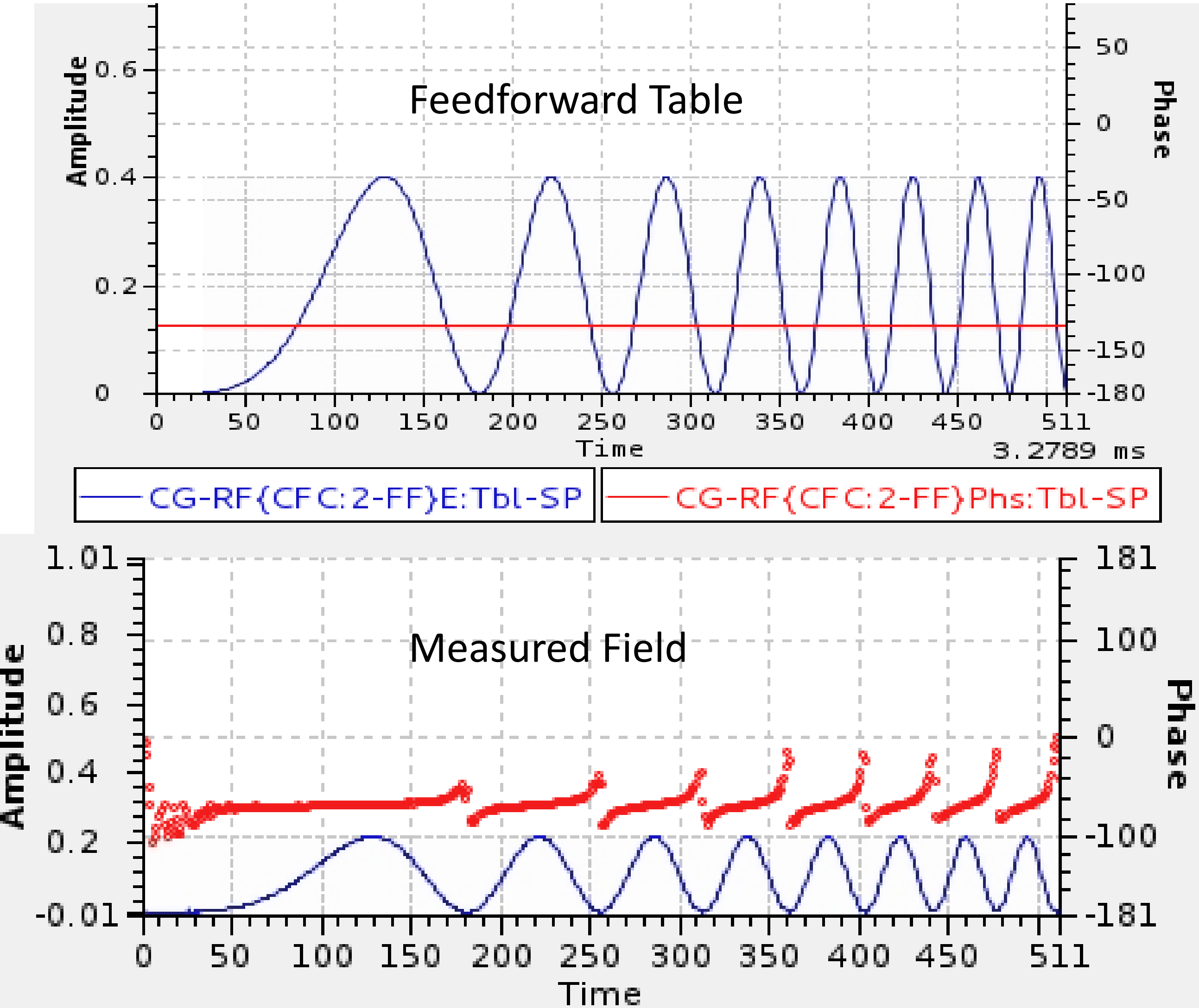




CIRCULAR BUFFER



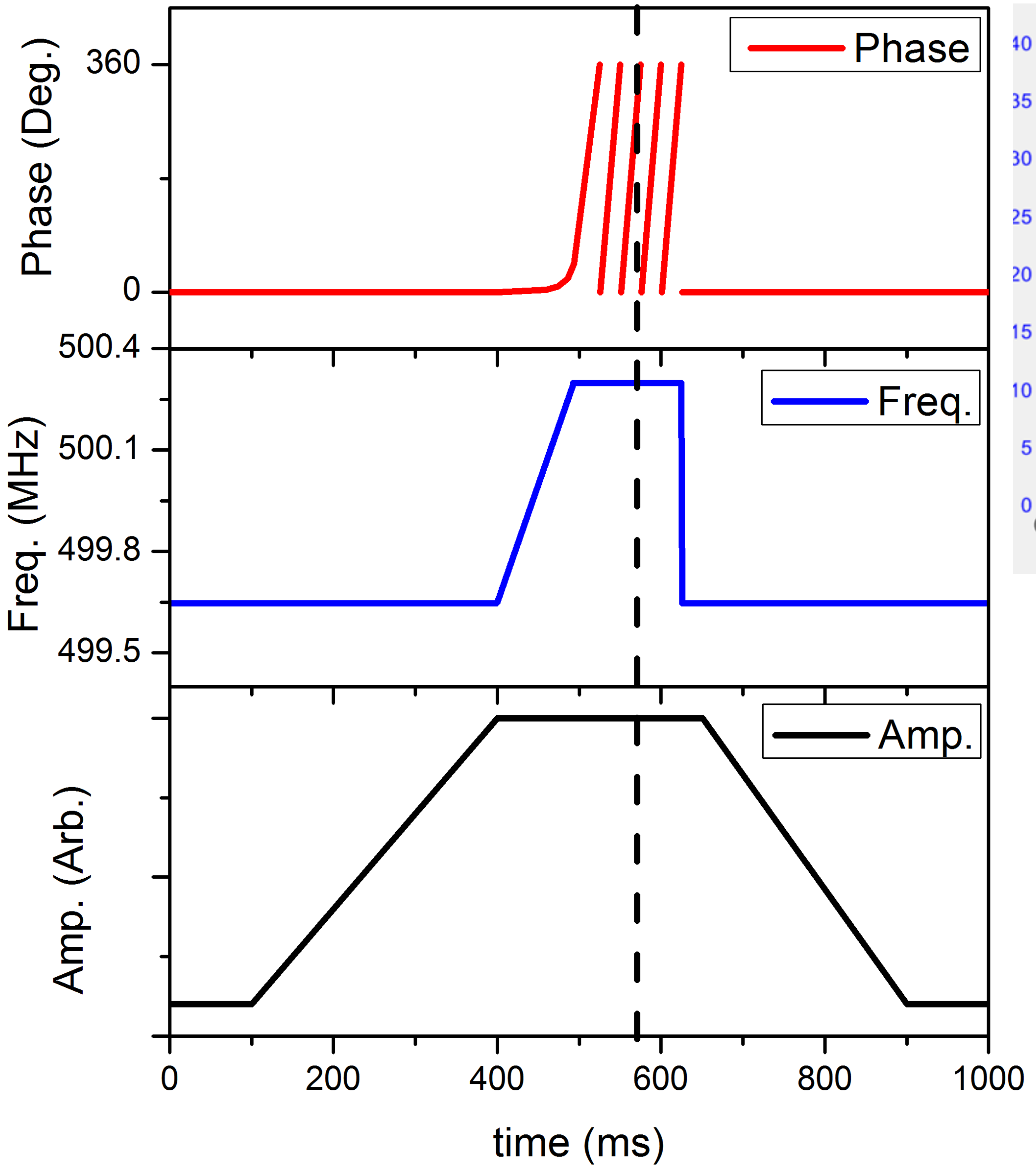
FEEDFORWARD TABLE

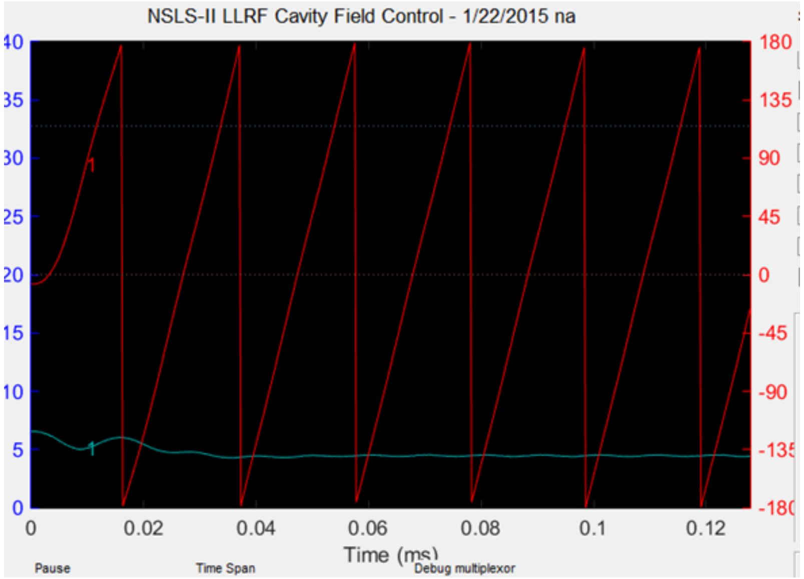


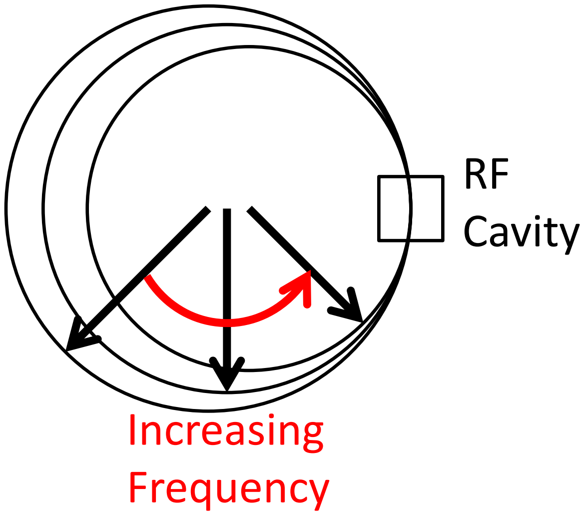
Scope span and ff-table output duration as a function of zoom. The numbers apply to a sample frequency of 40 MHz.

zoom	**scope span**	**ff-table duration**
0	25.6 µs	51.2 µs
1	128 µs	102 µs
2	230 µs	205 µs
3	435 µs	410 µs
4	845 µs	819 µs
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

