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SOLID STATE AMPLIFIER OF SC LINAC FOR SHINE

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Abstract

Shanghai HIgh rep-rate XFEL aNd Extreme light (SHINE) is 8GeV superconductivity LINAC, worked in CW operation mode and beam current is 0.2mA. Solid state amplifier will be employed to drive the 1.3GHz SC. One of four SSA prototypes had been manufactured and finished the factory test, the SSA output signal phase noise is about -88 dBc/Hz at 10Hz offset/1.3GHz and rms jitter is 45fs. The Spurious content is less than -70dBc. The long-term power stability is below 1%, and amplitude and phase stability are less than 0.1% and 0.1degree respectively. those parameters mentioned above and other parameters of SSA satisfies the RF requirement and are showed in this paper.

INTRODUCTION

Shanghai HIgh rep-rate XFEL aNd Extreme light facility (SHINE) is a platform for technique and science research which energy is 8GeV, operated in CW-mode and beam current is 0.2mA. It includes a LINAC of 8GeV, three undulator lines, three beam lines and ten experiment stations. SHINE is located underground 30 meters approximately. The lengths of facility are about 3kM and the length of LINAC is 1.2km. The acceleration architecture of LINAC consists of six hundred 1.3GHz and sixteen 3.9GHz TELSA type cavities. The 5.2kW SSA will drive the 1.3GHz superconductive cavities and 2kW SSA will power the 3.9GHz superconductive cavities.

Figure 1 shows the main part of the SHINE accelerator, in which include Gun, segment L0, L1, L2, L3 which are1.3GHz superconductivity cavities, HL segment which is the sixteen harmonic cavities and frequency are 3.9GHz. BC1and BC2 which are the chicane.

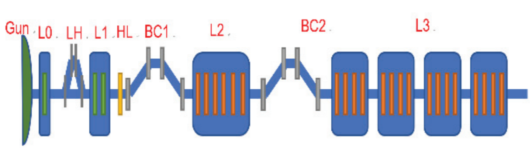

Figure 1: Sketch of SC LINAC for SHINE.

RF STATIONS

Figure 2 shows the RF station Architecture. One signal generator is used to phase reference and as reference of LLRF and timing. Single LLRF [1] drive the single SSA and single superconductivity cavity. One of the two motor drivers adjust the depth of coupler in order to change the Q_e of cavity. Another adjusts the cavity detune coarsely. Piezo driver is used to detune cavity fast and precisely. There are the interlock of each RF station.

The diameter of accelerator tunnel is 5.9m. Cavities are hung on top of tunnel, the control hardware, such as solid state amplifiers, signal distribution, LLRF, motor driver, piezo driver, vacuum monitor and interlock etc., are located at the bottom of tunnel. There is a radiation shielding platform between cavity and the control hardware in order to protect the electron chips. Figure 3 shows the layout of SSA and control hardware within one module which includes 8 9-cell cavities, magnet, BPM and other hardware related.

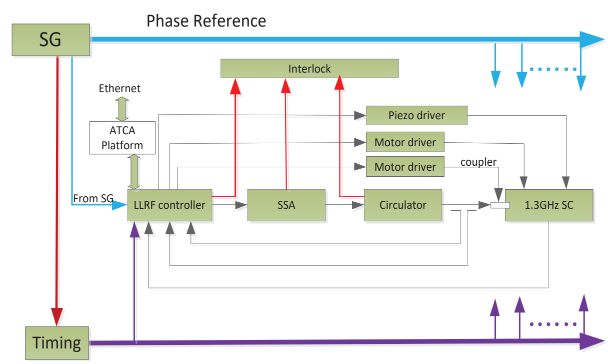

Figure 2: RF station architecture.

Figure 3: SSA and LLRF layout of one module (front and lateral view).

SSA BASIC REQUIREMENTS

The basic specification [2] of SSA is showed in Table 1. It is not showed here for other detailed requirements of SSA such as reliability, diagnostic, maintenance, interface, etc.

The SSA can be worked in pulse and CW mode. The machine will be operated in CW mode normally. But superconductive cavity need be conditioned in pulse mode. The water pressure is up to 10kg. The pump is located over ground in order to avoid vibration when it works Which maybe effect the cavity performance. All SSA cabins need keep constant temperature. So many hardware in the tunnel will release heat, in order to less the burden of air condition, it requires that the heat in all cabins are absorbed by water. The module consists of some transistors. The easiest damage part is transistors in SSA. So we require the module can be plug in and plug out. It is convenient to be replaced by the robot.

