Overview of MicroTCA-based LLRF at SXFEL

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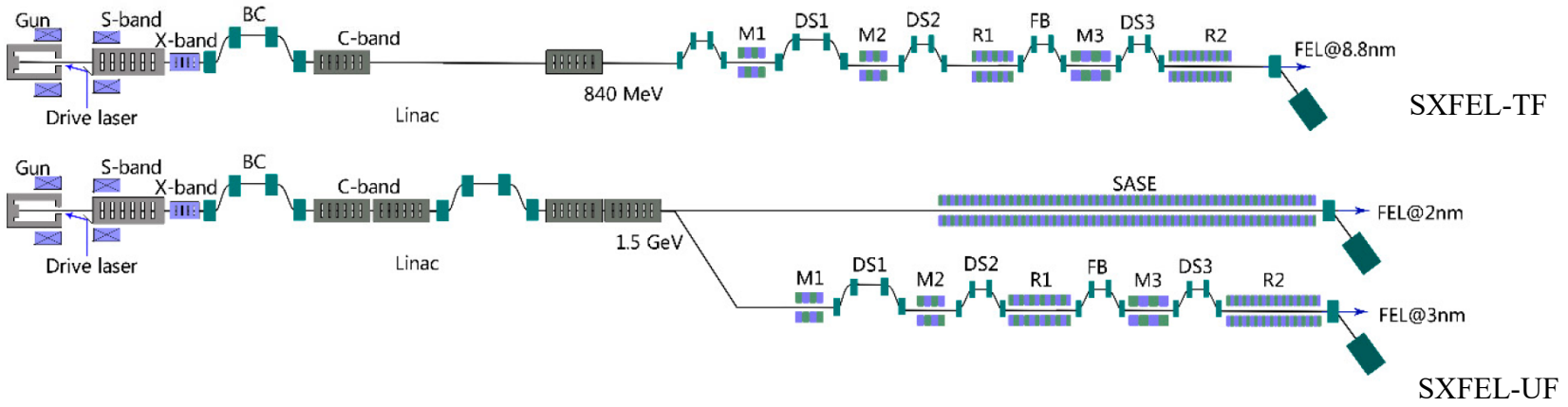
Outline

- SXFEL
  - SXFEL-TF
  - Milestones
  - SXFEL-UF
- MicroTCA-based LLRF
  - RF system
  - Firmware
  - Software
  - Operation problems

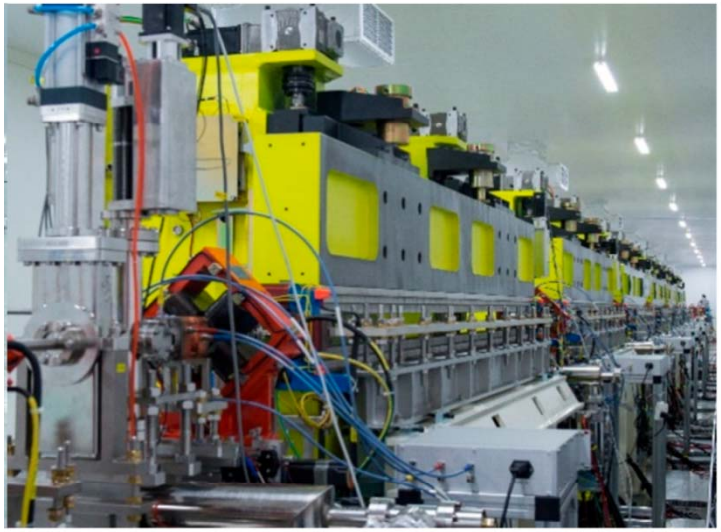
SXFEL

The Shanghai soft X-ray Free-Electron Laser facility (SXFEL) is located at the Shanghai Synchrotron Radiation Facility (SSRF) campus.

SXFEL is being developed in two steps: the test facility (SXFEL-TF), and the user facility (SXFEL-UF).



