STATUS OF THE SSRF BOOSTER

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Abstract

The SSRF booster is a 2Hz electron synchrotron. It accelerates electrons, coming from a 150 MeV linac, to a final energy of 3.5 GeV in 250ms and extracts them into the storage ring. The SSRF injector (Include 150 MeV linac, booster and two transport lines) was designed for Top-Up injection, which has single-bunch and multi-bunch beam modes. After 9 months installation and pre-commissioning, the 80 days beam commissioning of SSRF booster was smoothly taken from Sep. 30, 2007. The booster has been serving as a stable injector for storage ring since Dec. 21, 2007 [1]. In this paper, the specifications, installation and commissioning of the SSRF booster and transport lines are described.

INTRODUCTION

The SSRF is a third generation synchrotron radiation source facility, its storage ring calls for a 3.5GeV full energy injector, and the top-up injection is also demanded [2]. This project was approved in the beginning of year 2004. The SSRF injector was then redesigned to satisfy those new demands. The finally detailed scheme of SSRF injector was carried out [3]. Now the SSRF injector is comprised of a dedicated 150MeV linac, a two-fold 28 cells 2 Hz booster and two beam transport lines. Figure 1 shows the schematic layout of SSRF injector.

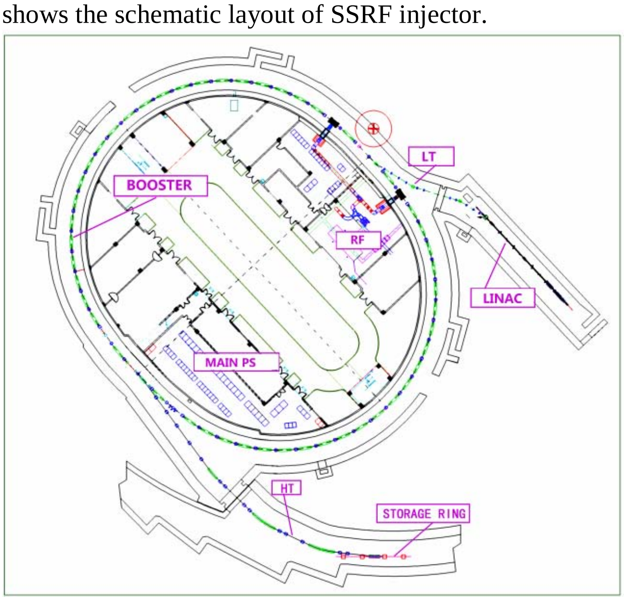

Figure 1: Schematic layout of the SSRF booster

With 2Hz cycle rate and 2mA single bunch, the booster can smoothly perform normal injections and continuous top-up injections. The multi-bunch mode of the injector can produce maximal 150 bunches occupying a total time of 300ns, but it seems a redundancy design after the commissioning of storage ring.

BOOSTER SPECIFICATIONS

The booster lattice is based on a FODO structure with missing dipoles, forming 28 cells with 8 straight sections of a 2-folder symmetry and 180m circumference. Figure 2 shows the all magnets on SSRF injector and transport lines.

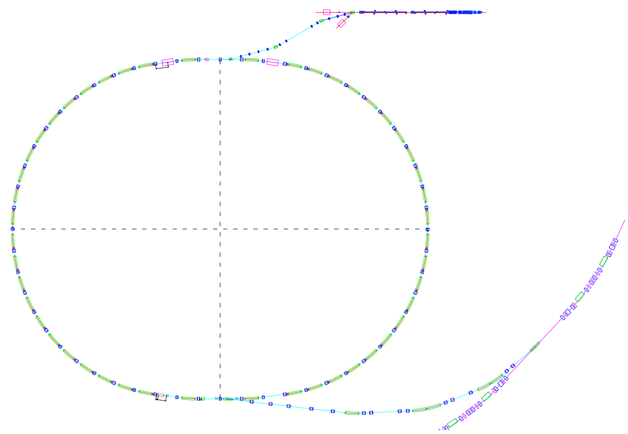

Figure 2: Layout of all magnets on SSRF injector.

Pre-Injector

The pre-injector of SSRF is a 150MeV s-band travelling wave electron linac. The key parameters are:

- 100kV thermionic cathode electron gun,
- 500MHz sub-harmonic buncher
- Two 45MW klystron, two 110 MW modulator.
- Single-bunch and Multi-bunch beam mode

Booster Lattice

Table 1: Main parameters of SSRF booster

Parameters item		Unit	Value
Injection energy		GeV	0.15
Extraction energy		GeV	3.5
Beam current	Single bunch	mA	2
	Multi-bunch	mA	<15
Cycle rate		Hz	2
Circumference		m	180
Cell number			28
Natural emittance at 3.5 GeV		nmrad	101
Nature Momentum spread			7.8×10^{-4}
Harmonic number			300
RF Frequency		MHz	499.65
RF Cavity (5 cells cavity)			2
Energy loss per turn(3.5GeV)		MeV	0.915
Required RF voltage V_0		MV	1.74

The SSRF booster is a 28 cells FODO structure electron synchrotron with 180.0m circumference and about 100 nm·rad nature emittance. The layout of one standard cell of booster is shown in Figure 3. Table 1 lists some main parameters of SSRF booster.

