THE SCHEME AND CONSTRUCTION PROGRESS OF SSRF INJECTOR

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Abstract

The injector system of the 3rd generation Shanghai Synchrotron Radiation Facility (SSRF) consists of the 300MeV linac, the 3.5GeV booster with 1Hz cycle rate, and two transport lines. The linac will also be used to be the electron source of a test facility of DUV FEL in near future. Two operating modes, single bunch mode and multi-buncher mode will be run in SSRF injector. A thermionic cathode gun could work on these two modes will be used in the first phase of SSRF project.

In this paper, the design of the injector system, the manufacture of some key devices on inject in the R&D of SSRF, electron gun and bunchers are described.

1 INTRODUCTION

As a 3rd generation synchrotron radiation source facility, the SSRF storage ring calls for the 3.5 GeV full energy injection. Referencing to other similar facilities, the scheme of using a low energy linac plus a booster synchrotron is adopted in SSRF design. Because the linac will also be used for the test device of DUV free electron laser in our plan, the electron energy after the linac is elevated to 300MeV[1]. After the transport through the low energy transport line, electron beam will be accelerated to 3.5GeV on the booster, then be transported to storage ring via the high energy transport line.

The cycle rate of SSRF booster is designed to be 1 Hz[2], because the positron beam injection is not demanded. In this case, the constructing difficulty will be alleviated for the magnet, the power supply and the vacuum chamber of the booster.

There are two main bunch modes in the storage ring: multi-bunch and single bunch. The linac and booster will also work in these two running modes. At the exit of linac, a single-bunch takes on the pulse intensity of about 1nc with the pulse width of 1ns. The envelope length of multi-bunch train with 150 bunches is 300ns and average pulse current is 180mA.

A thermionic cathode gun could produce these two modes beams will be used in the first phase of SSRF project to meet the requirements of the 3.5GeV booster[3]. A pre-buncher and a 1.36m long traveling-wave buncher are also employed as the pre-injection components of linac [4]. All these components have been developed in the R&D of SSRF.

We will adopt the proven technology for the injector on one hand to insure the reliability of the operation, and on the other hand, will develop some advanced technologies such as the RF gun, photo-cathode gun, and so on, in the second phase.

2 SCHEME OF LINAC

The 300MeV linac of Shanghai Synchrotron Radiation Facility (SSRF) will be used to be an injector of the 3.5GeV booster and a test facility of DUV FEL. In the first phase, a thermionic cathode gun, a pre-buncher and a buncher are employed to be the injector of the linac, and the linac will working in two beam modes: Single bunch mode and Multi-bunch mode. When used as the injector of SSRF, the linac takes the parameters in Table 1.

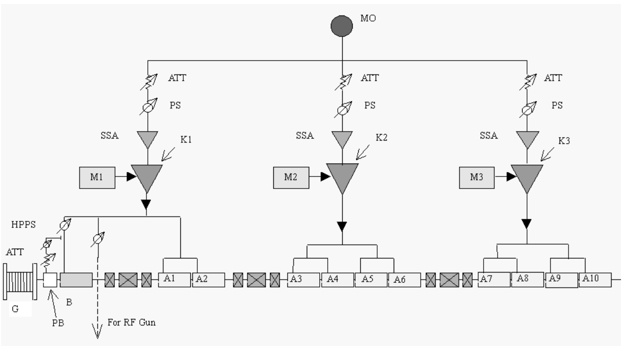
Table1. Beam Parameters of Linac

Nominal energy(MeV)	300
Beam pulse length(ns)	
Single bunch	1
Multi bunch	300
Current at exit(mA)	
Single bunch	1200
Multi bunch, average in macropulse	180
Energy spread	±1%
Beam emittance(πmm·mrad)	1.0

In the second phase, a photon-cathode RF gun will be developed to be a injector of linac to improve the characters of the beam and meet the requirements of the DUV FEL, while the existing thermionic cathode gun will still be adopted. The requirements of beam qualities for FEL use is more critical than for injector use. As one of the most important parts of the SSRF linac, a bunching system which consists of a re-entrant cavity (prebuncher) and 1.4m long, travelling-wave buncher. is adopted.

The accelerator section is comprised of complete SLAC type constant gradient tubes with the tube length of 3 meters and working frequency of 2856MHz. This kind of section has been working successfully in BEPC since 1988. To ensure the energy of 300MeV for the booster, it is reasonable to use 10 accelerator sections. Three units of high-power pulsed klystrons are employed as the main RF sources. To match the high demands of DUV FEL, we have planed to import all klystrons, and modulators must achieve the following specifications: Pulse power is 110MW, stability of pulse amplitude is good than 0.1%, flat-top is good than 0.3%, repetition frequency is from 1 to 100Hz.