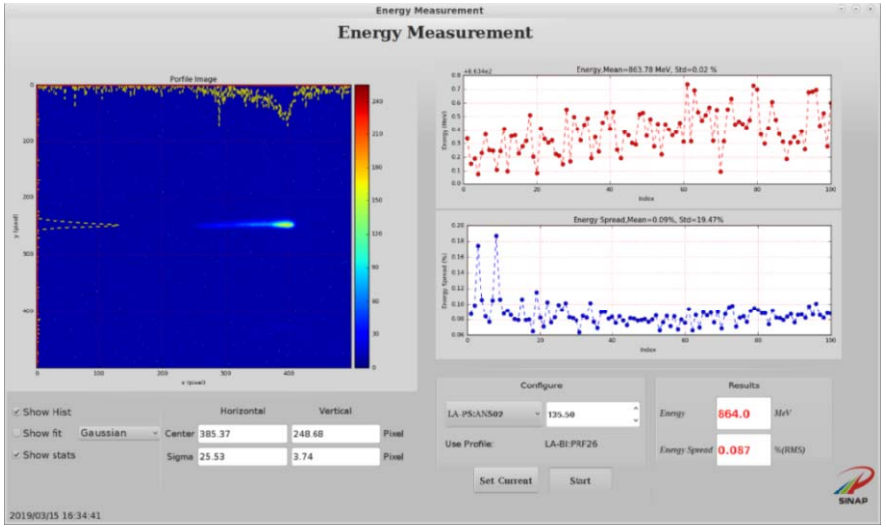
SXFEL-TF

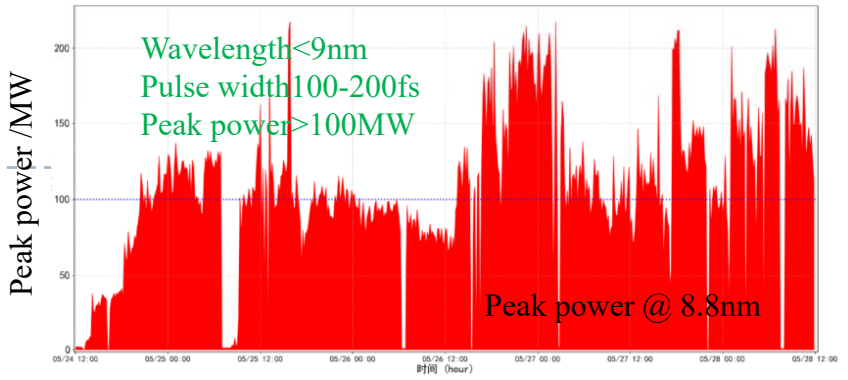


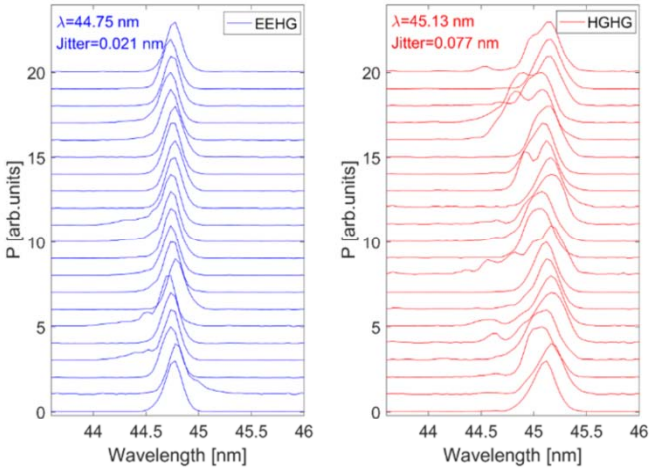
Linac		
Beam charge		≥0.5nC
Beam energy		≥840MeV
Energy spread		≤0.15rms. %
Peak current		≥500A
Beam length (FWHM)		≤1ps
Normalized emittance		≤2.5mm·mrad
Repetition rate		10Hz
Undulator		
Stage 1	Seed laser wavelength	265nm
	FEL output wavelength	44nm
	Modulator undulator period	80mm
	Modulator undulator K value	5.81
	Radiator undulator period	40mm
	Radiator undulator K value	2.22
Stage 2	FEL output wavelength	8.8nm
	Modulator undulator period	40mm
	Modulator undulator K value	2.22
	Radiator undulator period	23.5mm
	Radiator undulator K value	1.43

Milestones

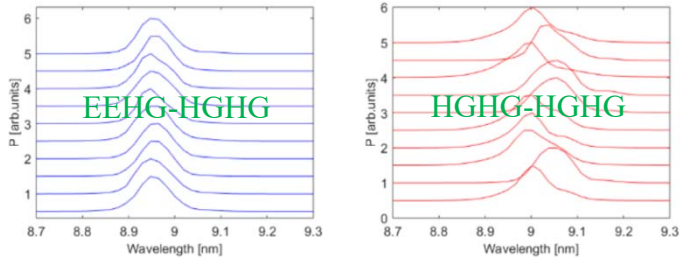
2014.12 Breaking ground
2016.06 Installation
2016.12 Commissioning
2019.03 Process testing of LINAC
2020.05 HGHG-HGHG process testing
2020.06 EEHG-HGHG process testing
2020.11.4 National acceptance







