ISBN: 978-3-95450-184-7 doi:10.18429/JACoW-IPAC2018-THPMK064

RF SYSTEM FOR SXFEL: C-BAND, X-BAND AND S-BAND*

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Abstract

Shanghai Soft X-ray FEL facility is under commissioning now, which linac is composed of one S-band injector, C-band main linac and X-band linearizer. In SXFEL S-band injector could provide 200MeV beam energy based on 4 RF power unit, and then 6 C-band RF units boost beam energy to 840MeV based on 33MV/m at least, which will be ramped to 40MV/m in the upgrading. In the middle of S-band and C-band RF system, a X-band RF unit is used as linearizer to make energy spread of electron beam linear distribution, which is important for bunch compressor and FEL radiation. In this paper, details of RF system design and status of SXFEL is introduced, and some operation results are presented.

INTRODUCTION

Shanghai Soft X-ray FEL test facility (SXFEL) was started in the end of 2014, and its installation was finished, recently has been under commissioning of beam and FEL radiation for several months. Beam energy of SXFEL is 840MeV, and it will be increased to 1.5GeV by upgrade of RF stations in the following years. SXFEL linac is composed of one S-band injector, C-band main linac and one X-band linearizer, in which S-band and C-band RF system is used for beam energy boosting, and X-band RF system is used to linearize bunch energy spread before bunch compressor, as shown in Fig. 1.

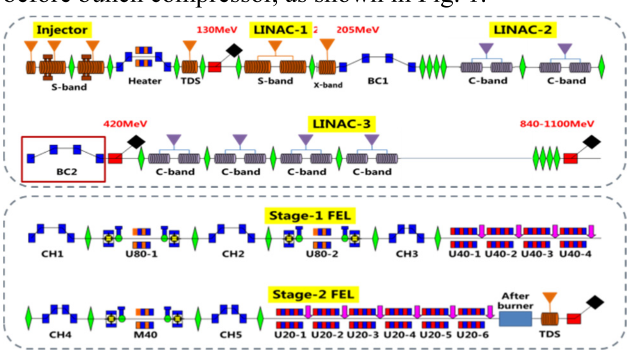

Figure 1: Layout of SXFEL linac (up) and FEL radiation (down).

SXFEL RF system is integrated by S-band, C-band and X-band technology, including 4 S-band RF units, 6 C-band RF units and one X-band RF unit. In S-band injector, one photocathode electron gun works on 100MV/m to reach 4MeV output energy, and 4 S-band accelerating structures are operated higher gradient with about 20MV/m, and finally reach about 200MeV with energy chirp before BC1. C-band linac follows BC1, and works on 33MV/m in routine operation, which is targeted on 40MV/m finally. X-band RF system is first experience at SINAP, and it can carry out bunch linear compression, which makes bunch current distribution flat, and is very crucial for HGHG and ECHO FEL radiation. SXFEL RF system is controlled by LLRF based on MTCA technology, and feedback is carried out locally for each RF unit.

In this paper, SXFEL RF system is introduced with details. Firstly overview layout of SXFEL RF system is introduced, including design, key technology and stability requirements. S-band, C-band and X-band RF are also presented, and more details including power source and RF structure are shown. Finally LLRF control system is also shown in the end of this paper, and details about temperature control methods for stability are also introduced in this section.

LAYOUT OVERVIEW OF RF SYSTEM

Total length of SXFEL is about 270m, to be upgraded to 550m in the following years, and linac length is about 100m, the RF system layout is shown in Fig. 2.

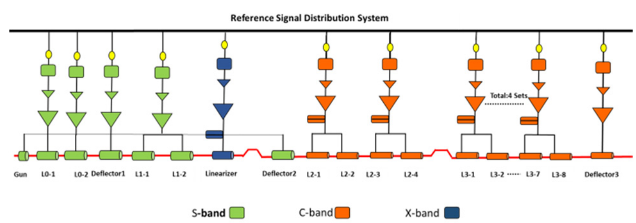

Figure 2: A one line figure caption is centred.