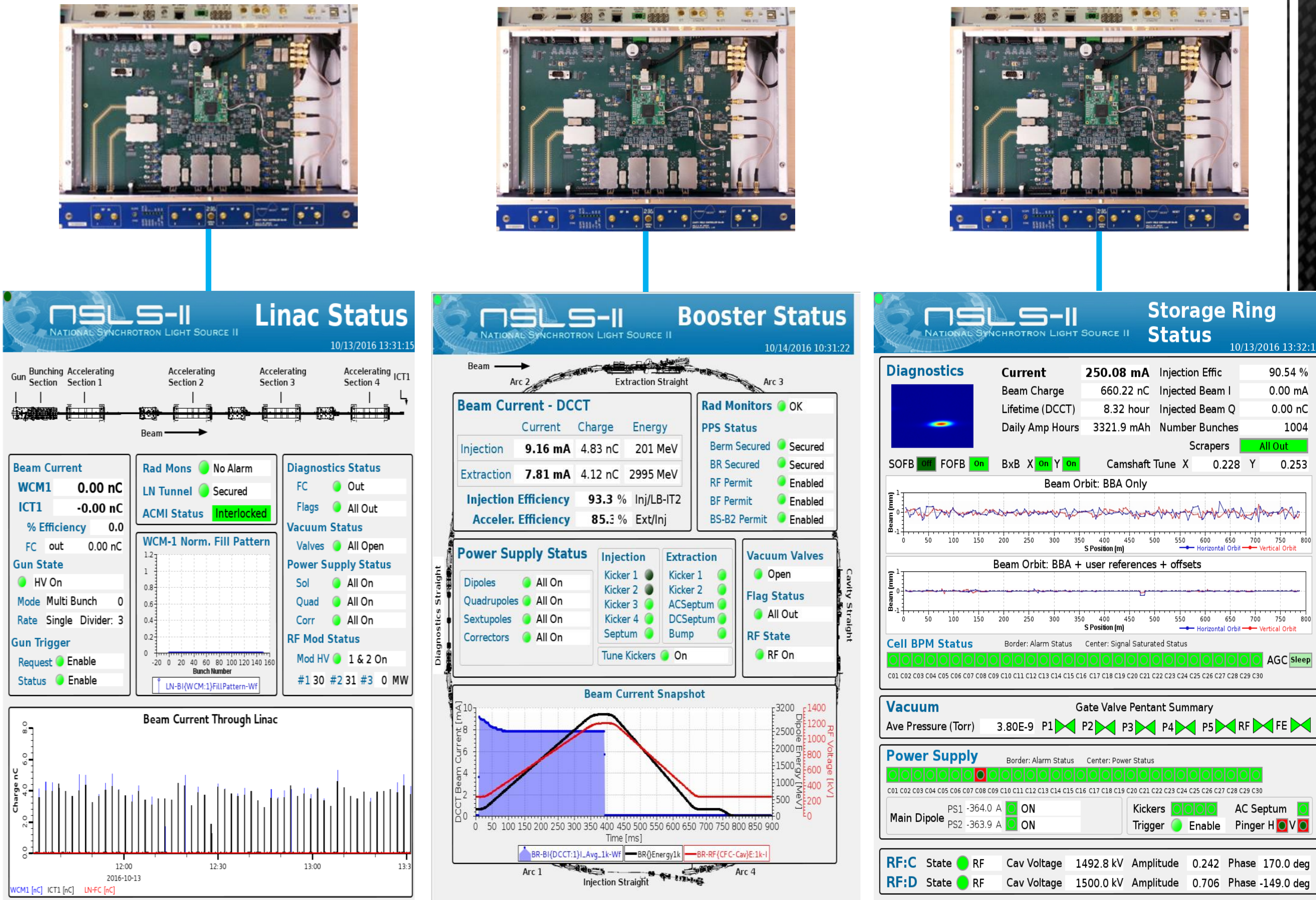
FEEDBACK SETPOINT TABLE