Wavelength and stability @ stage 1

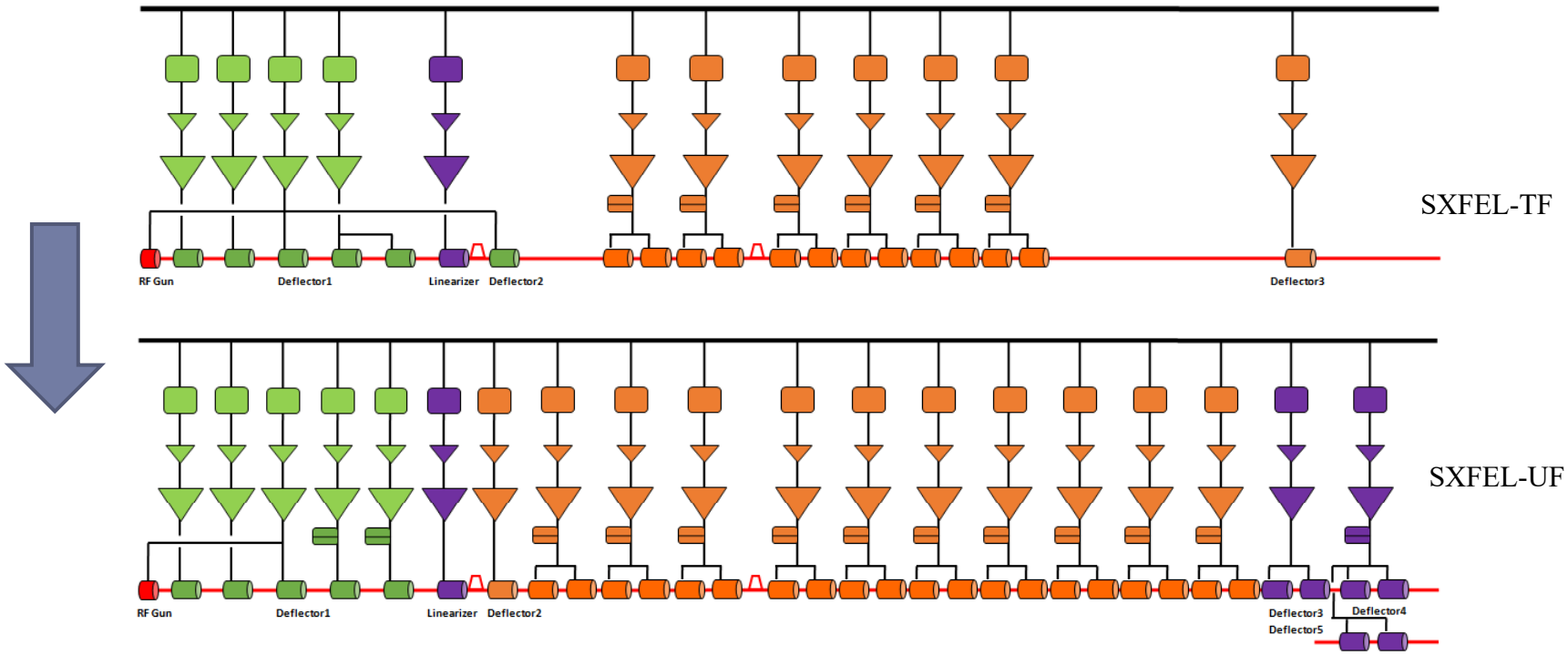


Wavelength and stability @ stage 2

SXFEL-UF

Linac		
Beam charge		≥0.5nC
Beam energy		1500MeV
Energy spread		≤0.15 rms.%
Peak current		≥700A
Beam length (FWHM）		≤0.7ps
Normalized emittance		≤1.5mm·mrad
Repetition rate		50Hz
Undulator		
Line1	FEL operation mode	SASE
	FEL output wavelength	~2nm
	FEL output pulse peak power	≥100MW
Line 2	FEL operation mode	External seeding
	FEL output wavelength	~3nm
	FEL output pulse peak power	≥100MW

