NEW SCHEME OF THE SSRF INJECTOR

D.M. Li, Q. Gu and Z.T. Zhao
Shanghai Institute of Applied Physics, P.O.Box 800-204, Shanghai 201800, China

Abstract

SSRF, a 3rd generation synchrotron radiation source facility, its storage ring calls for a 3.5GeV top-up injector that consists of a 100MeV linac, a two-fold full energy booster and two transport lines. The working frequency of linac has been selected at 2998MHz. To achieve the enough low emittance demanded by the optimized top-up injection of storage ring, 28 cells FODO type lattice of booster has been adopted and carefully optimized. In this paper, the main points for new design of injector system are described.

INTRODUCTION

As a 3rd generation synchrotron radiation source facility, the SSRF storage ring calls for a 3.5GeV full energy injector. A detailed design of SSRF injector was carried out before 2001 [1]. Since the lattice configuration of the SSRF storage ring has modified on the basis of top-up injection [2], the SSRF injector has also been re-designed. In the new scheme, the SSRF injector is consisted of a dedicated pre-injector, a two-fold booster and two beam transport lines. A high reliable 100MeV linac will be used as the pre-injector, which can meet the booster injection requirements.

The booster cycle rate has been increased to 2 Hz in the new injector design. With this cycle rate and single bunch of 1nC charge, the booster can smoothly provide the normal injection and continuous top-up injections to the storage ring [3].

There are two main operating modes of the storage ring: multi-bunch and single-bunch. For the single-bunch operating mode, the electron gun will generate a 1 ns pulse in one injection cycle [4]. In the case of multi-bunch mode, the electron gun will produce an electron bunch train consisting of maximum 150 bunches which occupy a total time length of 300ns. If the beam total transport efficiency from the linac exit under the multi-bunch mode is about 50%, the injecting time is around 100 seconds for fill a 300mA beam current in storage ring.

100MEV LINAC

The 100MeV linac is used as the injector of 3.5GeV booster. The thermionic cathode electron gun, the 500MHz sub-harmonic buncher and the 2998MHz buncher, are the main components of the linac injector section. The main beam parameters of the linac are given in table 1.

Table 1: The main parameters of linac

Nominal energy (MeV)	100
Repetition Rate (Hz)	1~5
Max. Beam chain width (ns)	
Single-bunch	1
Multi-bunch,	100~300 ns
Beam charge (nC)	
Single-bunch	1
Multi-bunch,	3~5
Pulse to pulse energy stability	0.25%
Relative energy spread	0.5% (rms)
Normalized Emittance (mm.mrad)	<100
Frequency (MHz)	2998

The SSRF linac contains four 3m long constant gradient accelerating sections, and its working frequency is 2998MHz, which is the multiple of the storage ring RF frequency (499.65MHz). Under this harmonic relationship, the sub-harmonic buncher can be used, then the bunch purity can be improved and this is also beneficial to top-up injection.

This linac includes some other components, such as focussing and steering magnets, cooling and temperature control system, beam control and diagnostics. The buncher and four accelerating structures are powered by a 45MW klystron, and the klystron will be driven by a 1kW solid-state amplifier.

The diagnostic components for the SSRF linac must have abilities to cover the different bunch modes in the charge range from 1pC to 10 nC.

BOOSTER AND ITS LATTICE

The booster is used to accelerate the electrons from the linac energy of 100MeV to the storage ring energy of 3.5GeV. In order to achieve the emittance demands of top-up injection of storage ring and to cut down the cost of construction and operation, the booster has been carefully re-optimized. The optimization goals are: 1) A reasonable low nature emittance and a relative large dynamic aperture must be achieved. 2) Keeping bending magnet field strength at about 0.8T to limit the energy loss per turn and therefore cut down the scale and cost of RF system. 3) As shown in figure 1, the SSRF booster synchrotron is installed in an independent tunnel for the convenience in commissioning and maintenance.