In Fig. 2, RF system of composed of S-band, C-band and X-band, including photocathode gun, acceleration units and TDS system. SXFEL linac starts with one S-band injector powered by four 50MW klystrons directly. In the C-band linac, there are totally six acceleration units, and each unit includes 50MW C-band klystron, one pulse compressor, two accelerating structures and waveguide system to boost energy from 200MeV to 840MeV. X-band RF system is first time developed at SINAP, and one integrated unit for linearizer is on operation in SXFEL now, in which one 6 MW X-band klystron powers one pulse compressor and one-meter X-band accelerating structure. The X-band RF system will work on 20MV/m, and make bunch energy spread linearly for 1.5GeV upgrading user facility in the future. In SXFEL there are three deflecting cavities (TDS), in which two are S-band in the start of SXFEL, and one C-band TDS in the end of SXFEL, they are used for measurement of bunch length, slice emittance and energy spread.

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Recently SXFEL has been installed, and RF system is located as Fig. 2 shows, all power sources are located in the gallery, and all RF structures are located in the facility tunnel, and present status is shown in Fig. 3. There are totally 11 power source units to power one photocathode gun, 17 accelerating structures and 3 deflecting cavities.

Figure 3: Present status of SXFEL.

S-BAND INJECTOR AND LINAC

As Fig. 1 and Fig. 2 show, S-band RF system serves for Injector and Linac-I, it provide 200MeV energy before BC1. This section is shown in Fig. 4.

Figure 4: S-band injector and linac-I.

Photocathode gun, TDS1 and TDS2 share one same 50MW S-band klystron, and only 7MW power is divided to gun by 7dB divider, meanwhile other 20MW are tranfer to power TDS1 or TDS2 switched alternatively. Waveguide layout for gun, TDS1 and TDS2 is very complicated to carry out multi-operation.

There are two S-band accelerating strutures powered indepandently by two S-band klystrons, which could reach 22MV/m with full power. The structure is feed by two power port, and racetrack coupler is used to eliminate dipole and quadrapole field together, the input coupler should be movable in order to assemble solenoid. This structure is shown in Fig. 5. In the linac-I, there two ordinary three-meter S-band accelerating structure with only one port coupler, they are powered by one 50MW S-band klystron, and can reach 17MV/m.

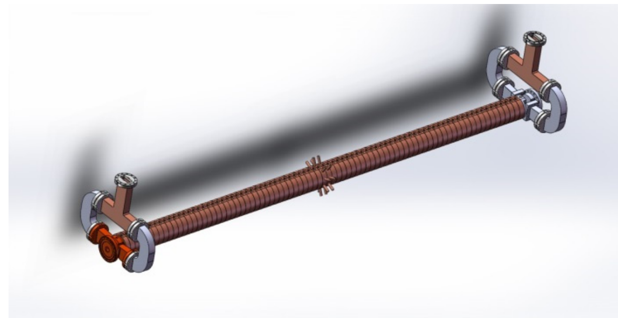

Figure 5: S-band three-meter accelerating structure.

C-BAND MAIN LINAC

C-band RF system is new technique compared to S-band technology, and could reach higher operation gradient, its first remrkable appliacation on 38MV/m is in SACLA which first lasing is in 2011 [1]. C-band linac in SXFEL is targeted on 40MV/m, which is powered by one 50MW klystron and pulse compressor. Key technique of accelerating structure [2] and pulse compresor [3] have been developed for several years, and now are stably operated in SXFEL, as in Fig. 6

Figure 6: C-band RF acceleration units.

There are totally six RF acceleration units, require gradient is 33MV/m lower than design target 40MV/m, each unit is powered by 50MW klystron, and then power is multiplied by pulse compressor to about 160MW, driving two 1.8-meter C-band accelerating structures. Each RF unit can provide 130MeV beam energy.

Recently average gradient of SXFEL C-band RF units has reached 34MV/m as shown in Fig. 7, and in particular four units reach 36.5MV/m. Two new C-band structures were also test only by high power, finally gradient reach 42MV/m and 41MV/m respectively in Fig. 7.

In the following year, SXFEL will be upgraded soon, and C-band linac is still crucial technique to improve beam energy. Besides adding more C-band RF units,

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gradient will be also improved to 40MV/m as design target, and beam energy could be boosted to 1.5GeV and more.

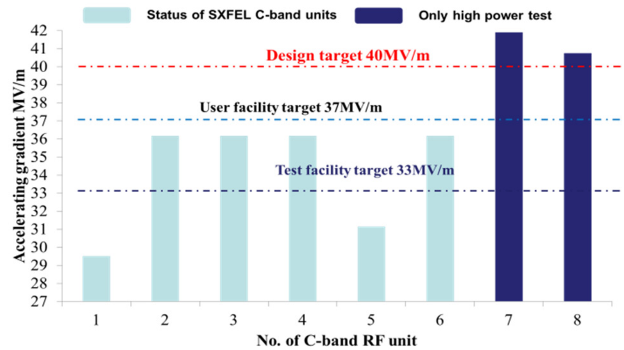

Figure 7: Accelerating gradient of C-band RF units.

