Current LLRF Activities at FNAL

B. Chase

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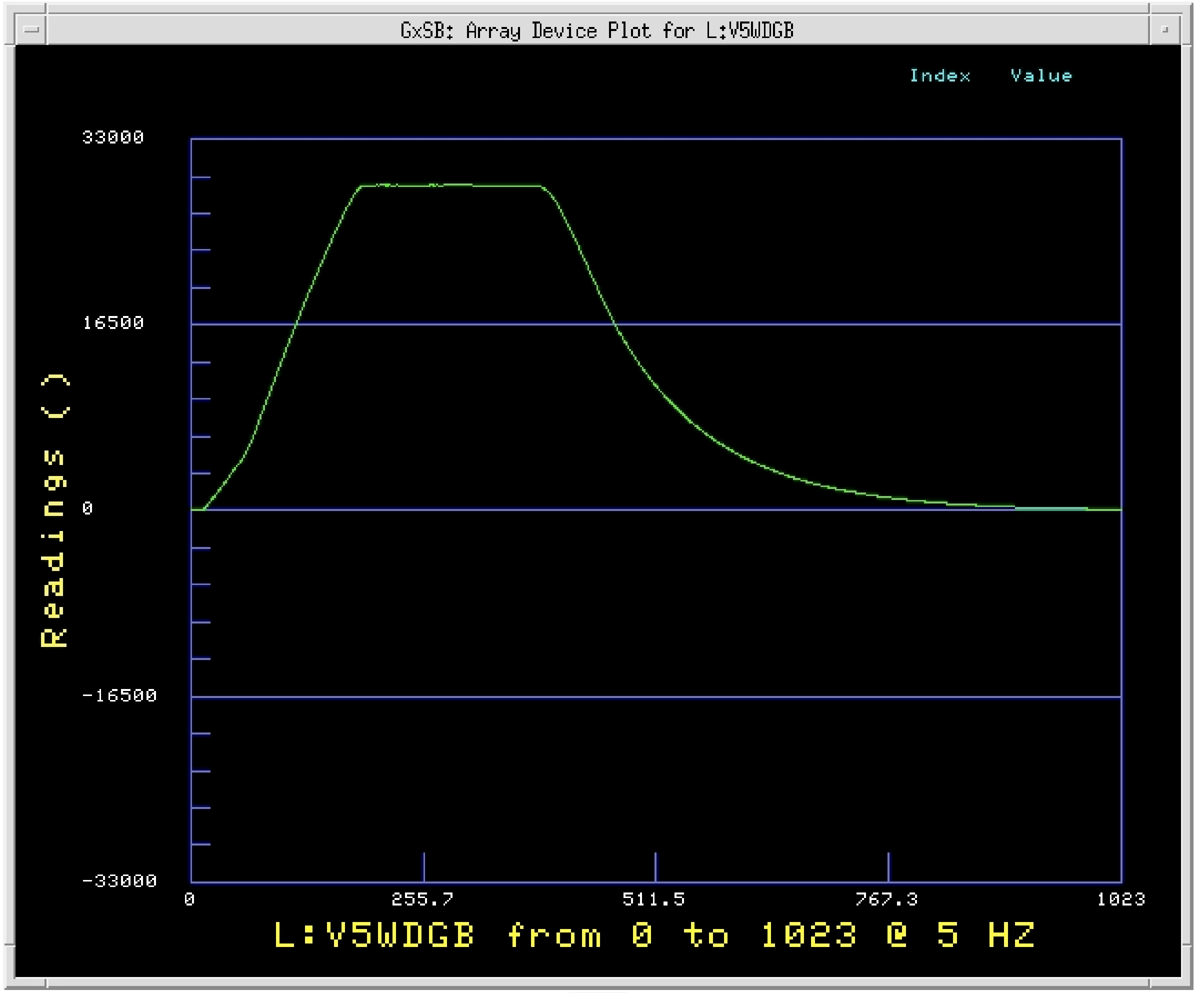
FNAL, AD/RF - LLRF

Projects

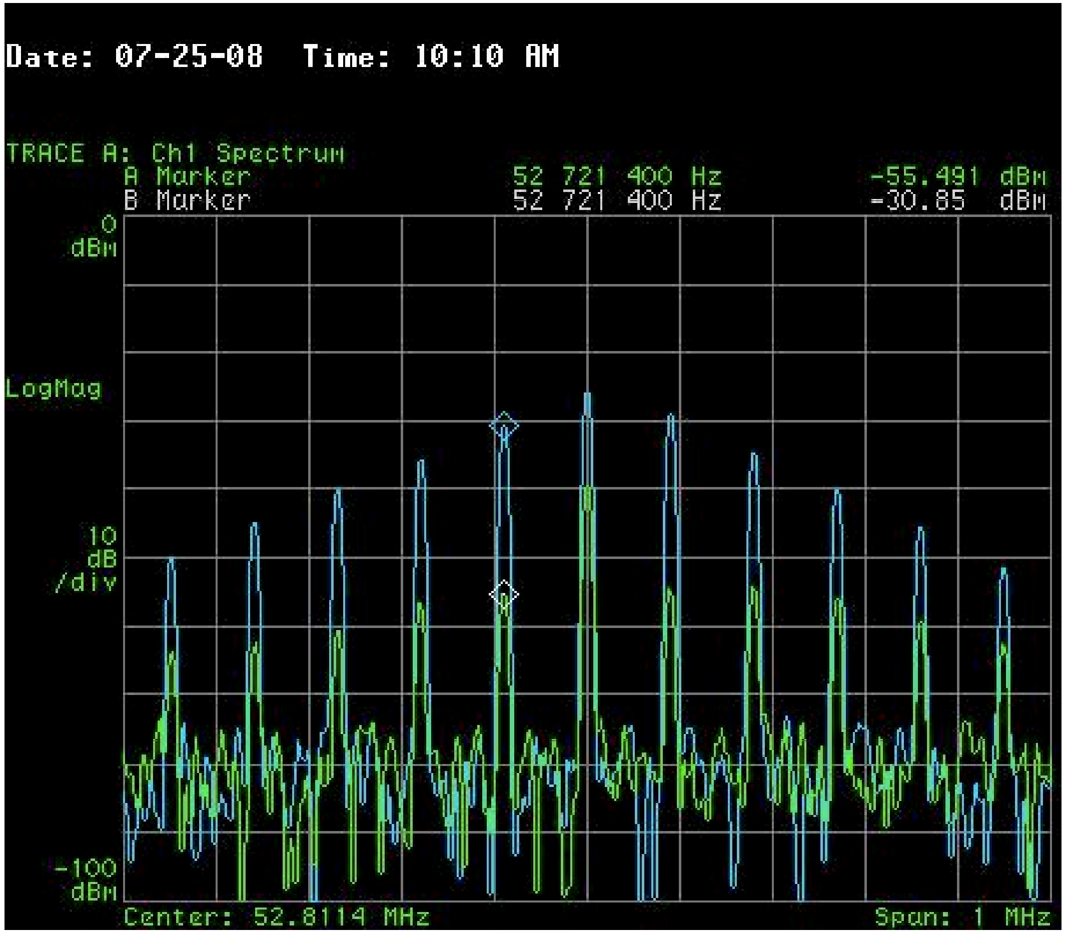
- Low Energy Linac LLRF Upgrade
  - Based on MFC Module
    - Commissioning in progress
- Main Injector Comb Filter
  - Based on MFC Module
    - Operational tests on one station
    - Production in progress (35 cards)
- HINS 325 MHz copper cavities
- SRF at A0, HTS, CC2, NML,
  - MFC and ESECON
- ILC design efforts
  - Piezo control
  - 9mA tests at FLASH

Linac LLRF Upgrade (MFC)



Amp and phase loop
Adaptive Feedforward
0.5 % 0.5 degree
Acnet control

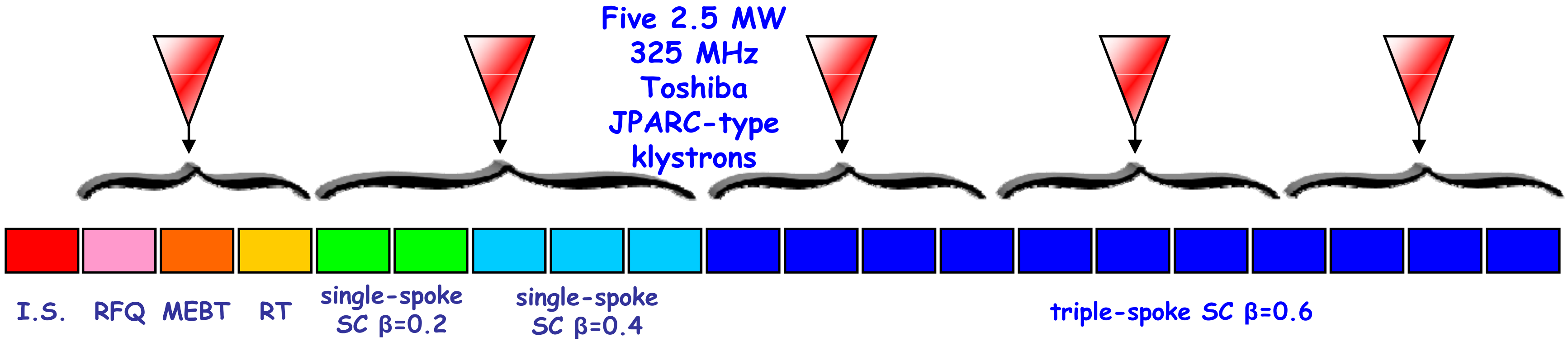
Main Injector Comb Filter



MFC based

- FF + Comb at injection
- 20 dB suppression of revolution lines

HINS Low-Energy Linac Layout



	Ion Source	RFQ	MEBT	Room Temp	SSR1	SSR2	TSR
Eout	50 keV	2.5 MeV	2.5 MeV	10 MeV	30 MeV	120 MeV	~600 MeV
Zout	0.7 m	3.7 m	5.7 m	15.8 m	31 m	61 m	188m
Cavities			2 buncher cavities and fast beam chopper	16 copper CH-spoke cavities	18 single-spoke SC β=0.2 cavities	33 single-spoke SC β=0.4 cavities	66 triple-spoke SC β=0.6 cavities
Gradient					10 MV/m	10 MV/m	10 MV/m
Focusing			3 SC solenoids	16 SC solenoids	18 SC solenoids	18 SC solenoids	66 SC quads
Cryomodules					2	3	11

