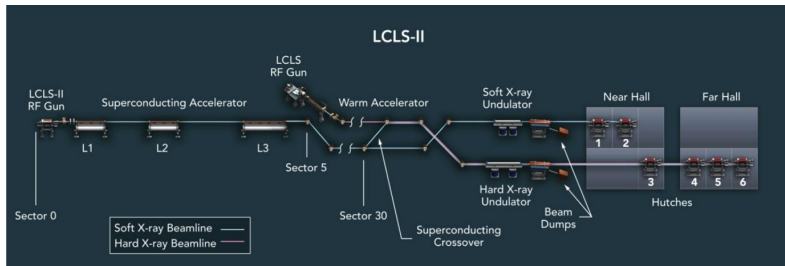


RF Controls for high- Q_L Cavities for the LCLS-II

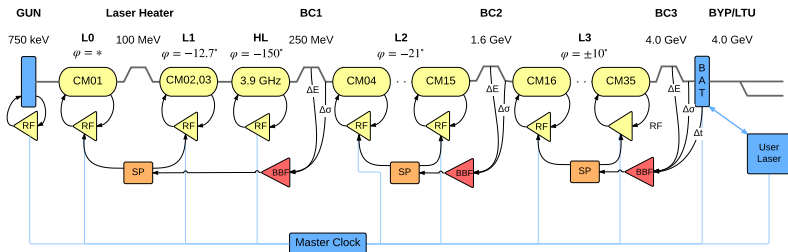
Carlos Serrano, representing the LCLS-II LLRF Collaboration



LCLS-II



LCLS-II Feedback



* = $(3^\circ, -15^\circ, 0^\circ, 0^\circ, 0^\circ, 15^\circ, 0^\circ)$

Source: Linac Requirements
(LCLS-II2.4-PR-0041-R4)

LLRF Requirements: 0.01% and 0.01° RMS (≥ 1 Hz)

LCLS-II LLRF scale

Region	Freq. (MHz)	# cavities	Type	LLRF Racks
Gun	185.7	1	NC	1
Buncher	1,300	1	NC	1
Linearizer	3,900	16	SC	4
Linac	1,300	280	SC	70

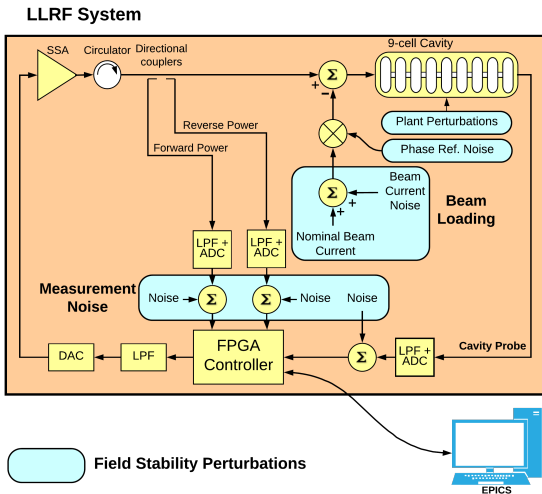
- Totals:
 - 76 LLRF racks,
 - ~ 300 LLRF chassis,
 - 3 frequencies,
 - One common platform.

1.3 GHz RF System & beam parameters

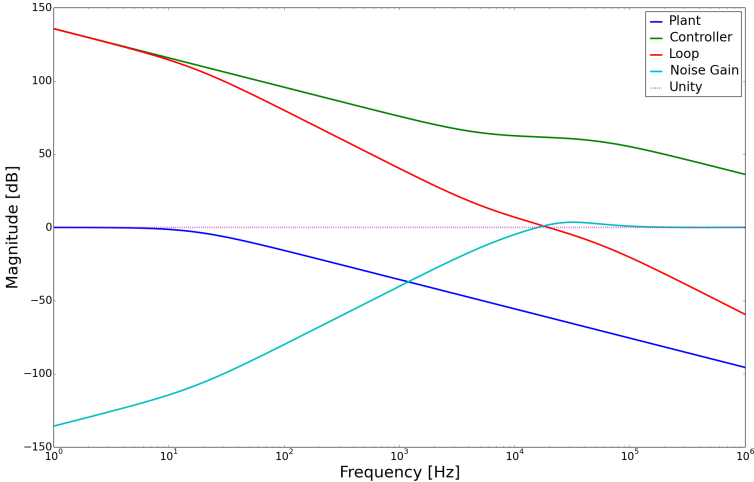
Parameter	Symbol	Value	Units
RF Frequency	f_{RF}	1.3	GHz
Unloaded Q	Q_0	$2.7 \cdot 10^{10}$	unitless
Loaded Q	Q_L	$4 \cdot 10^7$	unitless
Shunt Impedance	R/Q	1036	Ω
Microphonic Detuning	Δf_d	± 10	Hz
Bunch Charge	Q_b	≤ 300	pC
Bunch Charge Error	$\Delta Q_b/Q_b$	± 1	%
Bunch Rep. Rate (CW)	f_b	≤ 1	MHz
Avg. Beam Current	I_{av}	≤ 0.3	mA

***Source:** Performance and Functional Requirements for the LCLS-II LLRF System (LCLSII-2.7-FR-0371-R0)

LLRF System Topology



Analytical Transfer Functions



Physics requirements to LLRF specs

Core physics requirement is 0.01% and 0.01° *

Start with a coarse guideline for uncorrelated noise sources...