Including main accelerator sections, rf system, vacuum system, focus, steering and cooling system, beam instrumentation and control system , the total length of linac is about 47 meters. The layout of the linac is shown in Figure 1.



MO: Master oscillator, ATT: Attenuator, B: Buncher
PS: Phase Shifter, SSA: Solid State Amplifier
M: Modulator, K: Klystron, A: Accelerator section,
PB: Pre-Buncher, HPPS: High-power Phase shifter

Fig. 1 Schematic of RF system of SSRF Linac

3 LATTICE OF BOOSTER

The SSRF booster is a synchrotron, which can accelerate electrons from 300MeV to 3.5GeV in a reasonable cycle rate of 1 Hz. After booster, electron beams are transferred and injected into storage ring. By adopting the 1 Hz cycle rate, the constructing difficulty will be alleviated for the magnet, the power supply and the vacuum chamber of the booster. The key specifications of booster are low emittance and small energy spread. Another important demand is that the shock of electric line caused by ramping must be limited.

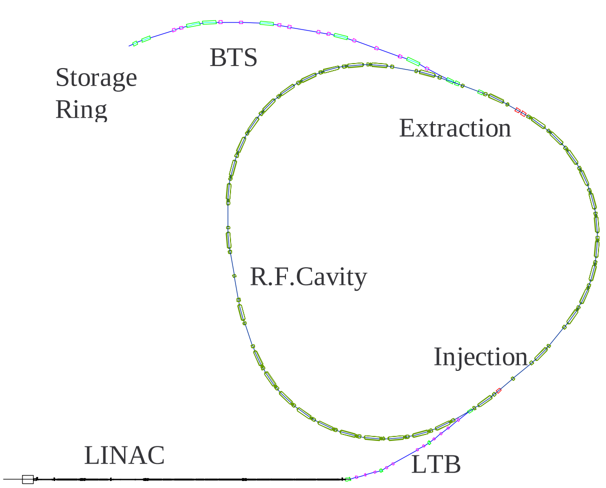


Fig.2 The Schematic layout of SSRC injector

Reliability is a top priority in the booster design. Therefore, the proven technology will be considered and adopted for all parts. On the other hand, the cost economization will also have to be considered.

The booster lattice is a simple FODO structure with 24 cells grouped into 3 superperiods. In this case, there are 3 separate straight sections for the injection, extraction and RF system. The schematic layout is displayed in Fig. 2. Some sextupoles and correct magnets are inserted into somewhere between the bending magnets and the quadrupole magnets. The circumference of the booster is 158.40 m, the cycle period of electrons is 528 ns, and the harmonic number is 264 which is one fifth of harmonics of storage ring. The beta function and dispersion function is showed in Fig. 3.

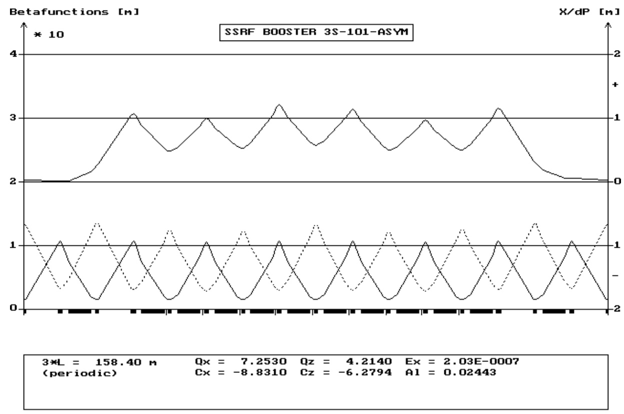


Fig.3 β functions and dispersion function of Booster

The Table 2 summarizing the main parameters of the SSRF booster. The Table 3 summarizing the magnet parameters of the SSRF booster.

