Overview of MicroTCA-based LLRF at SXFEL

Junqiang Zhang, Lin Li, Yajuan Liu, Chengcheng Xiao,

Shaopeng Zhong, Qiang Gu

Shanghai Advanced Research Institute, CAS

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Outline

SXFEL

SXFEL-TF

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- 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						
	≥0.5nC					
	≥840MeV					
	≤0.15rms. %					
	Peak current	≥500A				
	≤1ps					
	≤2.5mm·mrad					
	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 LINAC2020.05 HGHG-HGHG process testing2020.06 EEHG-HGHG process testing2020.11.4 National acceptance







Wavelength and stability @ stage 1





SXFEL-UF

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Linac						
	≥0.5nC					
	1500MeV					
	≤0.15 rms.%					
	≥700A					
E	≤0.7ps					
	≤1.5mm·mrad					
	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 $\pm 0.1^{\circ}$ C

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.



Parameter Setting			•	FF Setting	N (N (N)		
LA-Klystron3 Parameter Setting					LA-Klystron3 Param	neter Setting	N2
Delay Selling S	Setting Actual	Ki Correction Setting Actual	Allenualion	all. Compension		FF AMP Waveform	FF PHA Waveform
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CAUII Input 0	0	10/17/ Input 2.00 0.0 0.0	EXER Distpirt 63	EAUT Hulpot 122.24	Inu Time 2.00 up		
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C AD2 Input 🛛 🧝	U	VMICNI -8000 -8000	EALP Iniput 43	CA02 Oulpul 112.15	Inv. Amp 0.00	-5 0 5 10 15 20 25	-5 0 5 10 15 20 25
CARP Output 2	0	VM CN G COMUNICATION			Phase 0.00 us	Samples	Time / us
PI Setting Setti	ling Actual	Stability Cal StartTime_ns AvoTime_ns	Clock	·	End Amp 8.00	40000-	
-1030	0-1020	Deference0 4810100 100000	main_freq 10000000	ddr0_00_freq 4		30000-	
		UM3 Flitpit 4600.00 100.00	ext0_freq 10200000	ddr3_90_freq 40000000	SI FD Params	20000	
Amp Ki u	_	SSA3 Output 4000000 100000	ext1 (rep 10200080	utra dv Irea 20000000	Pata	10000	
Angria 0		K3 Find 4800 00 100 00	sol freq	200MHz Baf	Deca		
Pria_IU_eria	nable	K3 Reflec 4000000 100000			Q0	-10000-	
тике о	0	C/01 Input 4000 00 200 00	FE Setting			-20000-	
Pha Ki U	<u> </u>	CA01 Output (1000.00 200.00	0.51015	FF Table	Common Mode	-30000-	
External Trop	SALER	CAR2 Input 4800.00 100.00	Aug(%) 70.00 Phase(E	eu) •75.00	SET DAC1		
Interlock Time 100	100	C.402 Output 4000.00 100.00			SET DAC2	-5 0 5 10 15 20 25	
1			1			Samples	

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

DWC8VM1HF

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

Communication

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









	Clock	1	2	3	4	
Гор	Р	Р	Р	Р	Р	
Bottom	Ν	Ν	Ν	Ν	Ν	

Thanks for your attention!