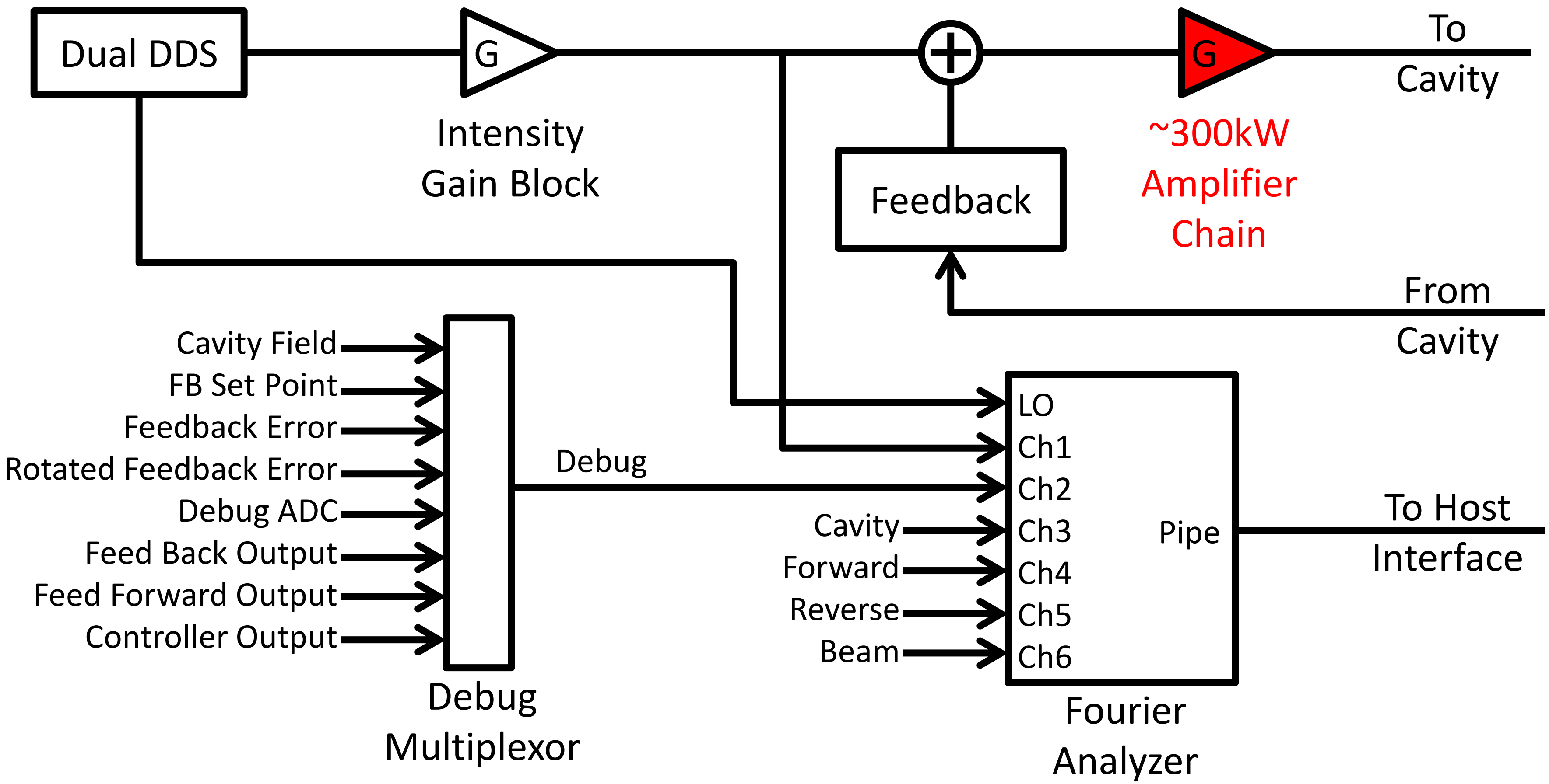




LLRF ACCELERATOR SUITE