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Table 1: The Basic Specification of SSA

Frequency	1.3GHz
Small signal delay	<300ns
Operation mode	CW and Pulse
1 dB compression	5.2kW @0dBm
Bandwidth(1dB)	2MHz
Phase noise	80dBc/Hz(10Hz offset @1.3GHz)
RF stability	Amplitude error <0.1% phase error <0.1deg @1s
Spurious content	<-70dBc
Noise figure	<10 dB
Harmonic content	<-30 dBc
Power supply	3×380 V AC ± 5%
Efficiency	>40% (at 5.2kW)
Output port	WR650
reliability	<1% transistors fail/year (but can still run with 1 failure)
cooling	20L/Min 25^{0}C water pressure
Communication port	Ethernet sending out all inner information
Cabin size	Within 600*1500*1800
Module design	Plug in and plug out
Total power reflected	24 hours

SSA PROTOTYPE DESIGN

The high power RF source is the Solid state amplifier in the light of the virtue of its architecture and performance. SSA power chain include two stages, the pre-amplifier and end power amplifier. The pre-amplifier get maximum 0 dBm signal and send out about 55dBm. And then it is divided four paths driving four end power amplifiers. The basic cell is 650W in end power amplifiers. three cells are integrated 1.5kW high power which is one module and some of power are lost because of combine, and then four modules are combined 5.2kW at least. Interlock and status information monitor are designed in SSA. The interlock includes those signals: input water flow and water temperature, power transistor temperature, circulator load, input RF limited, RF output reflected and forward power and so on. SSA will also accept outer interlock signal or machine protection signal which shutdown the RF output power and send inner interlock signal out which indicate some problem happen itself. All that interlock information, status of SSA will be send out through ethernet. One prototype of SSA block diagram [3] is showed in Fig. 4.

SSA TEST

One of SSA prototypes had been manufactured and the factory test had been finished. The phase noise of SSA output signal and signal generator output signal is showed in Fig. 5. The RMS jitter of SSA output signal is about 45fs. And phase noise of 10Hz offset/1.3GHz is as low as -88dBc. The short time (within one second) stability and long-terms (more than six hours) stability are showed in Fig. 6. The amplitude and phase stability are about 0.6% and 0.06 degree respectively in short time. The variation belt of power is less than 0.1% in long-term test.

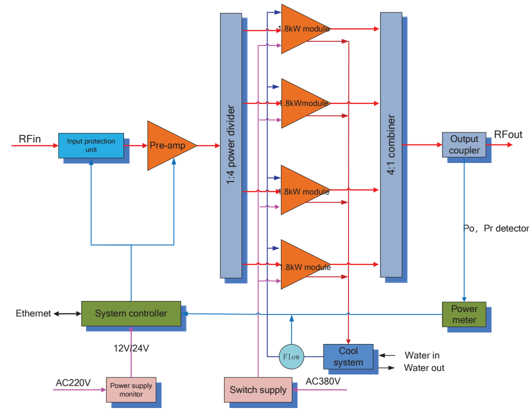

Figure 4: Block diagram of SSA.

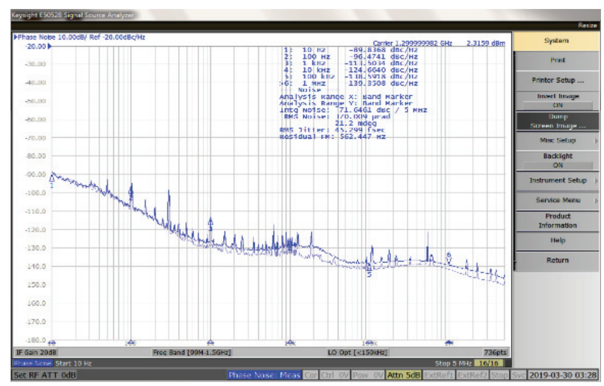

Figure 5: phase noise of SSA output signal and signal generator output signal (thick: SSA output signal, light: signal generator output signal).

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SUMMARY

Since April 2017, we first investigated the SSA factory, discussed with technician and submit the requirement of SSA. At August 2018, we chose four companies to design and manufacture the SSA. Now we finish the factory test of one prototype SSA. From the test result. The performance of SSA satisfy the requirement. From now on, we will test the long-term reliability of SSA.

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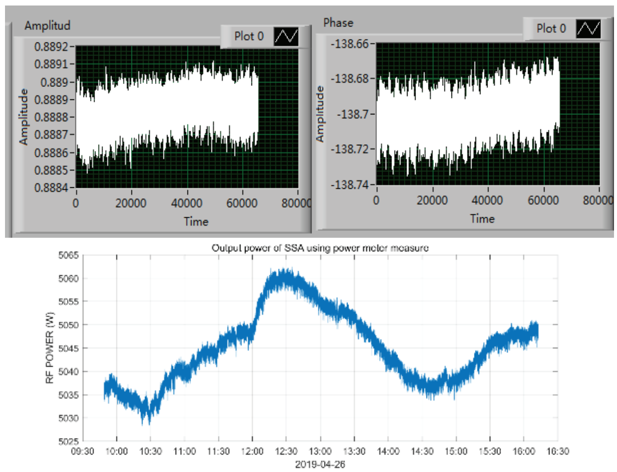

Figure 6: RF stability test result (Up: amplitude and phase stability, Down: power stability).

REFERENCES

[1] C. Hovater et al., "The LCLS-II LLRF System", in *Proc. 6th Int. Particle Accelerator Conf. (IPAC'15)*, Richmond, VA, USA, May 2015, pp. 1195-1197. doi:10.18429/JACoW-IPAC2015-MOPWI021

[2] A. Dian Yeremian for LCLS- II collaboration. "High power RF solid state amplifiers", private communication.

[3] The design of SSA by Chengdu 630 electronic equipment corporation company, private communication.