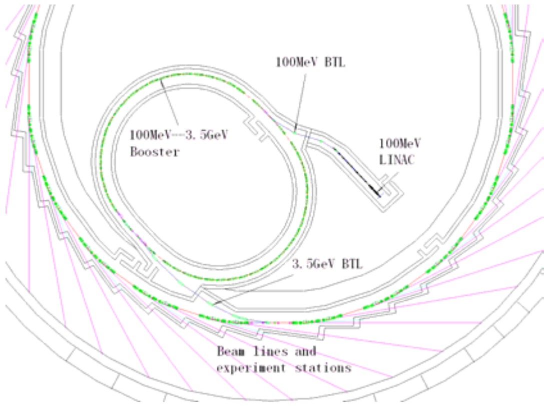

Figure 1: The Schematic layout of SSRF injector

According to above design criterions, a reasonable lattice structure has been figured out. This lattice structure can achieve the emittance to about 100 nm·rad. The circumference of the SSRF booster, comprising 28 cells, is 180.0 m. The layout of one standard cell of booster is showed in Fig. 2. The beta functions for one super-period are shown in Fig.3. Table 2 and Table 3 summarize the main parameters and magnet parameters of SSRF booster.

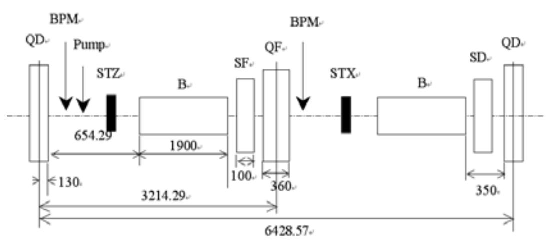

Figure 2: Schematic diagram for one cell

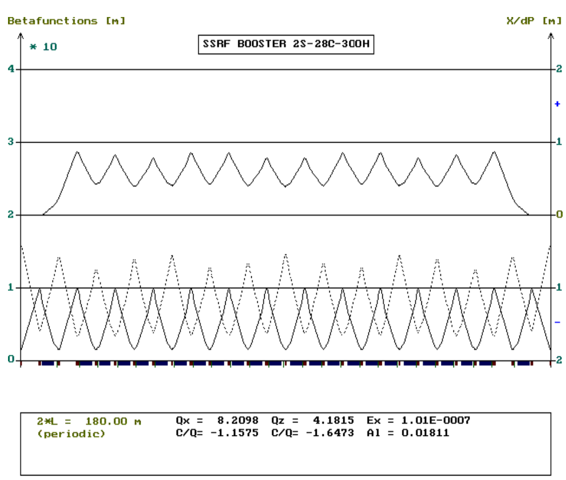

Figure 3: β-Function and Dispersion of Booster

Table 2: Main parameters of the SSRF booster.

Parameters item		Unit	Value
Injection energy		GeV	0.1
Extraction energy		GeV	3.5
Beam current	Single bunch	mA	1.6
	Multi-bunch	mA	15
Cycle rate		Hz	2
Circumference		m	180
Harmonic number			300
Superperiod number			2
Cell number			28
Natural emittance at 3.5 GeV		nmrad	101
Energy loss per turn(3.5GeV)		MeV	0.915
Lattice structure			FODO
Cell length		m	6.4286
Length of straight section		m	2.904
Betatron tune, ν_H / ν_V			8.2/4.18
Natural chromaticity, ξ_H/ξ_V			-9.50/-6.89
Max. β function, β_H/β_V		m	10.0/16.0
Max. dispersion D_H		m	0.878
Nature Momentum spread			7.800×10^{-4}
Momentum compaction, α_P			0.01811
Damping time, τH/τV/τL		ms	4.8/4.6/2.3
RF Frequency		MHz	499.65
RF Cavity (5 cells cavity)			2
Required RF voltage V_0		MV	1.74
Synchrotron tune, f_Z			0.0191

Table 3: Magnet parameters of the SSRF booster.

Bending magnet	
Number	48 (+1)
Magnetic length (m)	1.9
Max. dipole field (T)	0.804
Bending radius (m)	14.515
Gap height (mm)	32
Good field area, *H*×*V* (mm)	50×28
Quadrupole magnet	
Number	56 (28+28)
Magnetic length (m), QF/QD	0.36/0.26
Max. gradient (T/m), QF/QD	15.94/-15.64
Aperture radius (mm)	30
Good field area, Radius (mm)	25
Sextupole magnet	
Family number	2
Number of SF, SD	22, 26
Magnetic length (m)	0.10
Max. gradient, SF/SD, (T/m^2)	109/-102
Aperture radius (mm)	30
Correctors	
Number	56
Magnetic length (m)	0.12
Field (T)	0.05

INJECTION AND EXTRACTION OF THE SSRF BOOSTER

The booster injection system is consisted of a septum magnet and a fast kicker magnet. The 100 MeV electron beam comes from the linac, passes through the beam transport line (LTB) and travels to the septum exit with a 14 degrees deflection. After passing through a horizontal defocus quadrupole and drift spaces, the beam goes to center of the injection kicker. The beam is then kicked onto the booster orbit by a 12mrad deflecting.