NETWORK ANALYZER



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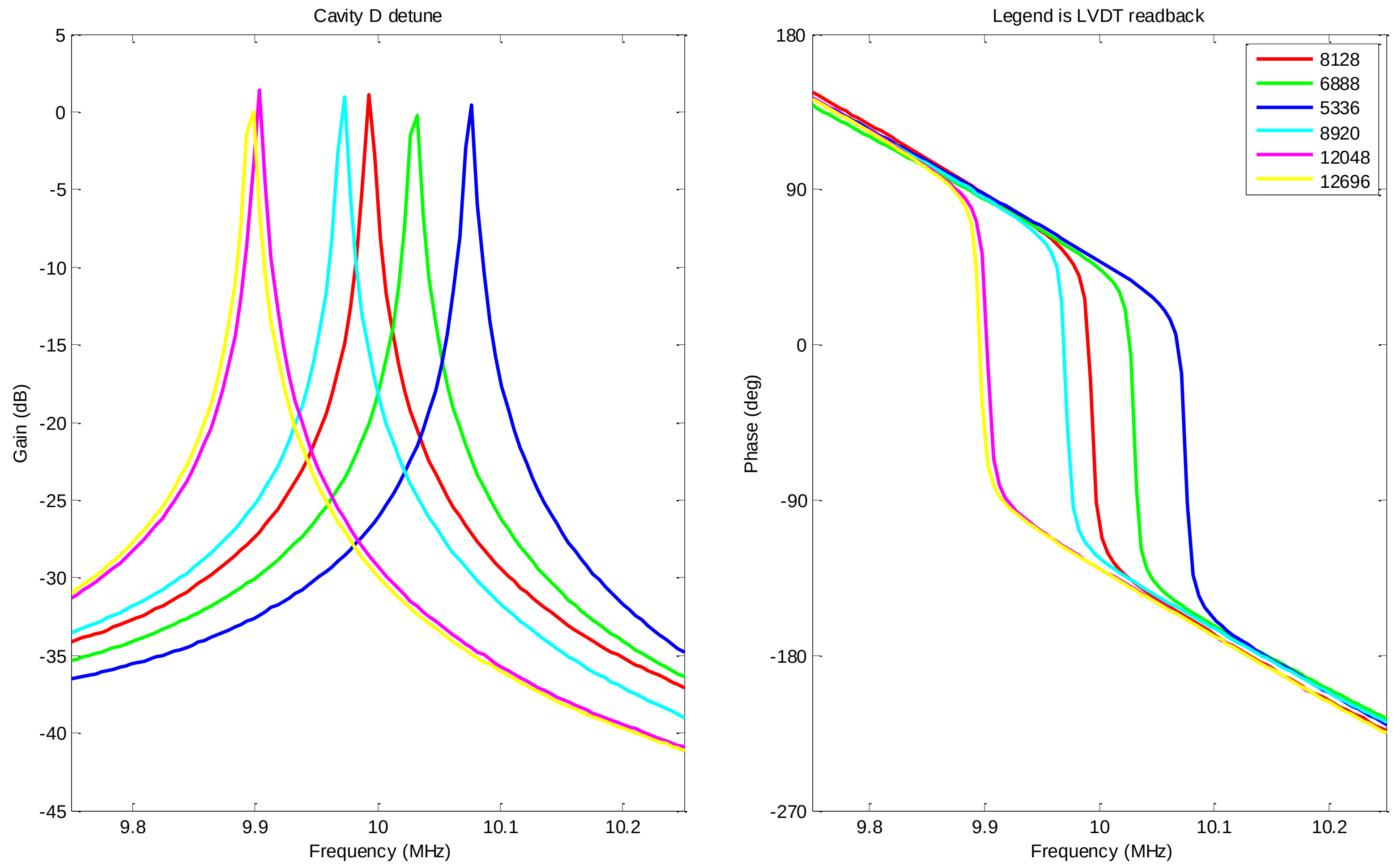
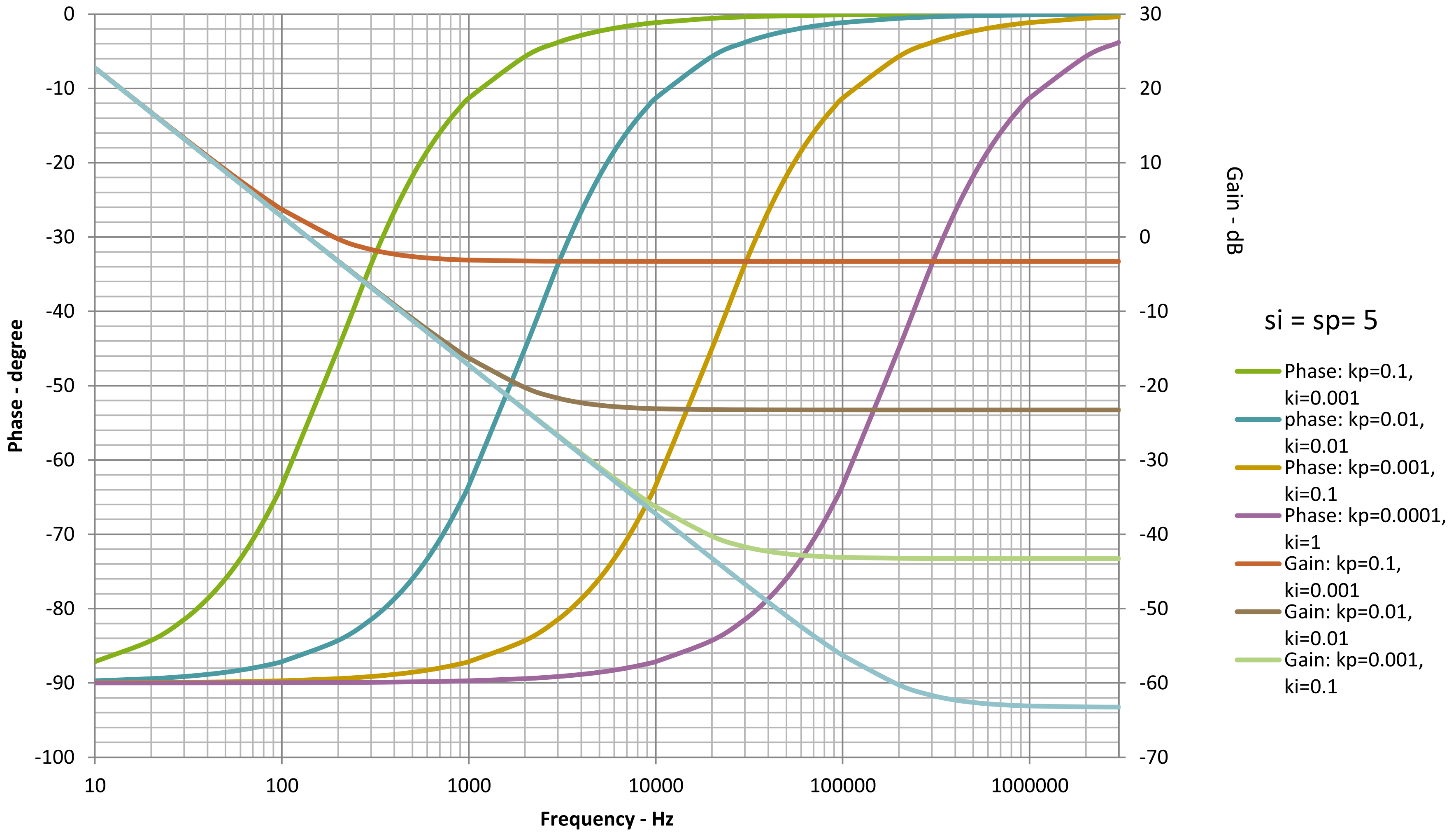