X-BAND LINEARIZER

X-band RF unit is originally designed for high gradient technology targeted at 80MV/m, which is power by two combined 50MW X-band klystrons [4]. In SXFEL X-band RF unit is powered by only 6MW/m, and X-band accelerating structure is same design as [4], finally it should reach 20MV/m for 1.5GeV operation.

X-band RF unit in SXFEL is installed as linearizer in Fig. 8, one pulse compressor is used to multiply klystron power, and then drive one-meter X-band klystron, two accurate chiller are used to stablize two cavities of pulse compressor, and each cavity could be tuned by chiller independantly with 0.02 degree stability.

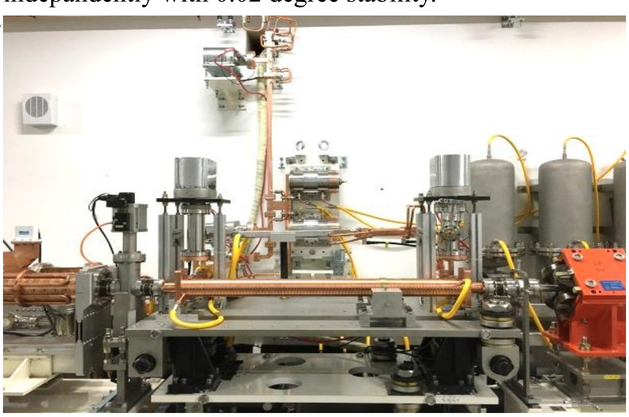

Figure 8: X-band RF unit in SXFEL.

LLRF CONTROL SYSTEM

LLRF system is based on MTCA 4.0 hardware and software driver, and was developed to carry out many functions, including amplitude and phase feedback and modulation, data acquisition and reflection protection. Each LLRF unit has 8 RF signals and 2 DC signals channels, which is typically distributed as Fig. 9.

Cabinet in Fig. 9 should be operated in stable temperature environment, and one stable chiller with 0.02 degree stability is used for temperature control of cabinet, and signal cable as well in Fig. 10. The temperature could be stabilized in 0.02 degree for cable and cabinet, in particular cable distributed around 28 degree water tube, and packed by heat insulating material.

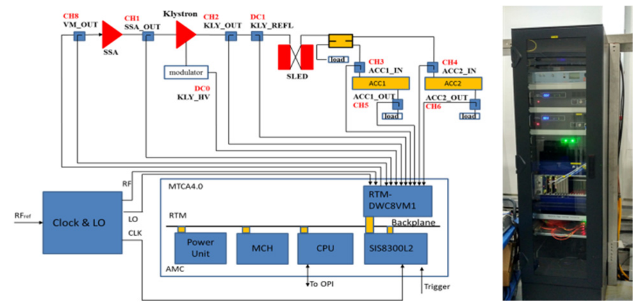

Figure 9: Typical layout of LLRF unit and cabinet.

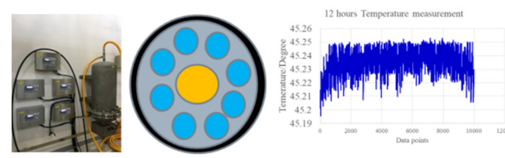

Figure 10: Temperature control.

UPGRADING TO USER FACILITY

In the following years after SXFEL test facility, beam energy will increased to 1.5GeV at least for short wavelength FEL radiation, and then this facility will be upgraded to be one user facility, and RF system will also be upgraded as Fig. 11.

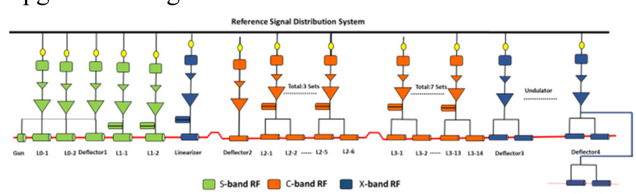

Figure 11: Layout of RF system in SXFEL user facility.

CONCLUSION

SXFEL test facility has been installed, and RF system has been also conditioned, and on routine operation now. After test facility, RF ssytem will be upgrade to new layout, and meet new requirement.

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