Cavities operating at different synchronous phase angles

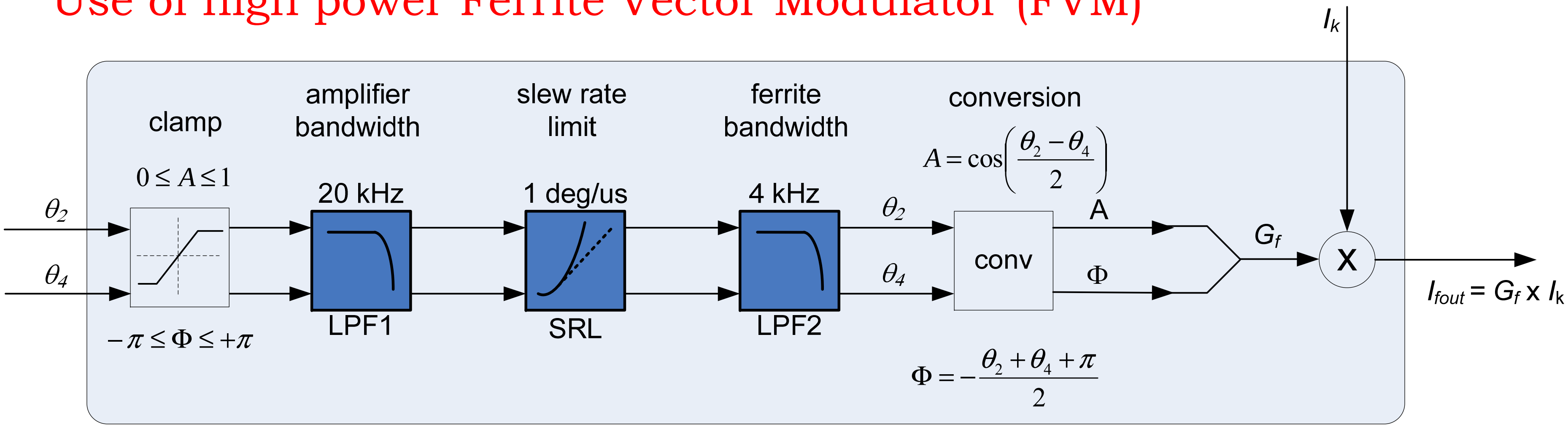
HINS/PROJECT X

What's unique

– normal and super conducting cavities with 1 klystron ?

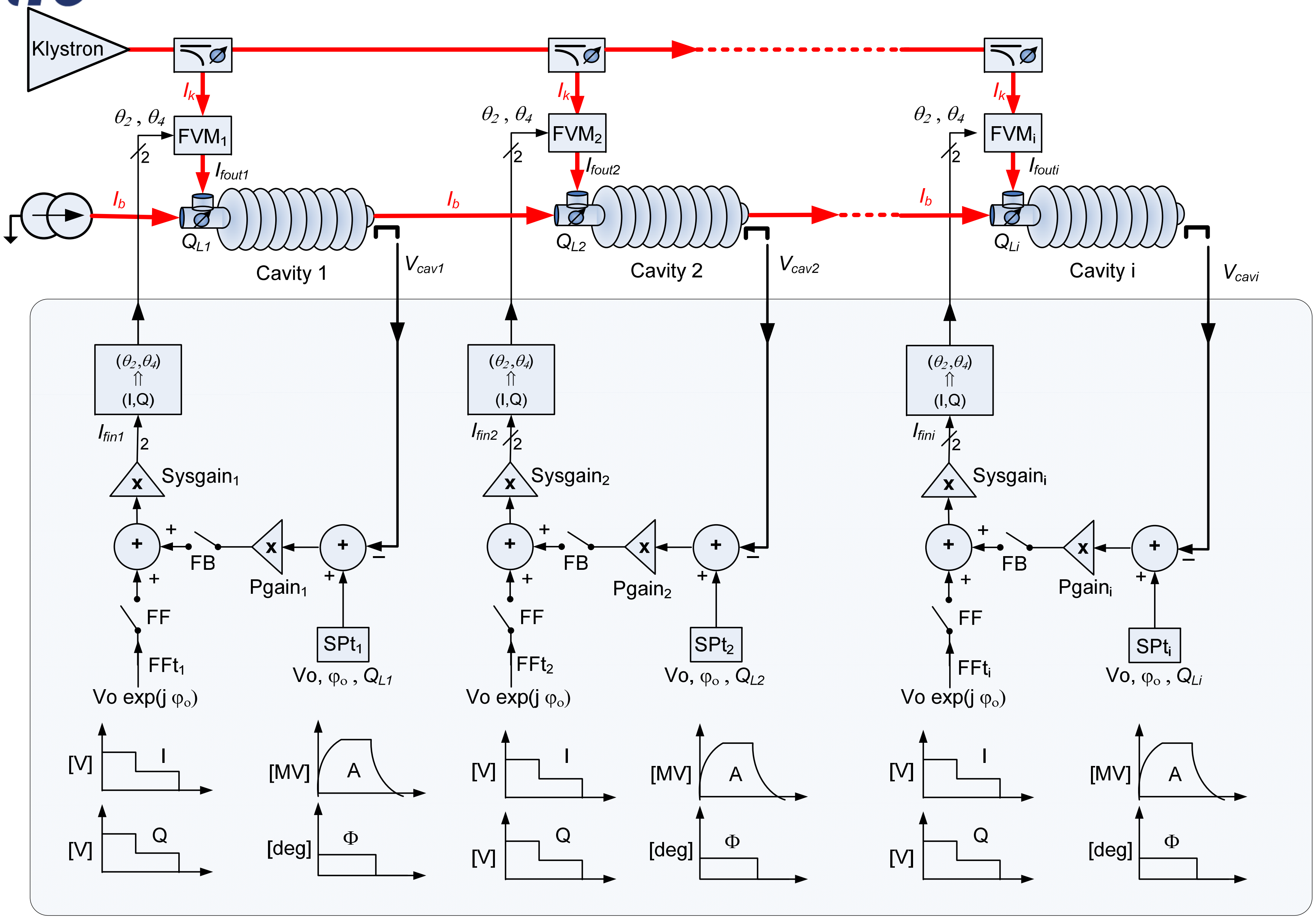
– each cavity has its own: Q_0, V_0, Φ_s, ψ, Q_L

Use of high power Ferrite Vector Modulator (FVM)



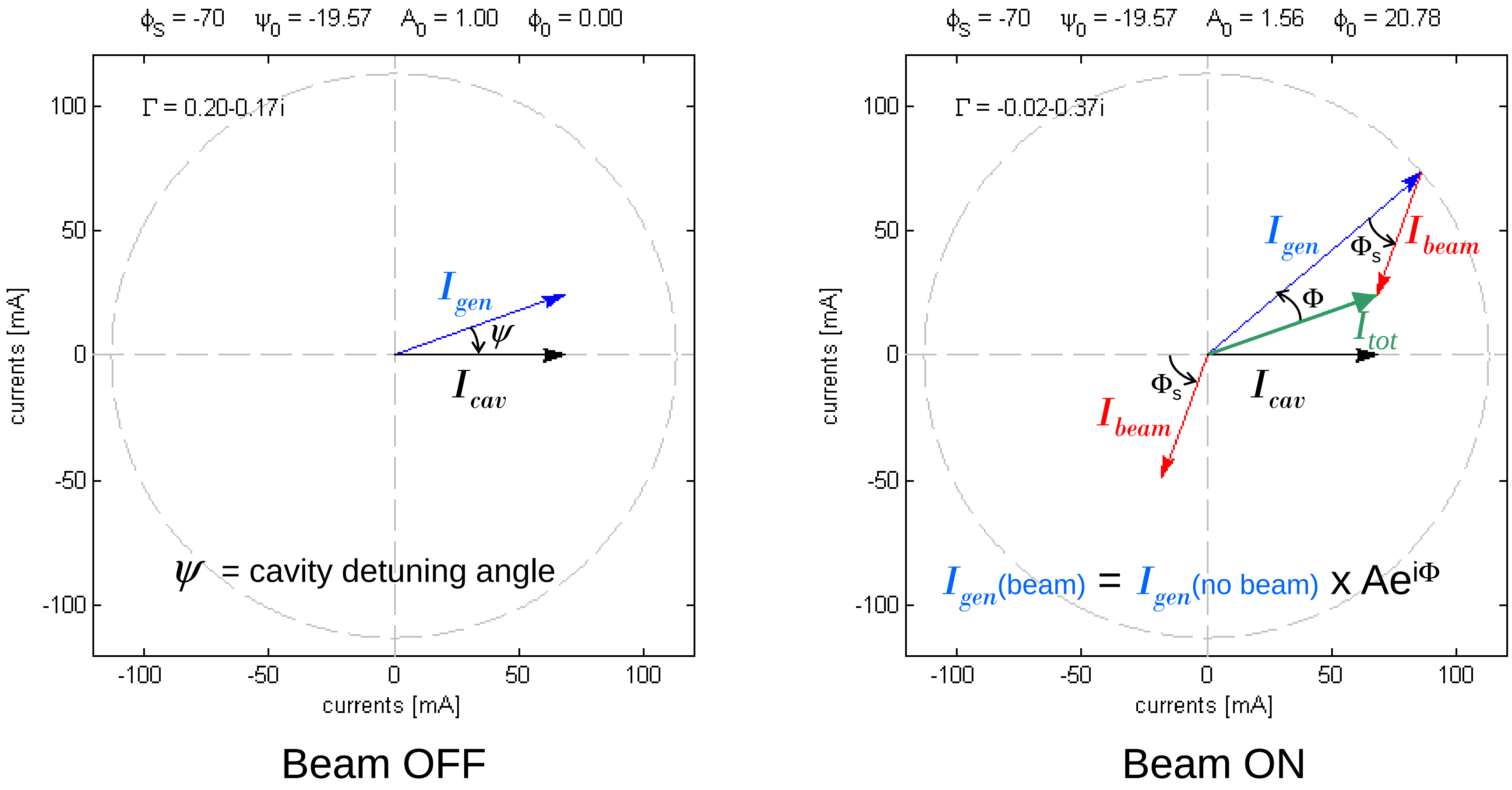
Can HINS work without FVM ?