Cavity S21 Frequency sweep vs. Tuner Position measured at 100kW!
Frequency axis is in the digital IF Frequency of ~10MHz which corresponds to the 500MHz RF Frequency

NETWORK ANALYZER

$$\phi = \arctan\left(\frac{-6250 \cdot 2^{\mathrm{si}} \cdot \mathrm{ki}}{f}\right) \qquad \mathrm{gain} = 20\log\left(0.214375 \cdot 2^{\mathrm{sp}} \cdot \mathrm{kp}\sqrt{\left(1 + \frac{6250 \cdot 2^{\mathrm{si}} \cdot \mathrm{ki}}{f}\right)^2}\right)$$



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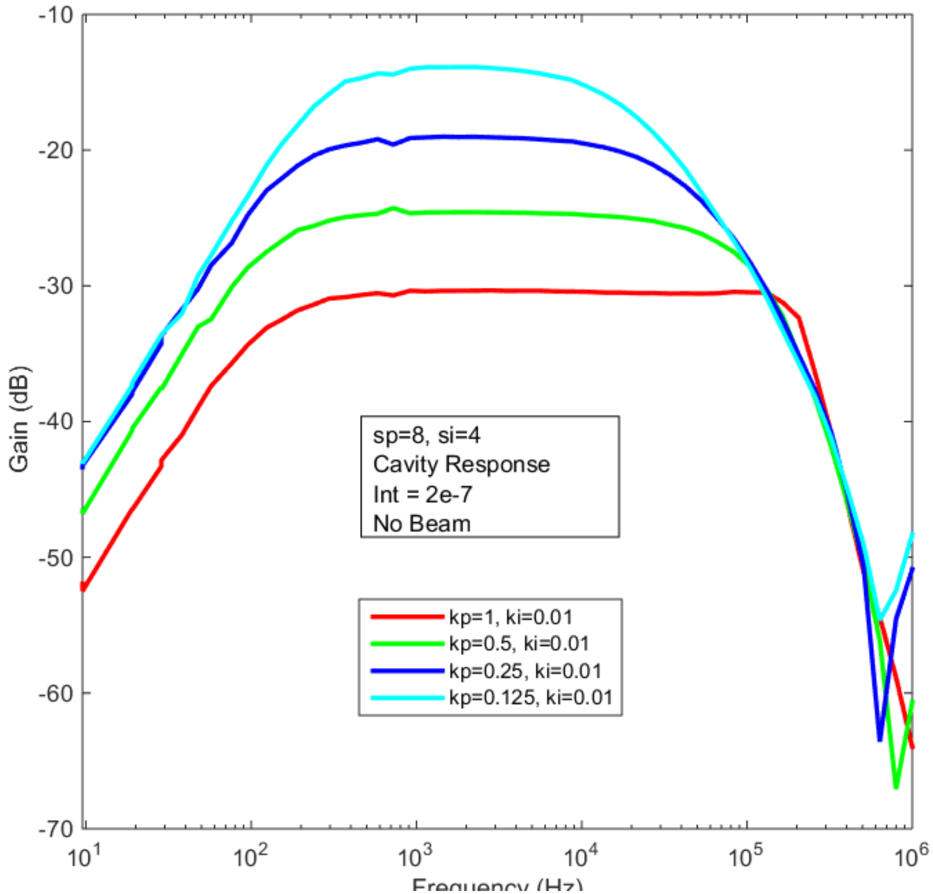