	SXFEL-TF	SXFEL-UF
S-band	4	5
C-band	7	11
X-band	1	3
Total	12	19



Layout of injector and main linac

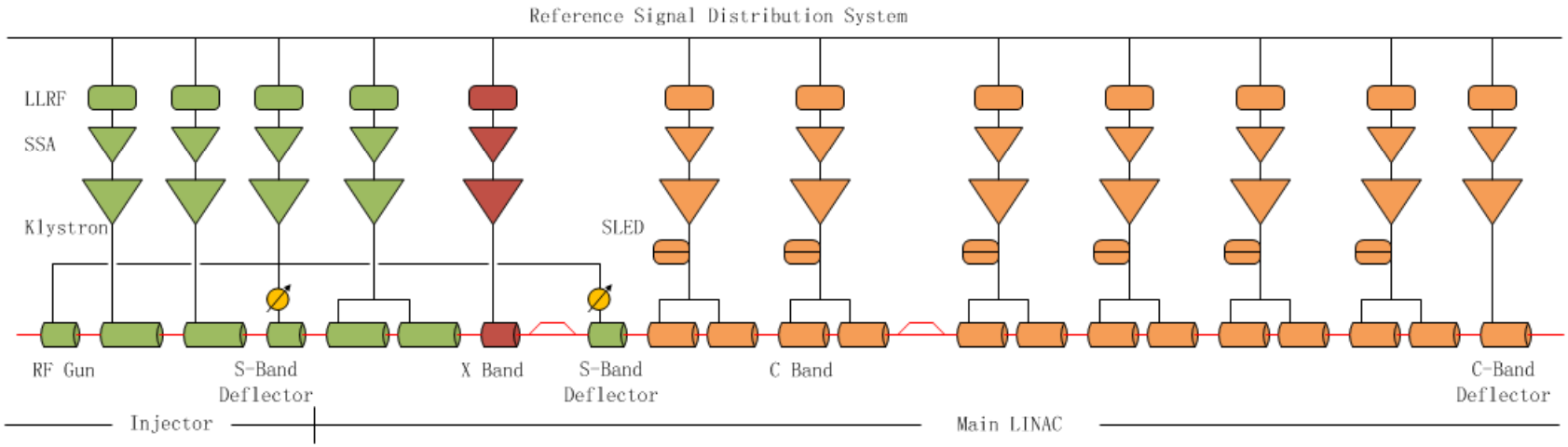
MicroTCA-based LLRF

RF system

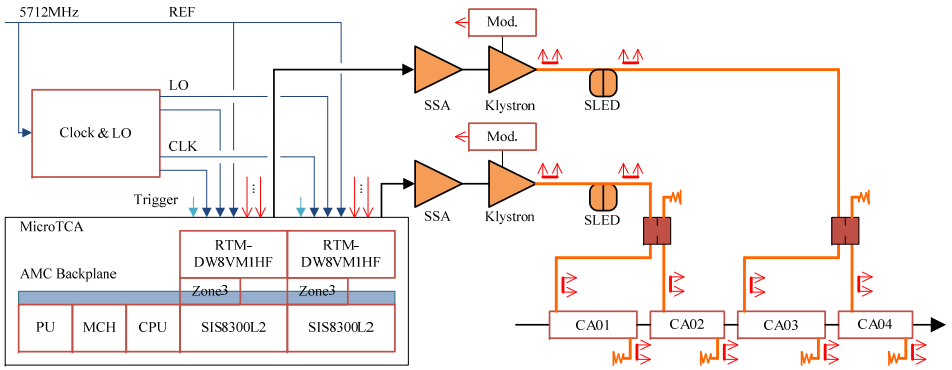
RF sources:

- 4 S-band
- 7 C-band
- 1 X-band

Characteristics	Unit	S Band	C Band	X Band
Working frequency	GHz	2.856	5.712	11.424
Repetition rate	Hz	1～10	1～10	1～10
E field gradient (max)	MV/m	20	40	80
Energy gain (max)	MV	60	72	80
Amplitude stability (rms)	%	<0.04	<0.04	<0.04
phase stability (rms)	Deg	<0.09	<0.18	<0.36



The RF layout of SXFEL Test facility



C-band RF station

Two sets of downconverter and digitizer are integrated in one crate to control two power sources. The MicroTCA.4 crate is installed in a cabinet, with temperature stability ±0.1ºC

LLRF cabinet:

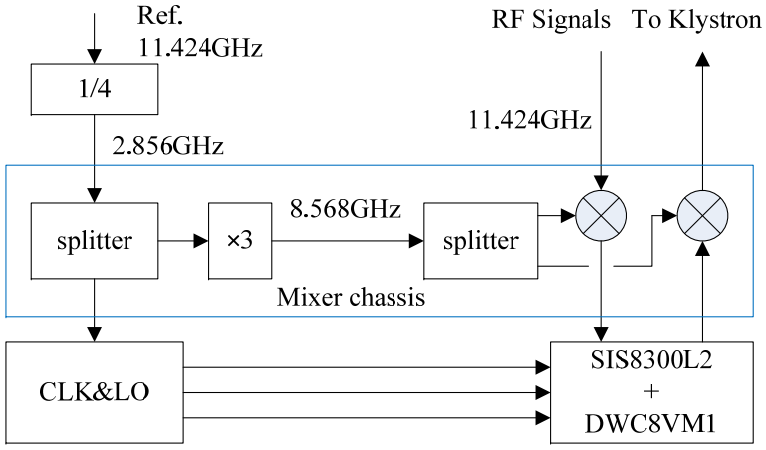
1.Reference signal
2.CLK & LO
3.MicroTCA.4 chassis
- SIS8300L2 *2
- DWC8VM1/DWC8VM1HF *2