HINS with FVM: individual Cavity Feedback Control



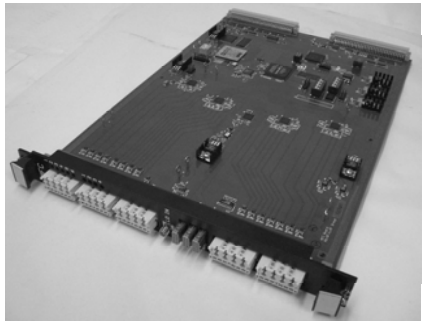
Using the klystron FF to compensate for beam loading

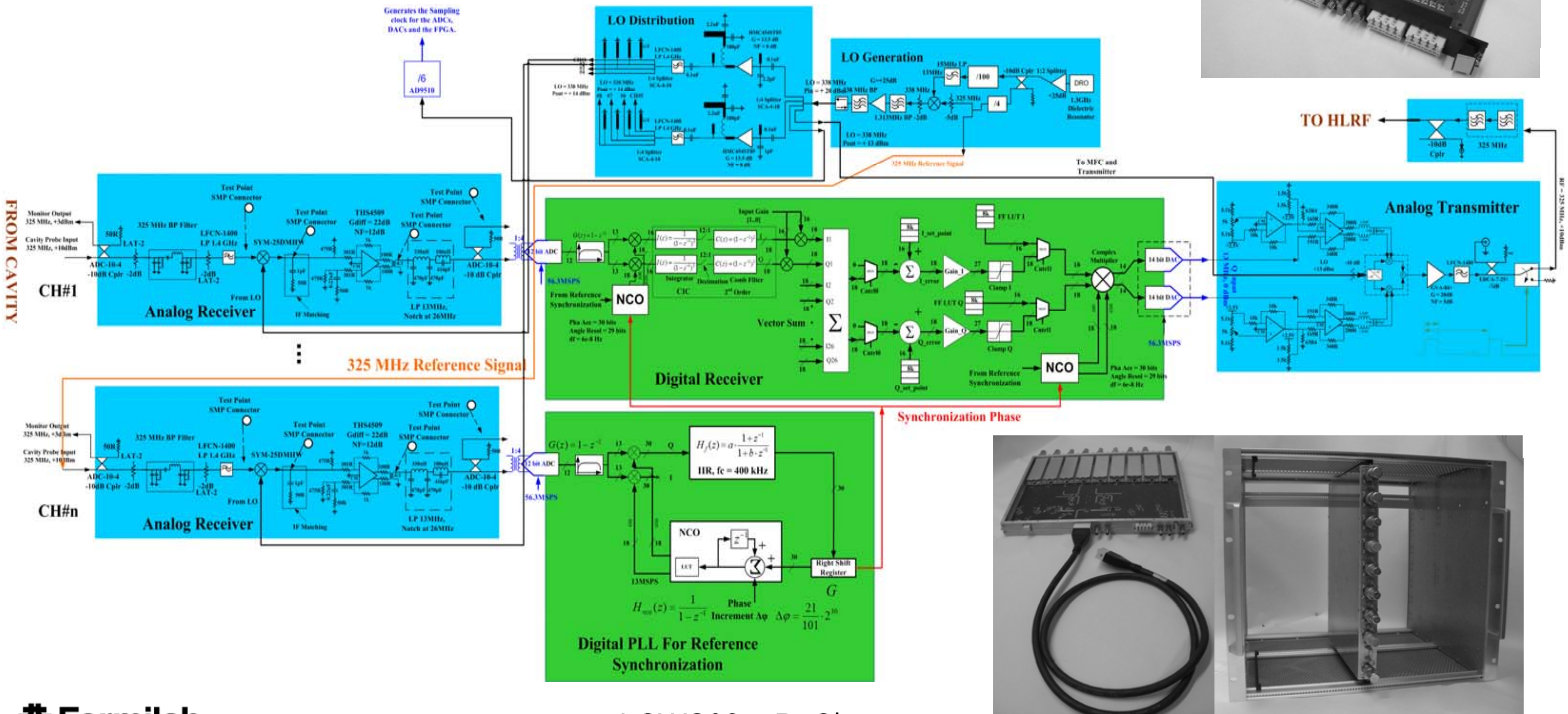
➔ No dynamic use of FVM



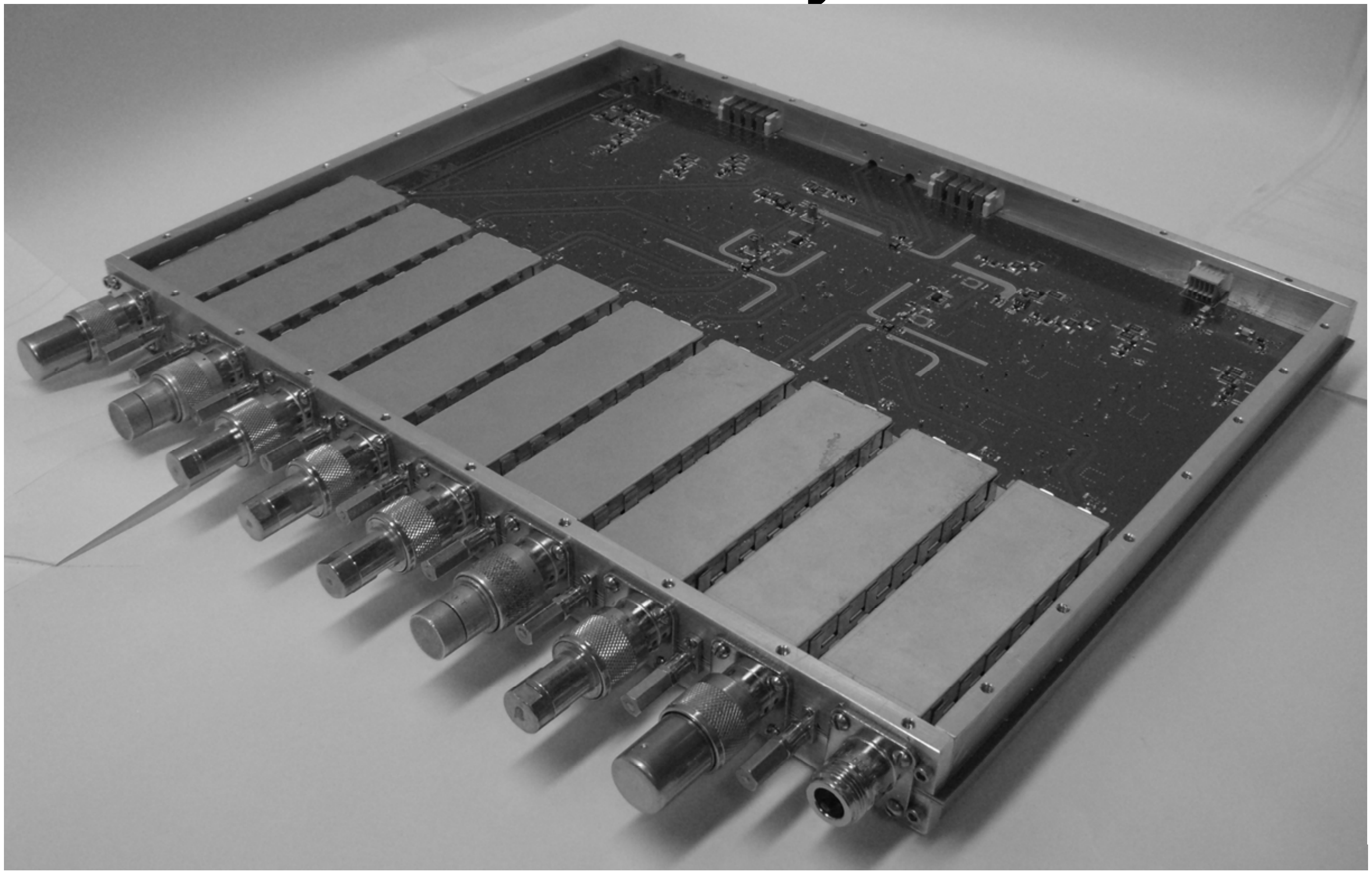
Assuming nominal beam loading, there is no need to modulate the klystron forward power using the ferrite vector modulator if $\boxed{I_{tot}\text{(beam OFF)} = I_{tot}\text{(beam ON)}}$