Table 2. main parameters of the SSRF booster.

name		unit	value
Injection energy		GeV	0.3
Extraction energy		GeV	3.5
Beam current	Single bunch	mA	0.5
	Multi-bunch	mA	20
Repetition Frequency		Hz	1
Circumference		m	158.40
Natural emittance		πmrad	203×10^{-9}
Harmonic number			264
Store particles number			6.6×10^{10}
Required RF frequency		MHz	499.65
Cycle frequency		MHz	1.8926
Energy loss/turn (3.5GeV)		MeV	1.159
RF voltage		MV	2.0
Vacuum pressure		Torr	$<2.0\times10^{-7}$
Lattice type			FODO
Superperiod number			3
Cells number			24
Cell length		m	6.600
Max straight_sec. length		m	2.99 - coil
Betatron tune ν_H/ν_V			7.253/4.214

Momentum spread		8.74×10^{-4}
Natural chromaticity,H/V		-8.831/-6.279
Maximum β function H/V	m	10.7/13.5
Maximum dispersion D_H	m	1.0344
Momentum compaction		0.02443
Sychrotron tune, ν_z		0.0219
Bunch length, σ_L	mm	24.6
Damping partition,		0.95/1.00/2.05
Damping time, $\tau_H/\tau_V/\tau_L$	mS	3.38/3.19/1.56

Table 3. magnet parameters of the SSRF booster.

Magnet	
Bending magnet	
Number	36
Magnetic length (m)	2.0
Max. dipole field (T)	1.02
Bending radius (m)	11.459
Quadrupole magnet	
Number	48 (24+24)
Magnetic length (m)	0.36/0.26
Max. gradient (T/m), QF/QD	16.0/-16.2
Sextupole magnet	
Family number	2
Number of SF /SD	12 /18
Magnetic length (m)	0.1
Correction dipoles	
Number	48
Magnetic length (m)	0.1
Field (T)	0.05

4 TRANSPORT LINES DESIGN

The schematic layout of the the linac to booster transport line(LTB) is shown in Fig. 4. Quadrupole TLQ1, TLQ2, TLQ3 and TLB1, TLB2 provide the required focusing field and make up achromatization of beam. TLB1, TLQ4 to TLQ7, and TLB2 comprise an achromatic section. Phase-space matching to the booster acceptance is provided by TLQ8 to TLQ11.

At the exit of the linac, the emittance will be 1π mm-mrad in both transverse planes. After the transfer line, at the injection point, the β-function and dispersion function must match the booster's. The architecture layout of linac and booster must be think over when design a transport line.

TLB1 is a switching magnet, which can also direct the beam to another area for the possible DUV FEL experiment facility in the future.

The schematic layout of the booster to storage ring transport line(BTS) is shown in Fig. 5. Due to the general layout of the storage ring, a total bending angle of 45° for the extraction beam from the exit of last septum of booster is required. Therefore, 5 bending magnets (each bends 9° angle) being made up of the slice using in the booster magnet, will be installed on the transfer line. B2, THQ5-- THQ 8, and THB3 comprise an achromatic section. THQ9--THQ12 are used to match the beam phase space from the booster to the storage ring transversely.

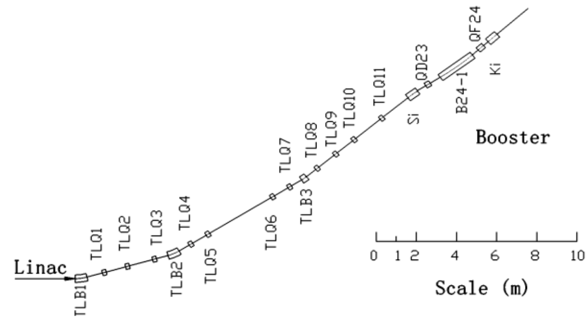


Fig. 4 The Schematic Layout of LTB

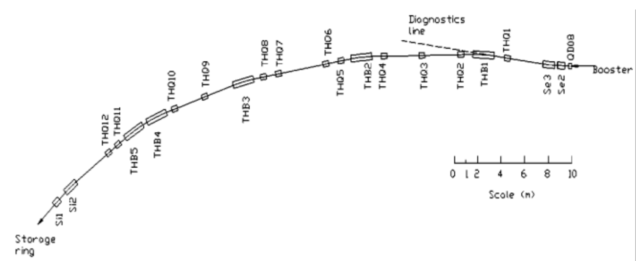


Fig. 5 The Schematic Layout of BTS

5 CONCLUSION

In last two years, SSRF project team have done the whole and detail technical design of SSRF and have finished study and manufacture of over forty prototypes under the supports of SSRF R&D program. A 100kV DC electron gun [3], a pre-buncher and a buncher [4] were developed and tested satisfied their specifications. Some key prototypes of the booster vacuum, magnets and power supplies were constructed under the preassigned specification and requirements.

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