4.Trigger(TTL-LVDS)
5.Solide state amplifier *2

Downconverter Parameters

- •MTCA.4 (µTCA for Physics) RTM Implementation
- •Class A1.1 compatible
- •8 channels downconverter
- •One channel vector modulator
- •8 Channel FBM multi coax. connector (CH1 to CH8)
- •SMA vector modulator output
- •350 MHz - 500 MHz (DWC8VM1LF)
- •500 MHz - 3500 MHz (DWC8VM1)
- •3500 MHz - 6000 MHz (DWC8VM1HF)
- •Various intermediate frequencies
- •Switchable front end attenuators
- •LO clock from front panel or RF backplane
- •LO power level monitor
- •I2C support

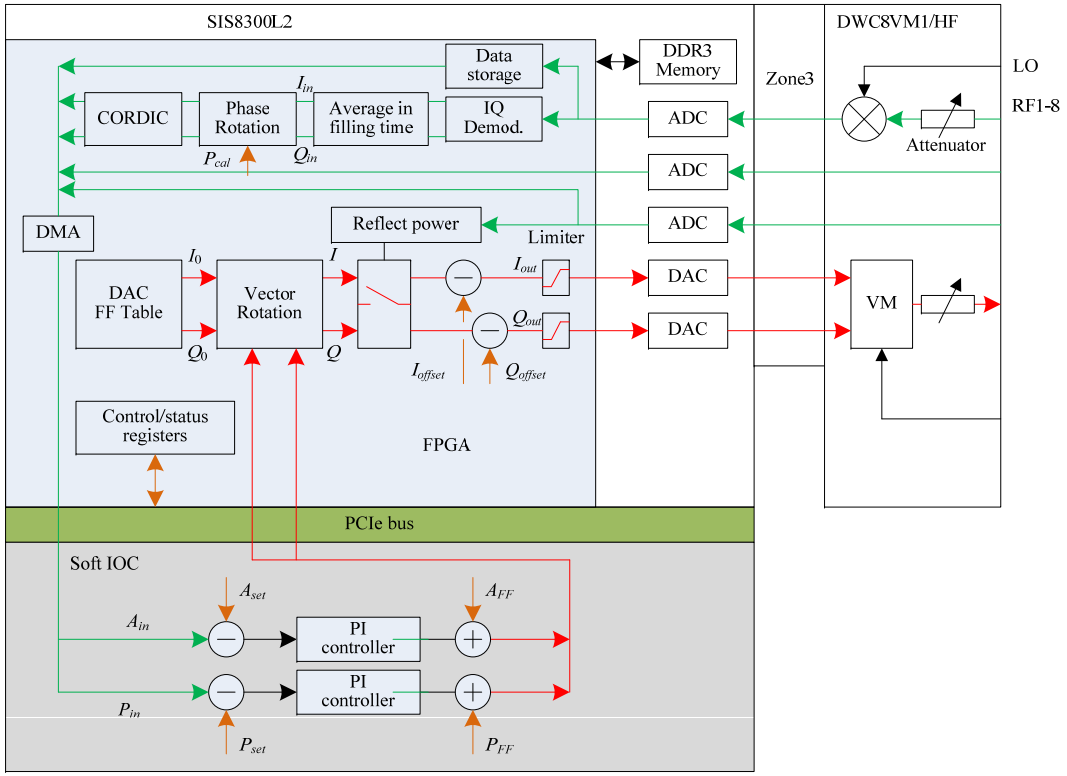
DWC8VM1 & SIS8300L2
From STRUCK



For X band, a mixer chassis is used to downconverter X band signal to S band, and then upconverter S band to X band.