325 MHz LLRF System With MO and LO Generation

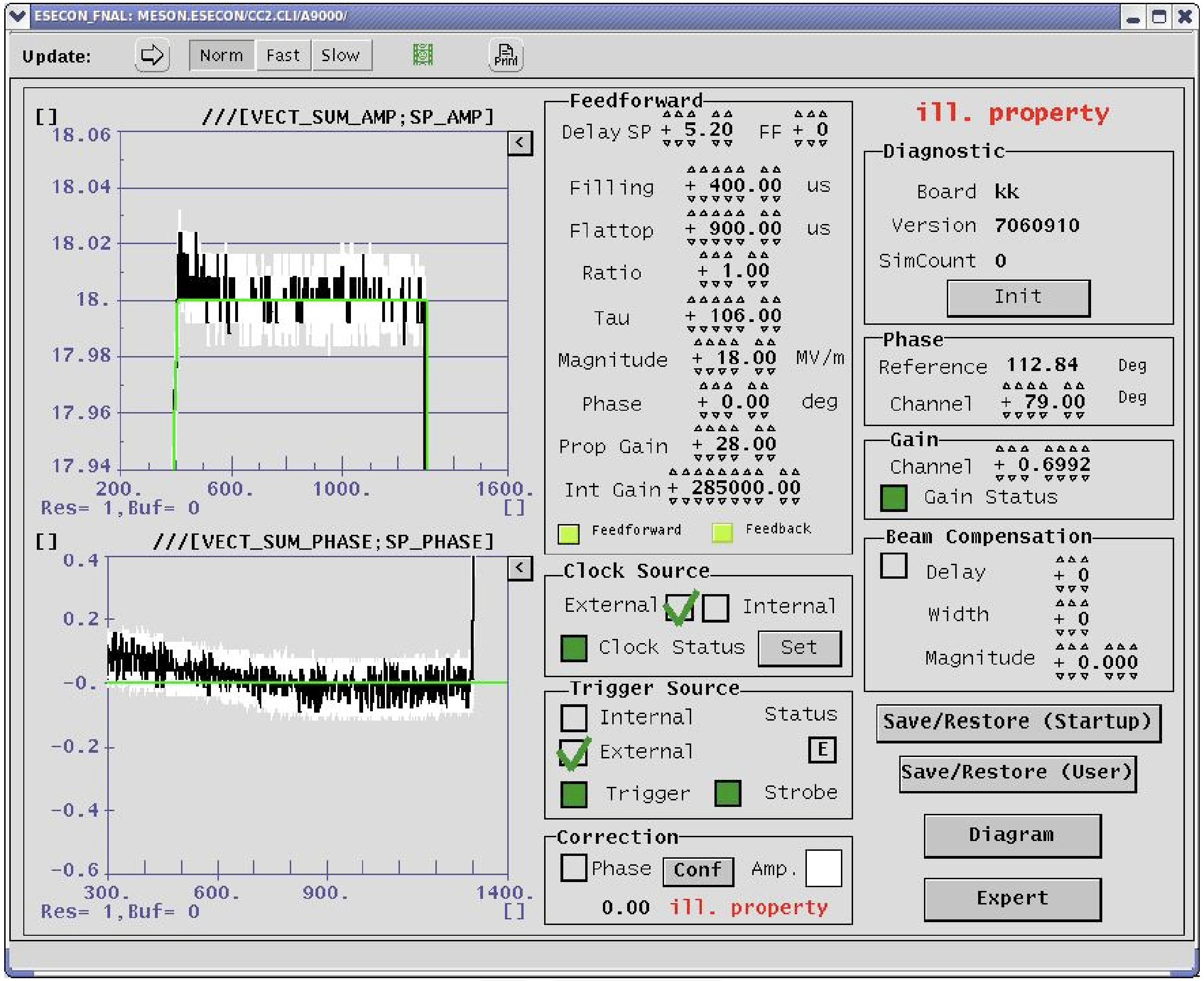




Modified 1.3 GHz Board for 3.9 GHz System



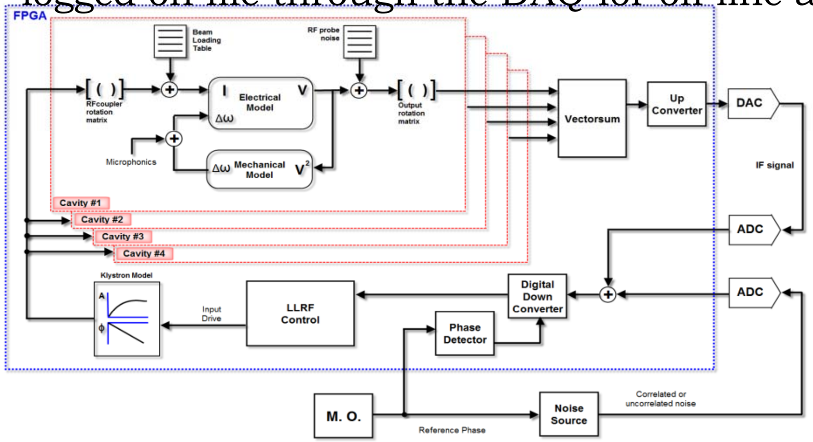
3.9GHz Regulation - ESECON



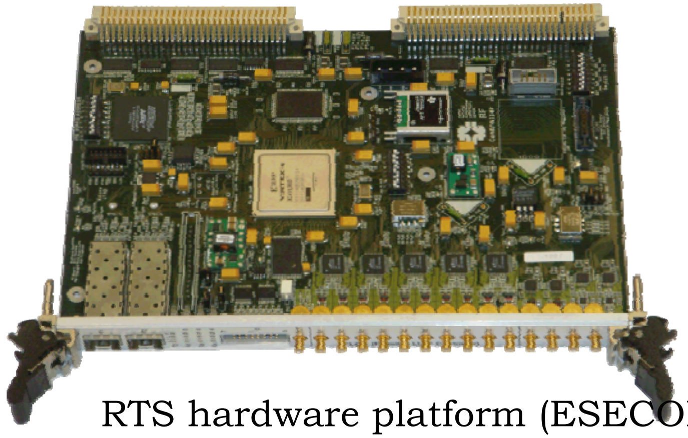
HTS cavity 3 QL = 1.2
w12 = 9.42 Krad/s Pg
Igain 285000.

Real Time RF Simulator (RTS) and control

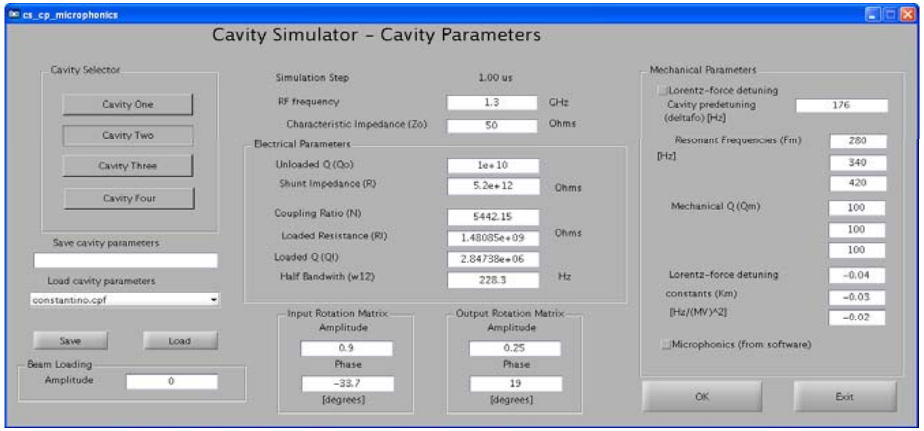
The RTS simulates the amplitude and phase dynamics of multiple RF cavities. The RTS implements the TTF electrical and mechanical dynamic models. It also includes several noise and disturbance sources. Al simulation parameters can be uploaded or saved to a file, or entered through the RTS control panel. The simulator outputs can be displayed on an oscilloscope and they are also logged on file through the DAQ for off line analysis.



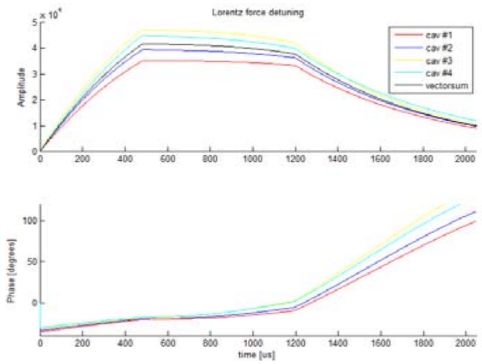
RTS block diagram



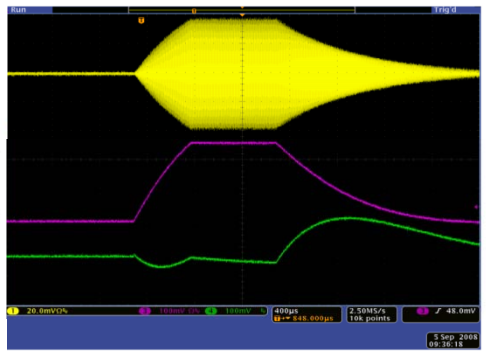
RTS hardware platform (ESECON)