Noise Source	Amplitude	Phase
Measurement	0.005%	0.004°
PRL	N/A	0.004°
Plant pert.	0.005%	0.004°
Beam loading	0.005%	0.004°
Other/unknown	0.005%	0.004°

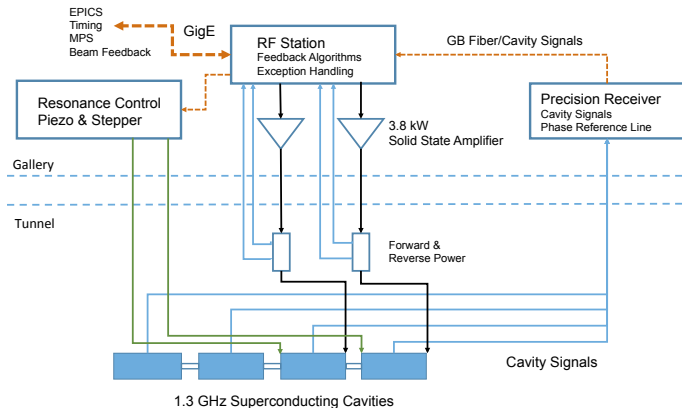
... and adjust with empirical evidence.

***Source:** Performance and Functional Requirements for the LCLS-II LLRF System (LCLSII-2.7-FR-0371-R0)

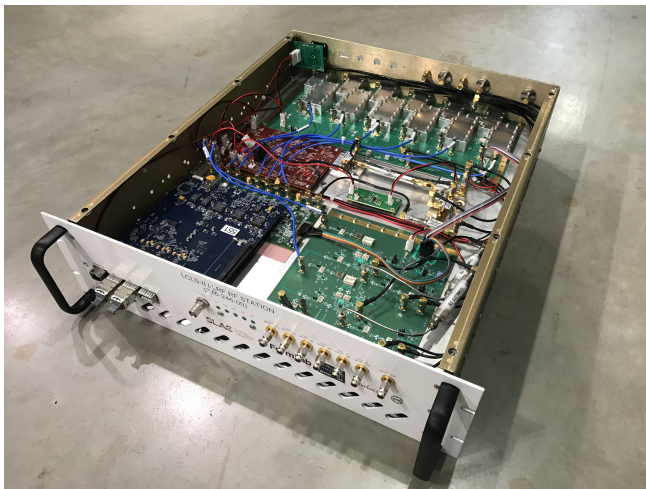
LLRF specs to engineering

- High- Q_L superconducting \implies sensitive in the audio band and low bandwidth,
- Tight field regulation specs \implies high noise rejection,
- High noise rejection and low bandwidth \implies very high gains,
- High gains \implies measurement noise is amplified greatly,
- Tight regulation of high- Q_L SRF cavities \implies low noise design and careful engineering

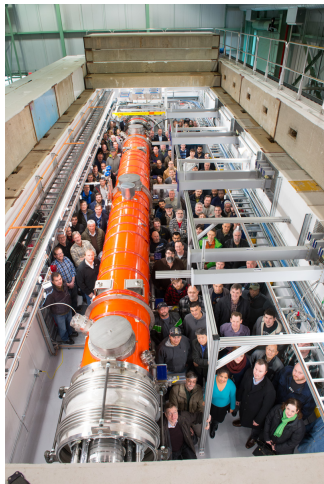
LCLS-II LLRF System Architecture



LCLS-II LLRF RFS Chassis



LCLS-II LLRF Assembly



Cavity turn-on process



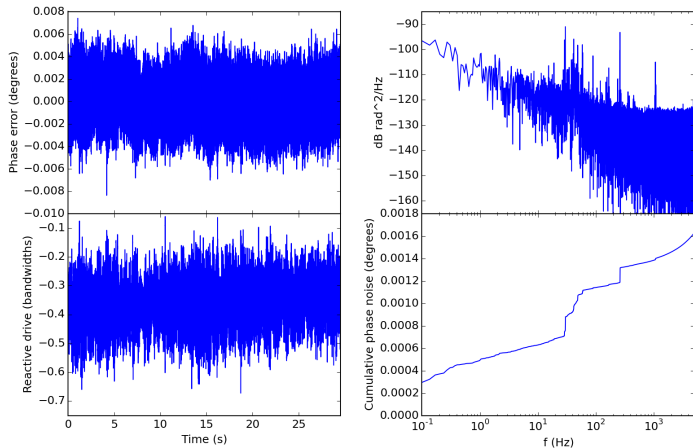
Tests at CMTF (FNAL)

Noise Source	Amplitude	Phase
Measurement	0.005%	0.004°
PRL	N/A	0.004°
Plant pert.	0.005%	0.004°
Beam loading	0.005%	0.004°
Other/unknown	0.005%	0.004°

- Out-of-loop measurements performed using FNAL system,
- Measurement band limitation (0.1 Hz - 5 kHz),
- Different environment than the LCLS-II tunnel,
- For noise sources emulated in this setup the phase noise budget is 5.6×10^{-3} deg. RMS

Results

F1.3-03 Cavity 2 out-of-loop -7.2 dBFS; phase error: $1.63\text{e-}03$ degrees rms (0.1 Hz - 5.0 kHz) 170705_1730_lcls2



Status and outlook

- Demonstrated RF controls of 8 cavities simultaneously at 16 MV/m with good field stability,
- Demonstrated effectiveness of Active Resonance Controls to keep detuning under ± 10 Hz peak,
- Both firmware and software are almost at the test-stand operational level,
- LERF at JLab will provide a very good framework to continue progress,
- Hardware production on track to start Linac commissioning in late 2019.

Acknowledgements

LLRF Team

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