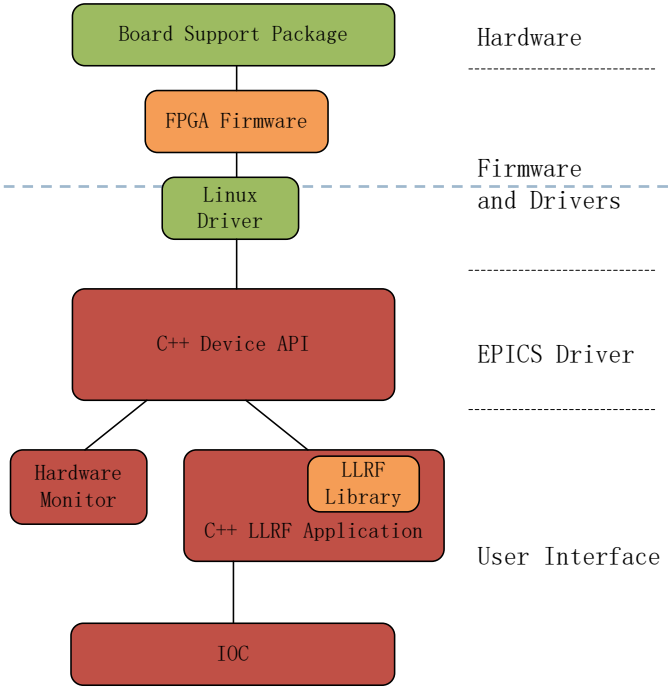
Firmware

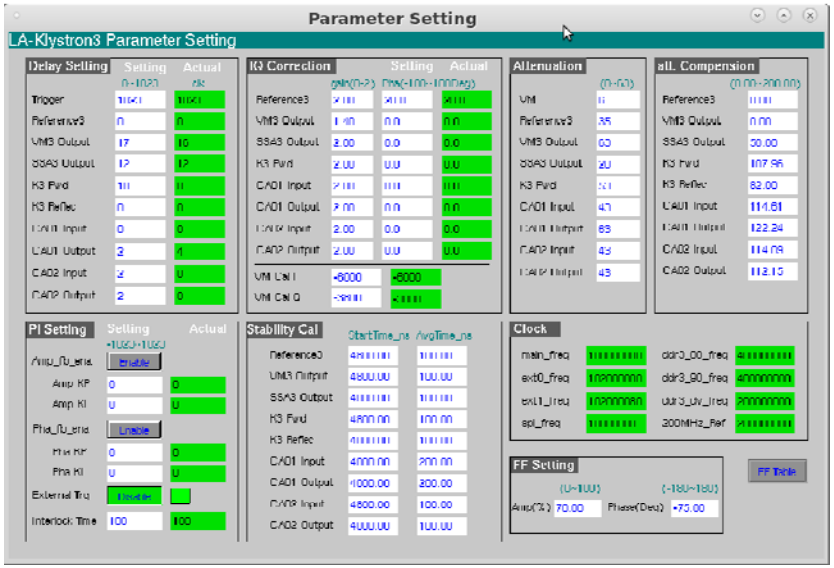
Implements the fast real-time functions for the RF control, including raw data acquisition, IQ demodulation of the RF signals, interlock protection, vector rotation for output correction, and VM calibration for DC offset.

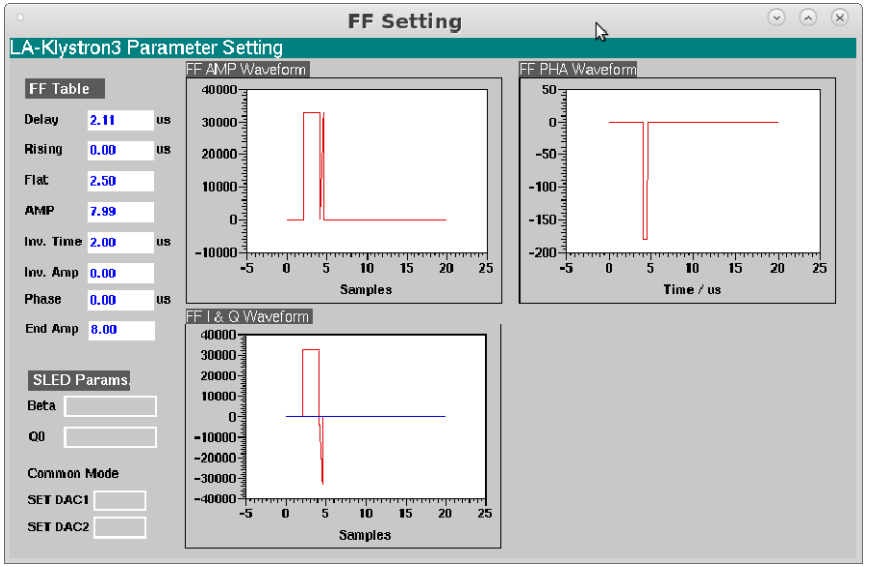


Software

Performs some simple algorithms within the LLRF system, such as rotation matrix for phase and amplitude correction, pulse to pulse phase and amplitude control, power calculation of each channel according to the ADC readback and cable attenuation.