RTS control panel

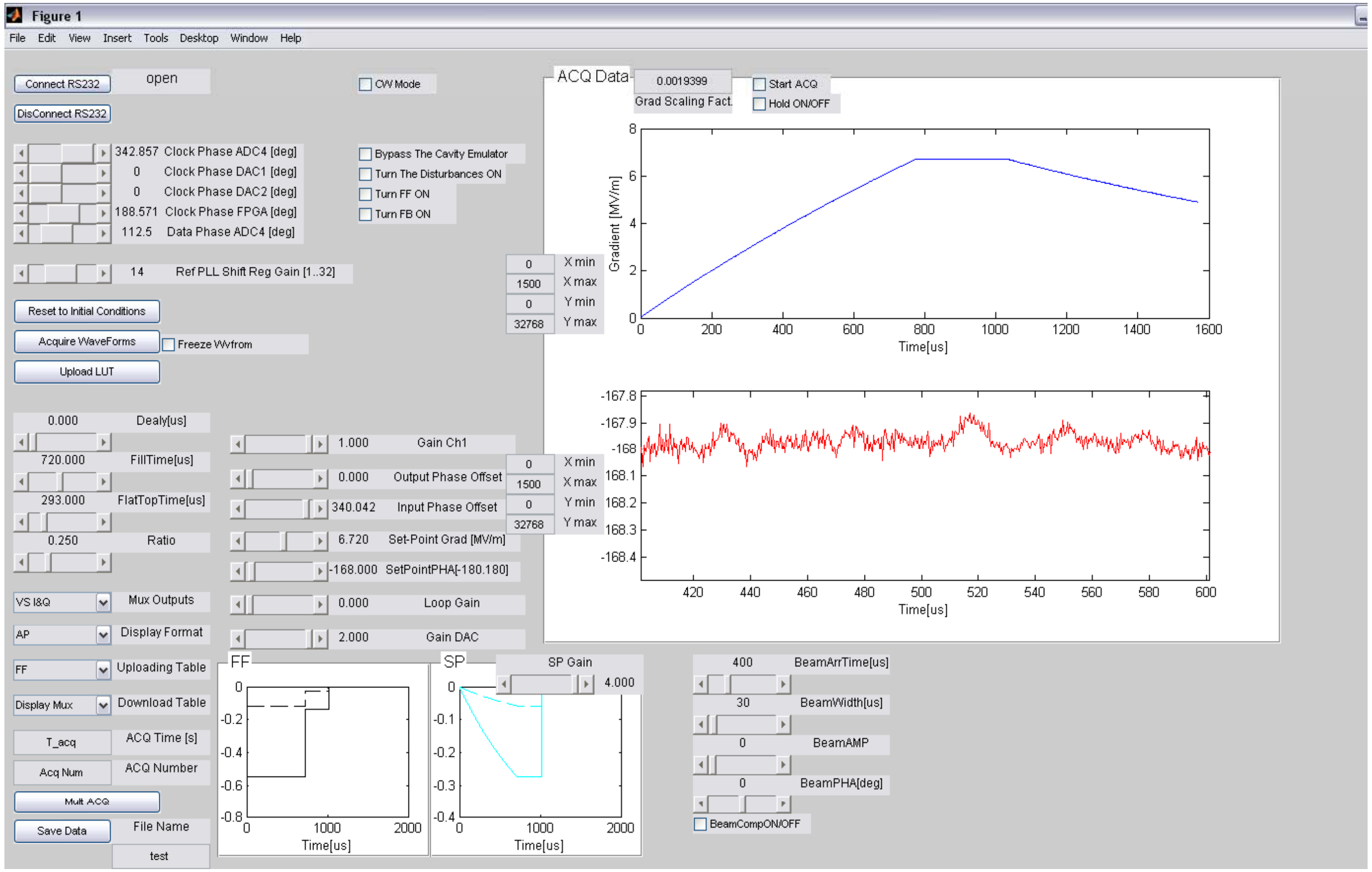


RTS cavity outputs into DAQ log file



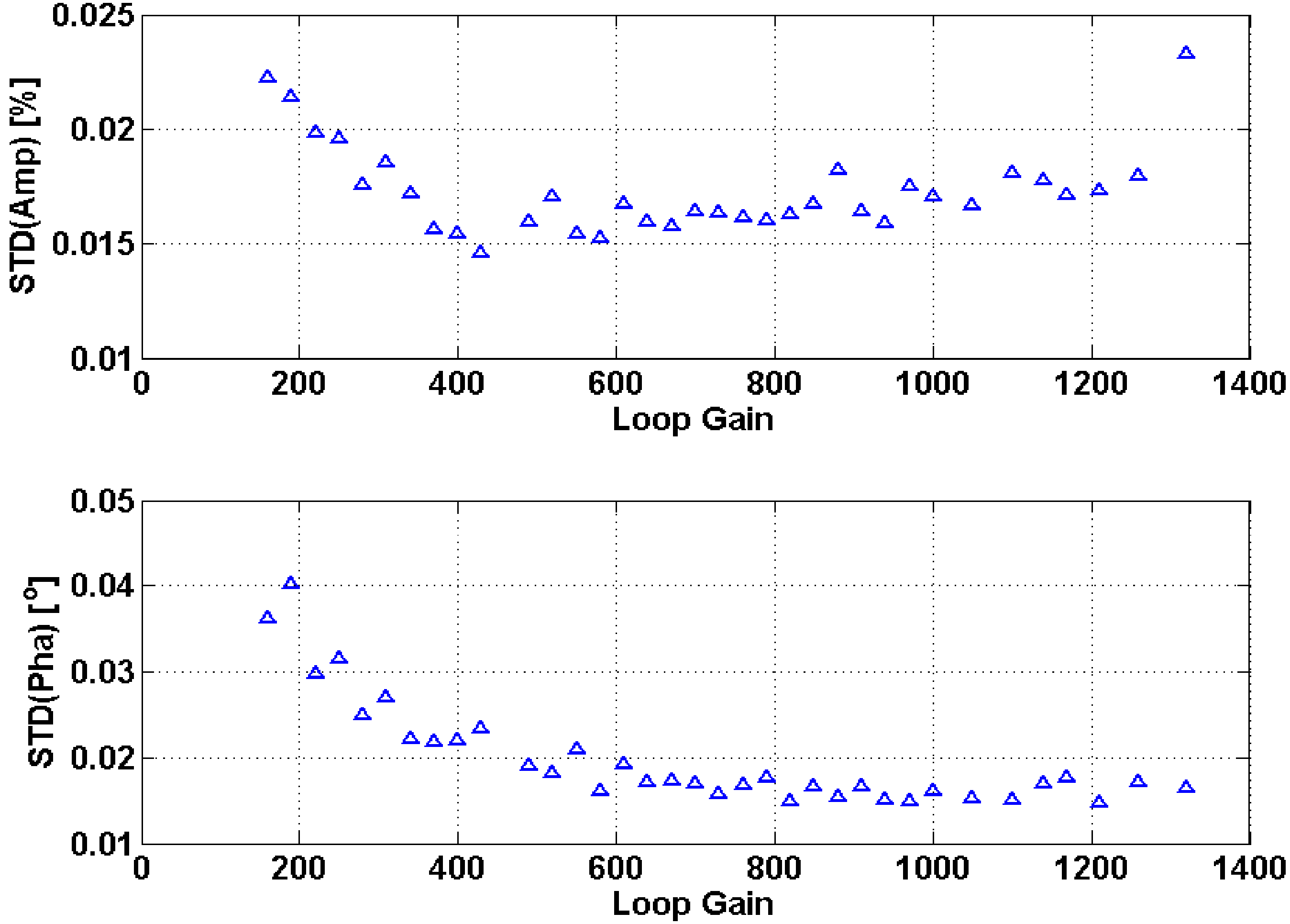
RTS outputs on the oscilloscope

Regulation of CC1 at A0

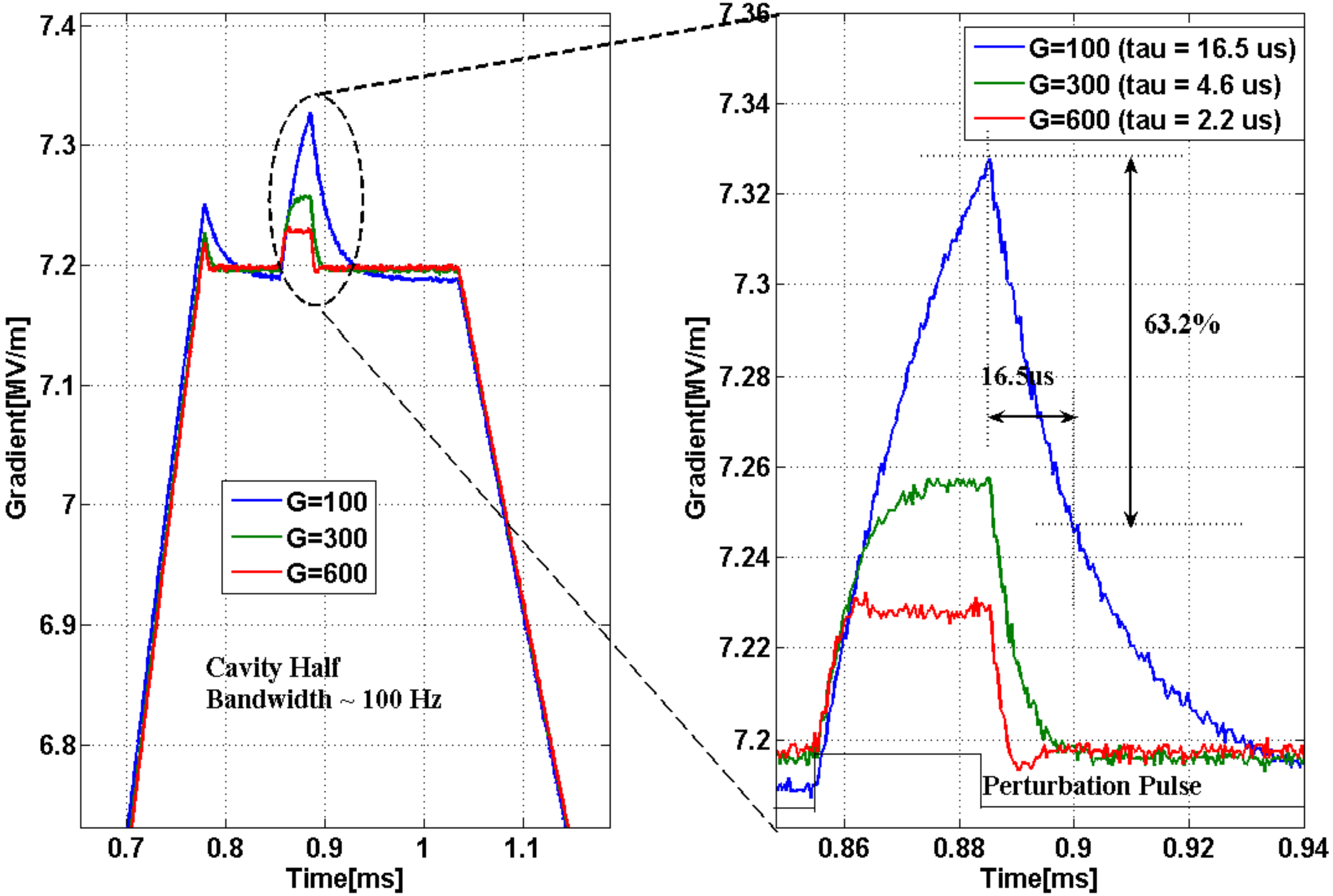


loop gain up to 1200
0.016% of amplitude stability and 0.007deg phase stability

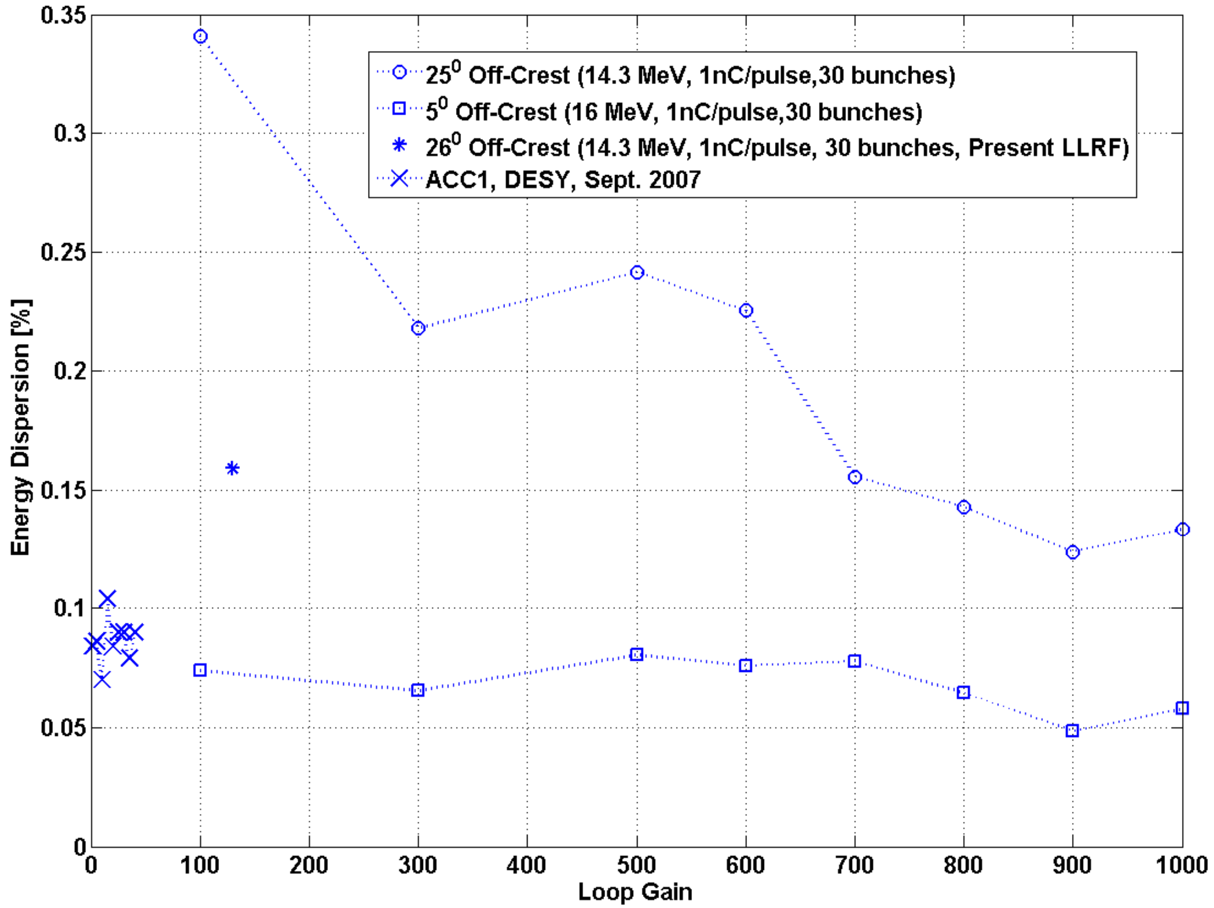
CC1- Error as a Function of Gain