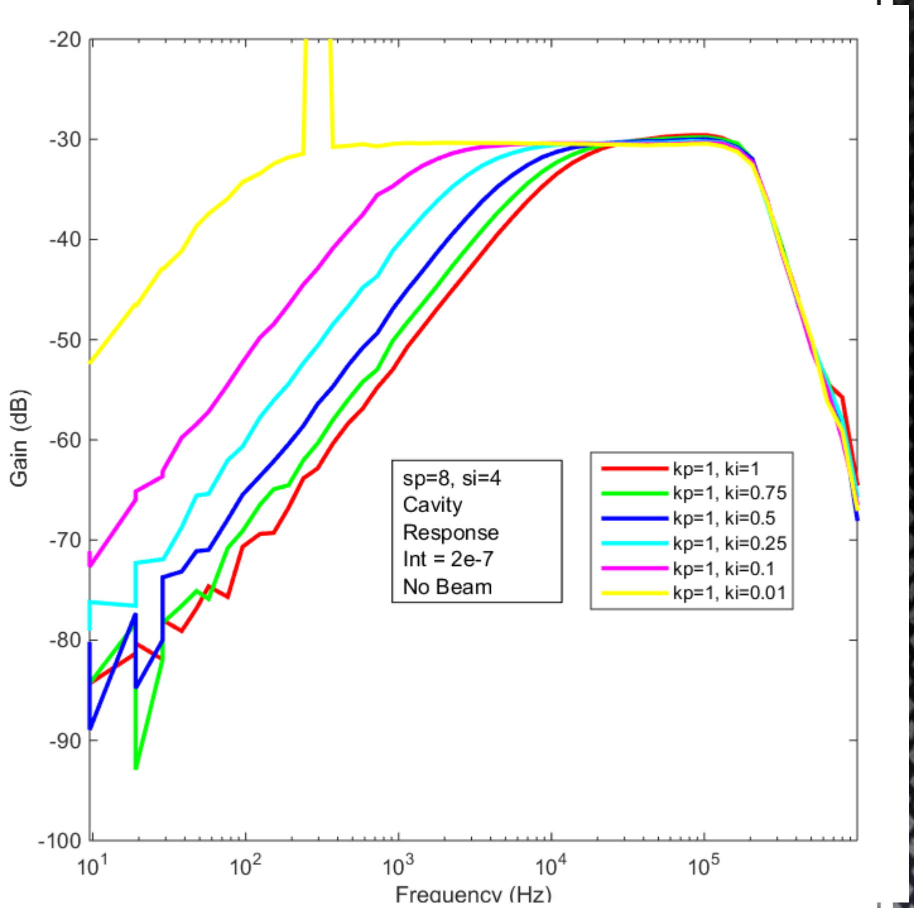

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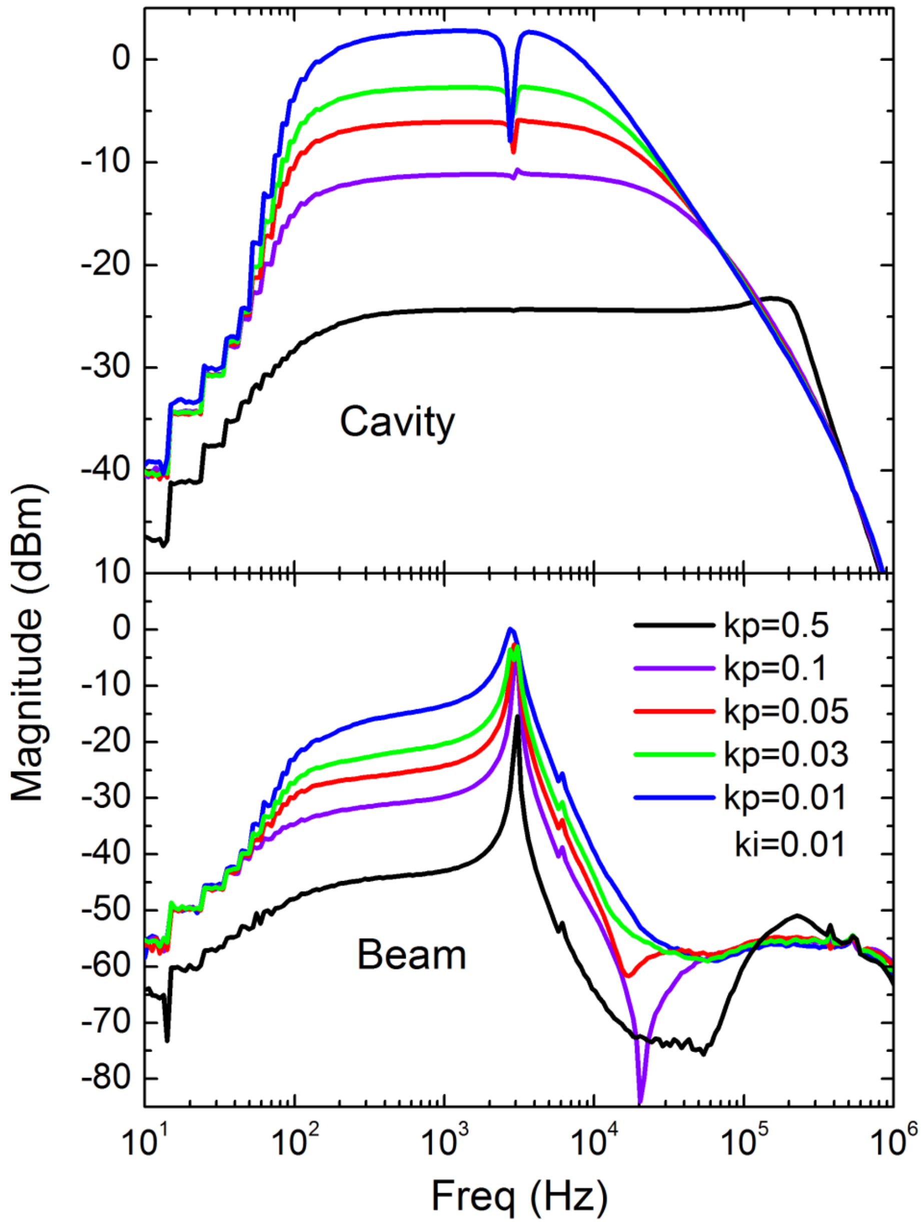

CONCLUSION

- 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 +/- 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.

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OBRIGADO!

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