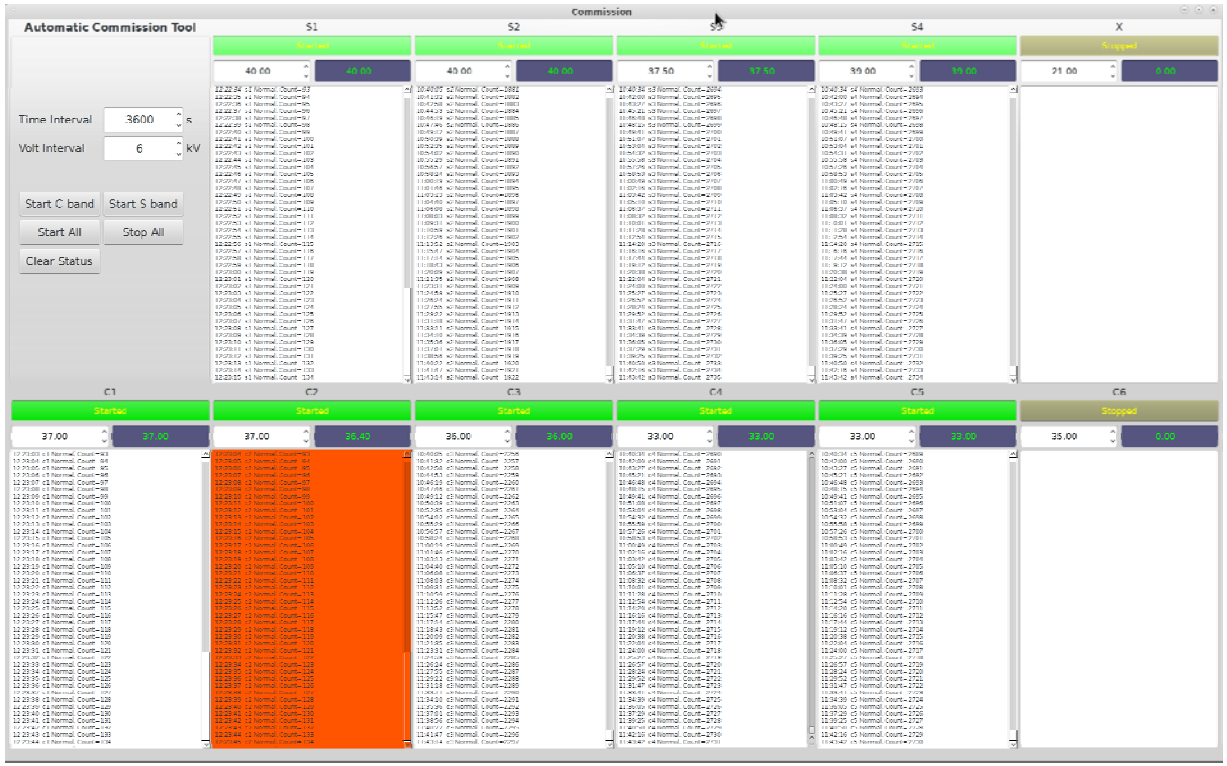






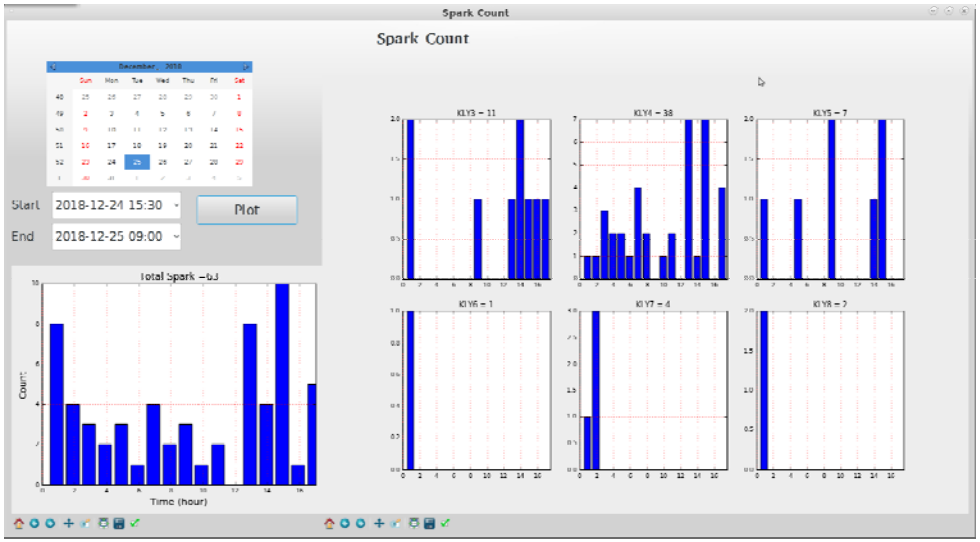
Automatic control system

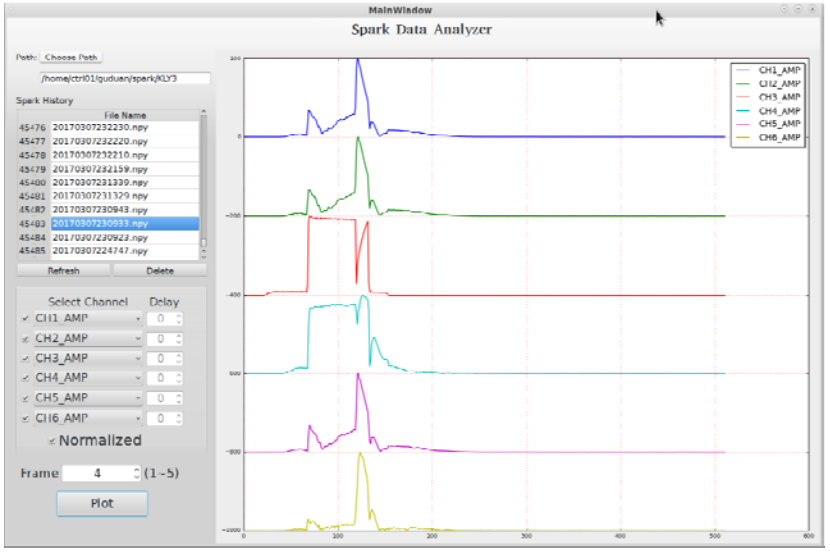
- Automatic RF conditioning
- Monitoring the status of all power sources
- When breakdown occurs, power supply is stopped for10s in the LLRF firmware, dropped the high voltage of the modulator, and then ramped slowly. LLRF will be automatically switched to open loop/closed loop.
- All the operation during breakdown events is controlled automatically on the software layer