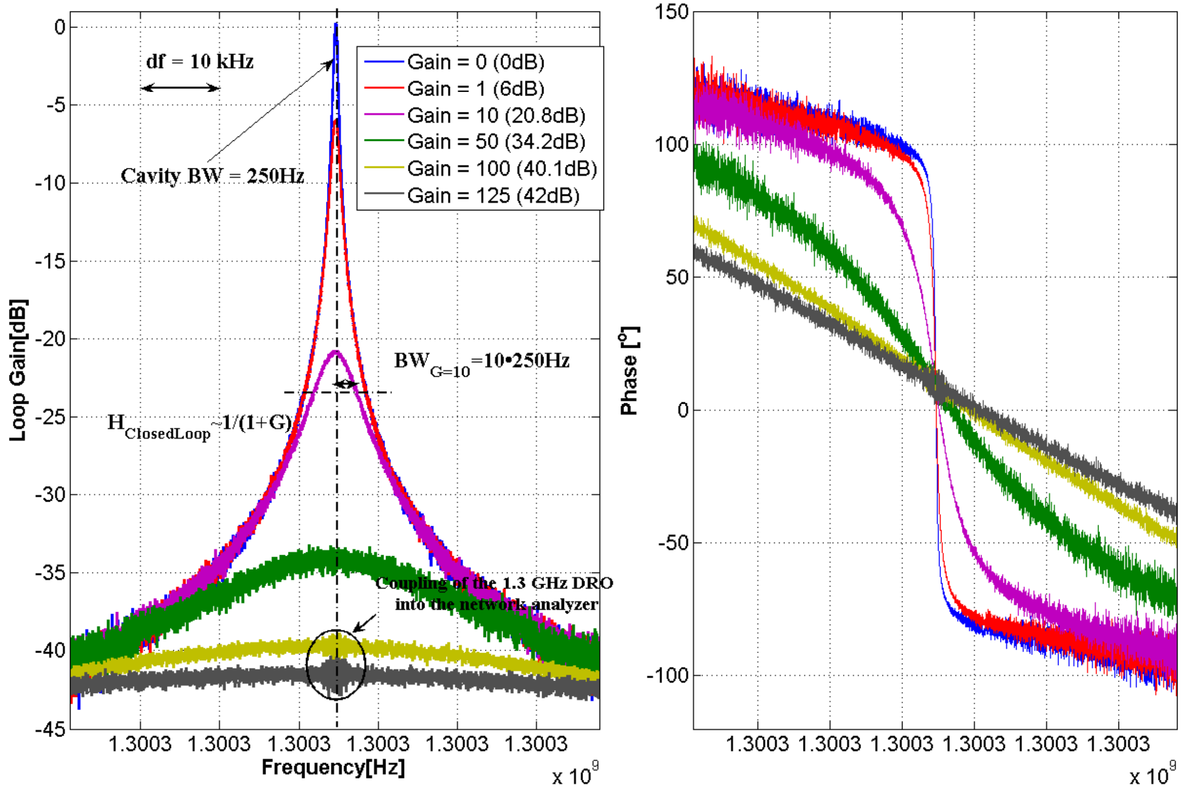
Response to Disturbance



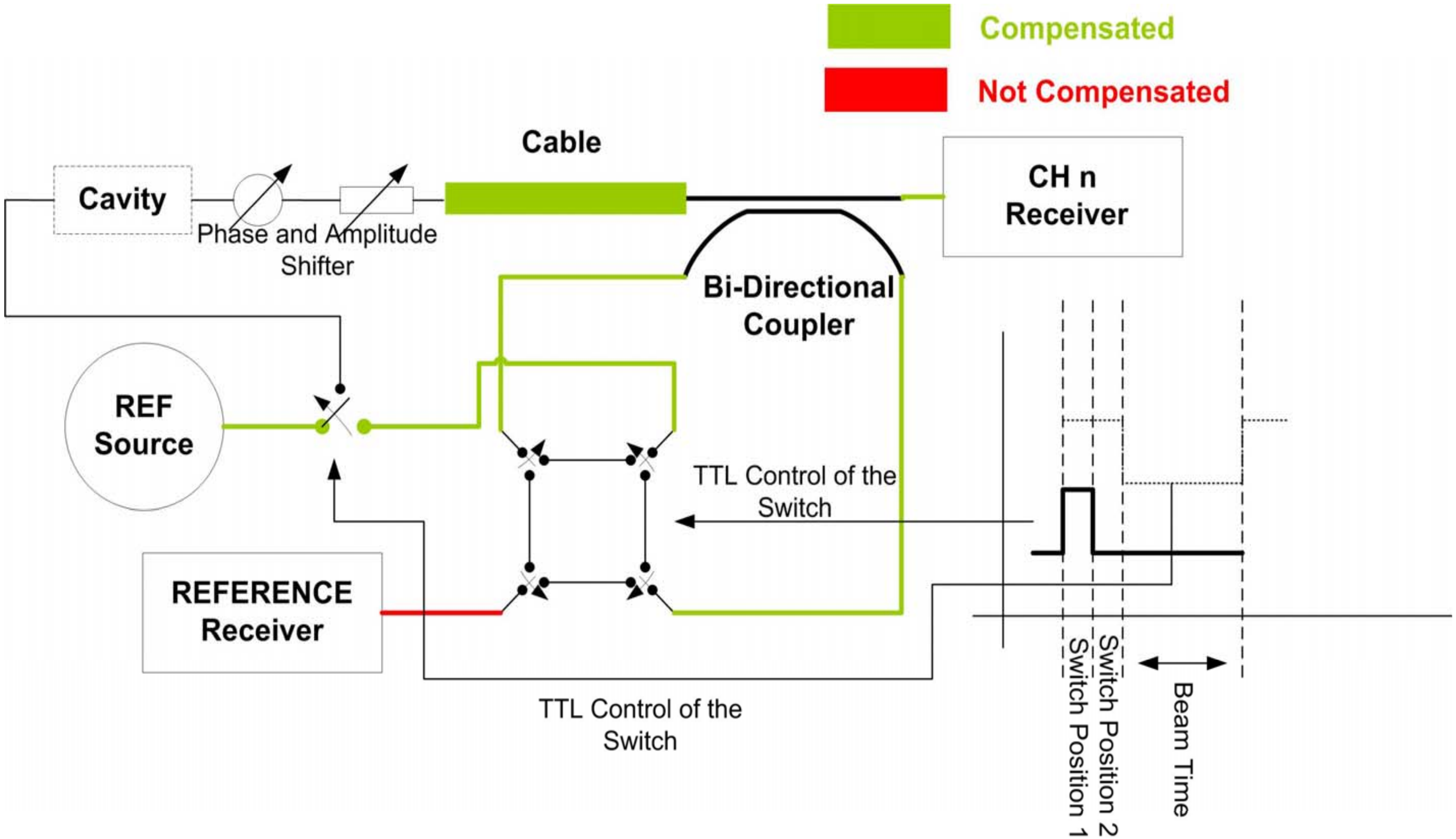
Beam Jitter Measurements



Closed Loop Response of Cavity Model and Controller



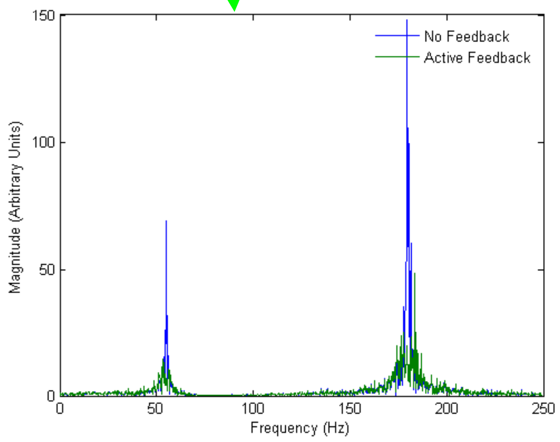
Drift Calibration



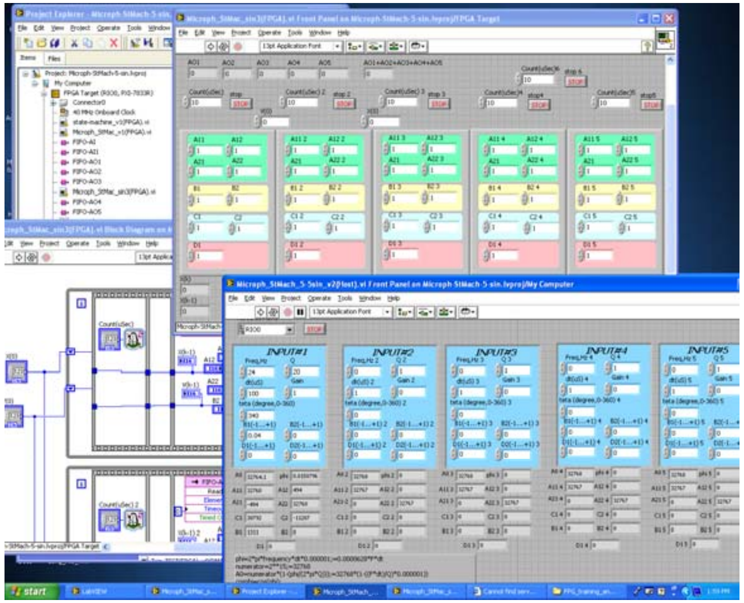
Active Compensation of Microphonics in CCII

- Reviewed 3 different algorithms used with SCRF cavities to actively dump random vibrations.
  - *High Order Transfer Function (DESY)*
  - *LMS Adaptive Filter (FNAL)*
  - ***Narrow Band Filter Bank (Michigan State)***

- Developed code and implemented on NI FPGA PXI-7833R " **Narrow Band Filter Bank** " algorithm (with up to 5 resonances/poles).
- Matlab simulation of NBFB in CW cavity. Two mode system (55 Hz and 180 Hz) driven by white noise. Predicts 15 dB of suppression possible.