The booster extraction system is composed of a fast kicker, three bump magnets, a thin septum and a thick septum. Firstly, the 3 bump magnets bump the orbit to a closed bumped orbit with the radial offset of 18.4mm. At the extracting moment, the fast kicker kicks beam with an extra offset of 10.4mm at the entrance of thin septum magnet. The thin septum and the second QD then guide the beam to the entrance of a thick septum magnet. Finally, this thick septum deflects the beam by 6.57 degrees and the beam goes into the transport line. The schematic layout and beam envelops of injection and extraction are shown in Fig.4 and Fig.5 respectively.

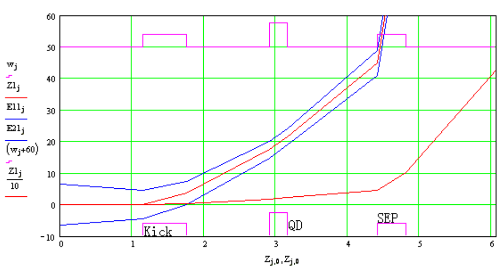

Figure 4: Schematic Layout of Booster Injection

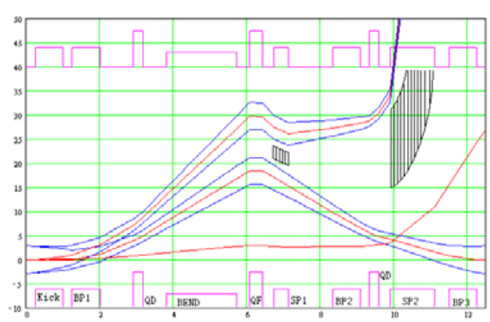

Figure 5: Schematic Layout of Booster Extraction

TRANSPORT LINES

A schematic layout of the low energy beam transport line (linac to booster, LTB) is shown in Fig.6. In LTB, quadrupoles TLQ1-3, and bending magnets TLB1, TLB2 provide the required focusing field. TLB1, TLQ4-7, and TLB2 comprise an achromatic section. The total length of the LTB is about 24 m. TLB1, TLB2 and TLB3 are the same type of magnets with the length of 0.6m and nominal field of 0.5tesla. TLB1 is also used as a switching magnet.

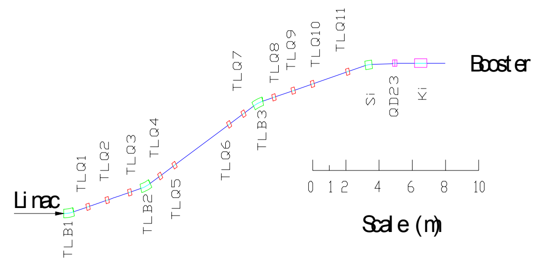

Figure 6: The Schematic Layout of LTB

The layout of the high energy beam transport line (booster to storage ring, BTS) is shown in Fig. 7. In BTS, five bending magnets (THB1-THB5) are installed on the transport line. Each bending magnet has the length of 1.9m and the working field is about 0.97T. There is an achromatic section between THB2 and THB3. The total length of the BTS is about 40m (not include septums).

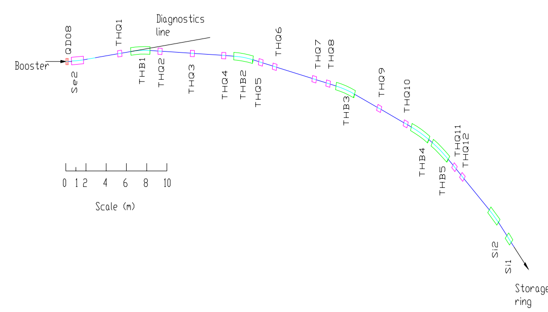

Figure 7: The Schematic Layout of BTS

REFERENCES

[1] D.M. Li, Y.X. Luo, S.G. Shen, et al, "The Scheme And Construction Progress of SSRF Injector", APAC'01, Beijing, Sept. 17-21, 2001.

[2] Z.T. Zhao, H.J. Xu, "Progress of the Shanghai Synchrotron Radiation Facility", this conference.

[3] G.M. Liu, Z.M. Dai and Z.T. Zhao, "Lattice Optimization for the SSRF Storage Ring", this conference.

[4] S.G. Sheng, G.Q. Lin, Q. Gu and D.M. Li, "Electron Gun For SSRF", APAC'01, Beijing, Sept. 17-21, 2001.