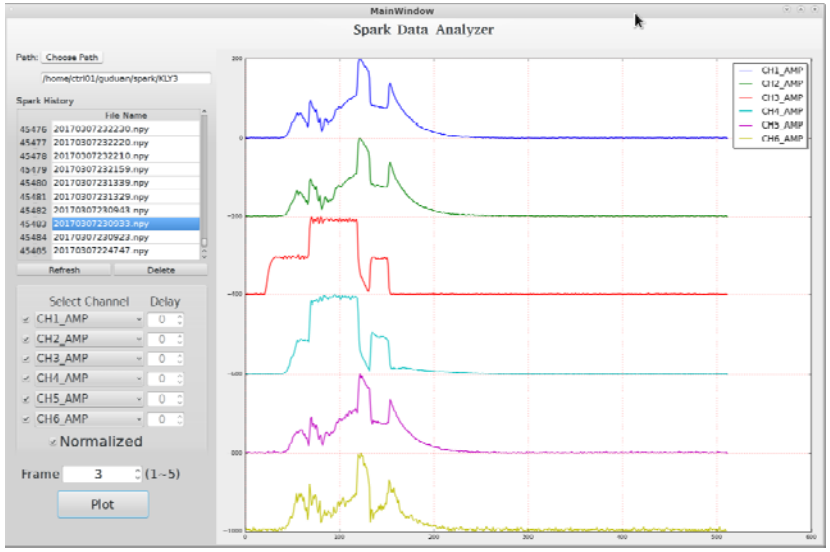


- Automatic statistics of breakdown rates

- All the data before and after the breakdown events are stored, and could be analyzed for any time duration.



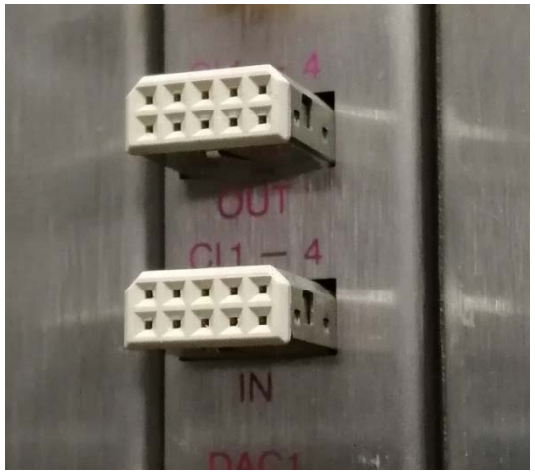




Operation problems

Harlink LVDS inputs

- Problem of TTL-LVDS transformer, trigger channel damaged, can not work at external trigger
- changed to another trigger channel



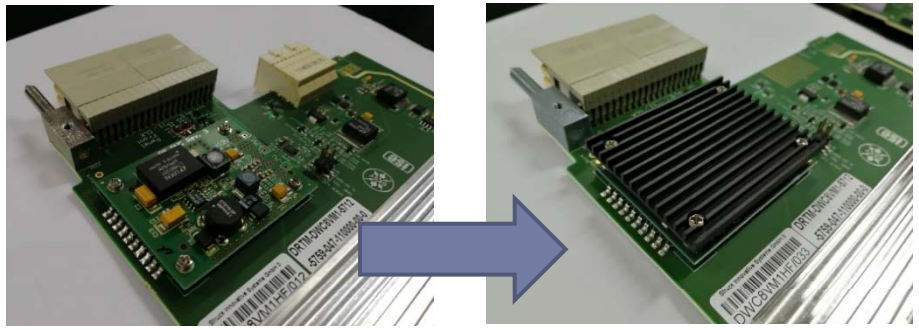
	Clock	1	2	3	4
Top	P	P	P	P	P
Bottom	N	N	N	N	N

DWC8VM1HF

- Downconverter has no power output
- Changed power module with a hear sink

Communication

- Data updated failed, hardware works well
- Improved the software



Thanks for your

attention!