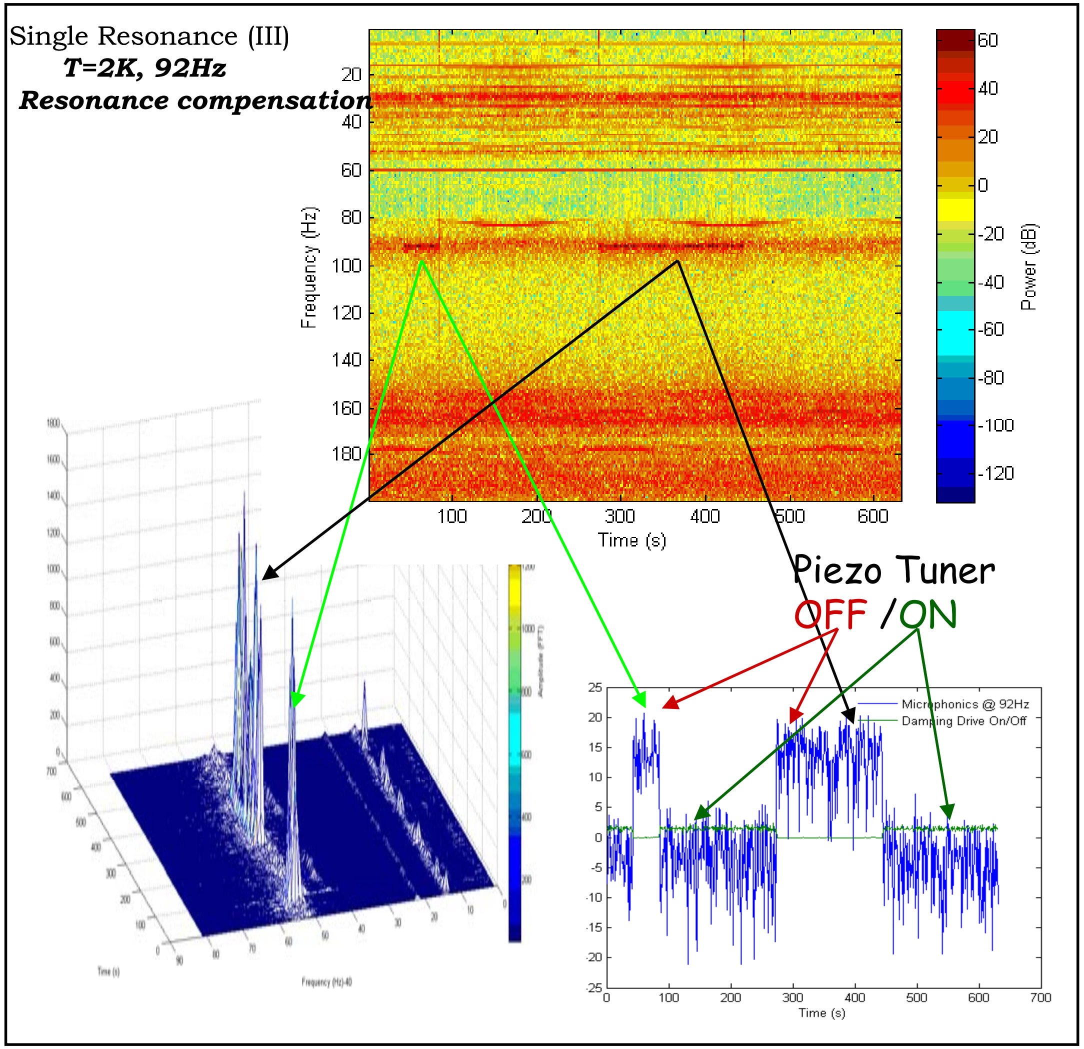


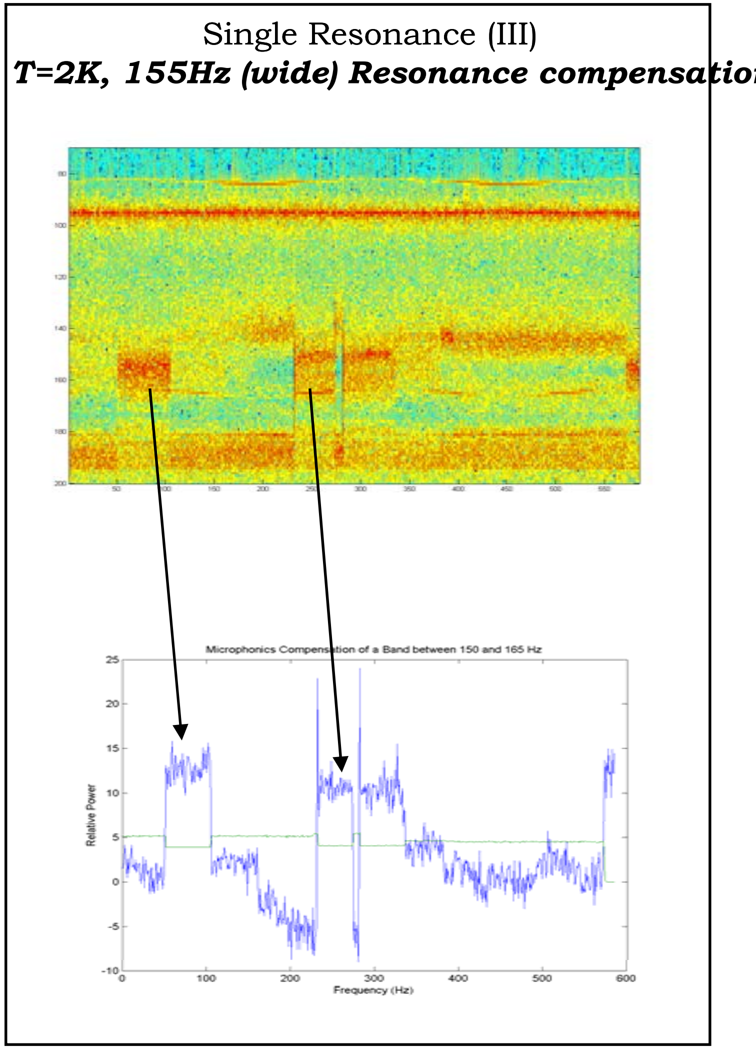
Matlab simulation of NBFB in CW cavity



Active Compensation of Microphonics in CCII (cont.)

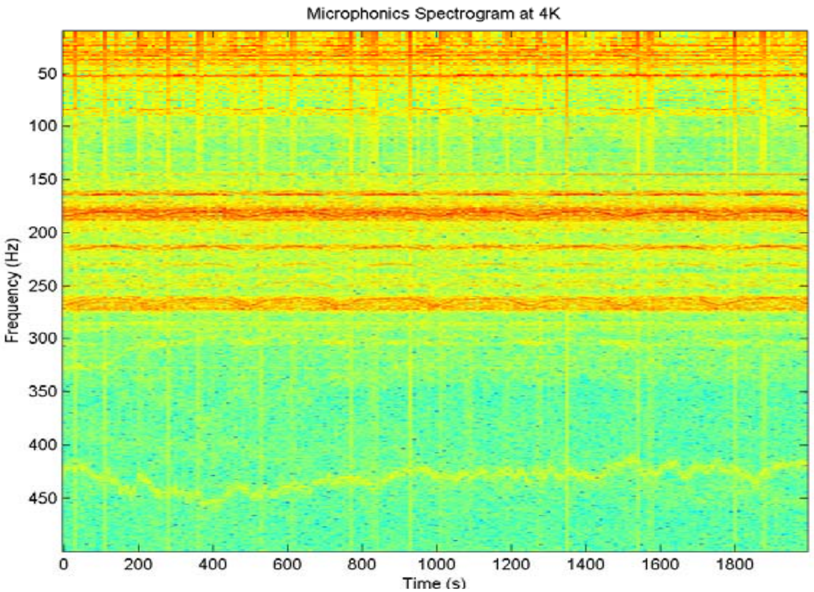
- Run CCII in CW mode (low power). Forward Power and Probe signals feed to AD8302EB (RF/IF Gain and Phase Detector board from Analog Devices). Analog Phase detector signal used as input signal for "**Narrow Band Filter**".
- Illustrated dumping vibration of CCII (at 52Hz, 92Hz, 155Hz, etc.) up to 15db.

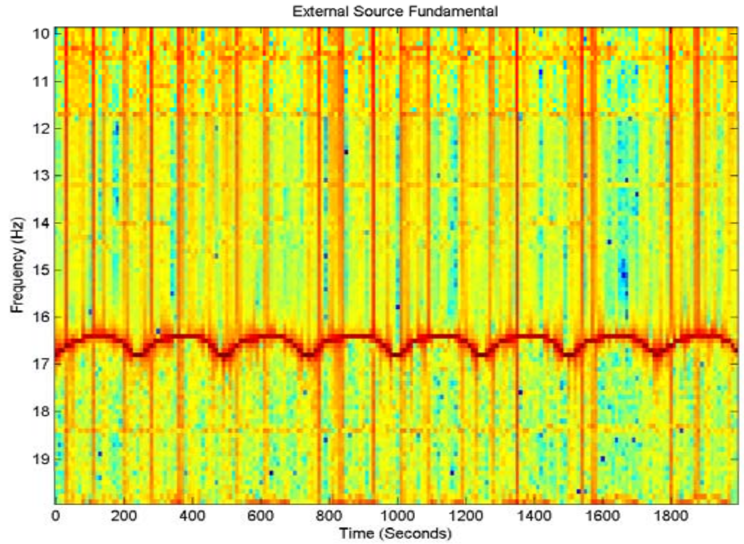


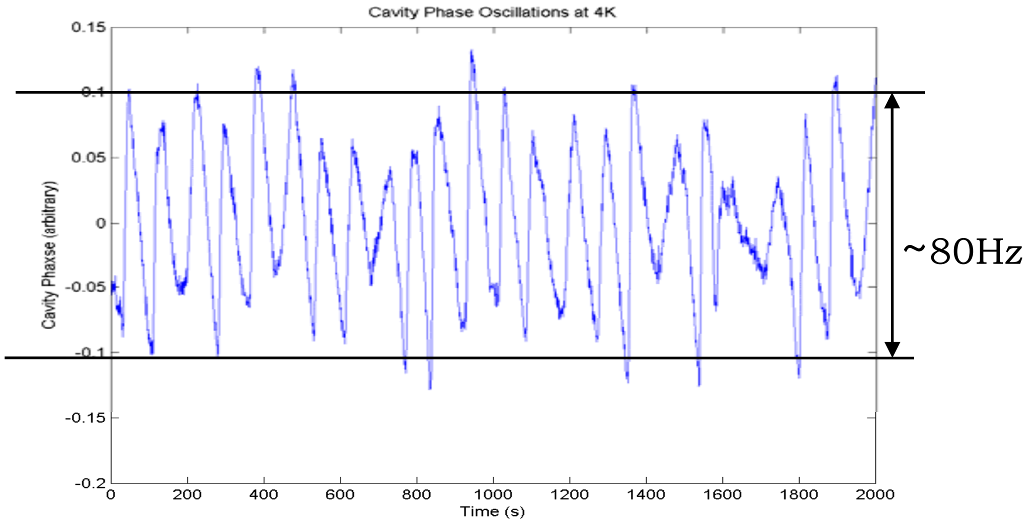


Active Compensation of Microphonics in CCII (cont.)

- Measured CCII vibration at 4K, 2K during many hours of operation (long term stability of microphonics vibrations).





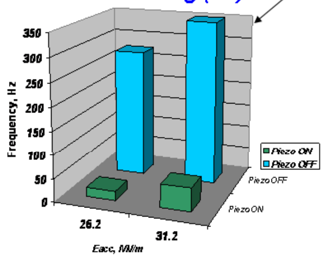


Experimental results with LFDC system proposed for NML/CM1/CC2

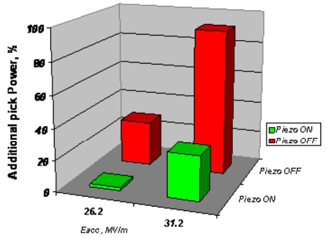
FNAL's Resonance Control Group used this system for LFD compensation at **CC2**.

	Detuning (Hz)		Additional Forward Power at FT (pick)		Piezo Voltage, [V] (max=120V)
	Piezo OFF	Piezo ON	Piezo OFF	Piezo ON	
26.2 MV/m	275	20	29%	2%	20V
31.2 MV/m	350	50	92%	28%	40V

Detuning (Hz)



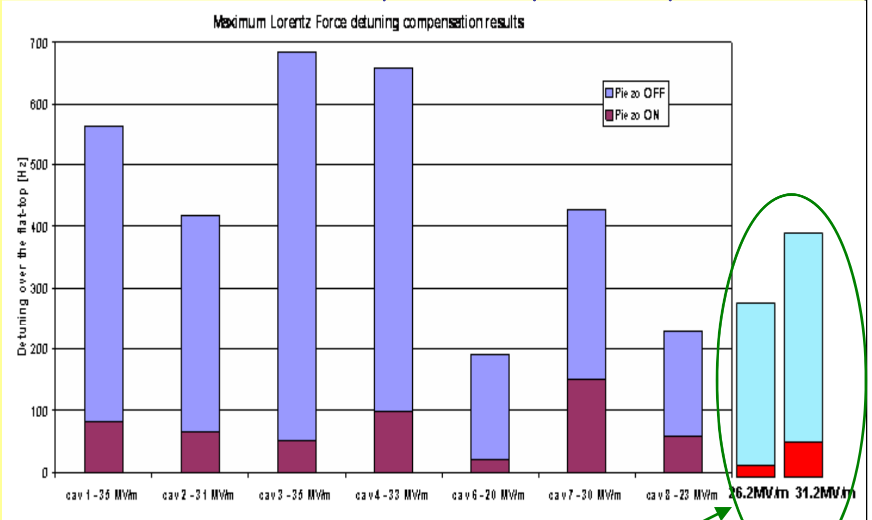
Additional Forward Power at FT (pick)



DESY

Experimental results from **FLASH**, Module#6 (L. Lilje)

Maximum Compensation per Cavity



CC2 results

Plans for 2009

- Complete Linac and Comb Filter projects
- Control 8 cavity cryomodule at NML
  - MFC and ESECON drive and monitor
- Control 6 copper cavities for HINS
- Build new Recycler LLRF for NOVA
- Continue with 9mA tests at FLASH