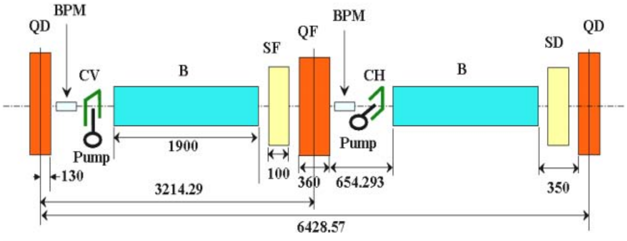

Figure 3: Schematic diagram of standard cell of booster

Magnet And Alignment

Total 48 dipoles on booster were made in Shanghai, which are arc-shaped alternate field magnets. Table 2 lists the main parameters for dipoles, quadrupoles and sextupoles.

Table 2: Magnet parameters of the SSRF booster

Bending magnet		
Number		48
Length	m	1.9
Peak dipole field	T	0.804
Gap height	mm	32
Quadrupole magnet		
Number, QF/QD		28/28
Length, QF/QD	m	0.36/0.26
Max. gradient, QF/QD	T/m	16.5 / -17.5
Aperture radius	mm	30
Sextupole magnet		
Number, SF/SD		24/22
Length (m)	m	0.10
Max. gradient, SF/SD	T/m^2	104/-166
Aperture radius	mm	30

There are 56 DC horizontal or vertical correctors on the booster used to correct close orbit for low energy injection beam.

Alignment tolerance requirements of booster magnets are proper high. The alignment error of quadrupoles transversal position was achieved 0.2mm rms from retest result after installation.

Figure 4 is a photo taken from booster and high energy transport tunnel.

Figure 4: SSRF booster and high energy transport

Injection / Extraction

The booster injection system consists of a septum and a fast kicker. The extraction system is comprised of a fast kicker, three bump magnets, and three septa. Pulsed magnets layout and beam envelops for the injection and extraction is shown in Figure 5. All pulsed magnets and power supplies were home made and achieves very good performances. Figure 6 shows the SSRF booster extraction system.

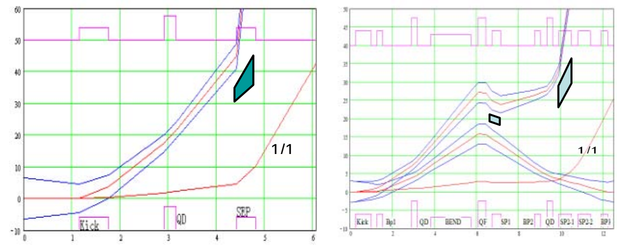

Figure 5: Beam envelope of injection and extraction

Figure 6: SSRF booster extraction system

Power Supply

There are 6 dynamic and 102 static power supplies on SSRF booster. All of them are digital regulated and made in China.

The biased sinusoidal wave is used as the booster dipoles and quadrupoles magnetic field ramping curve, and the current of quadrupoles must exactly trace the dipoles current with precision of $<1\times10^{-3}$ in full range of 3%-100%. There are two 1150A/1000V dynamic dipole power supplies used for booster ramping simultaneously.

Figure 7 is the dynamic power supplies for dipole and quadrupole.

Figure 7: The dynamic power supplies for SSRF booster

Rf System

The booster RF system is basically imported from Europe. The main parameters are showed as following:

- Working frequency: 499.654 MHz.
- PSM power supply + 180kW klystron (TH2161) manufacture by THALES
- Two 5-cell cavities, total RF Voltage >1.8MV, manufacture by ACCEL
- Cavity voltage is ramping from 200 kV (or 400kV) to 1.8MV.

Vacuum

The main characters of SSRF booster are:

- Bending vacuum chamber: 0.7mm thin arc-shaped stainless steel pipe, 50mm*28mm ellipse shape.
- Two 100 L/s ion pumps in each cell. Dynamic pressure achieved is about 10^{-7} to 10^{-8} Pa.
- Without any shocked current break ring on booster ring.

Beam Diagnostics

The beam diagnostics system for booster consists:

- 50 BPM detectors + 30 Libera electronics in booster ring.
- 4 Profiles, 1 WCM, 1 DCCT, and X+Y tune kickers in booster ring.
- Several profiles, BPM, WCM, ICT on transport lines.
- Synchrotron light detector was in design but does not carry out.

BOOSTER INSTALLATION AND COMMISSIONING

SSRF was started construction in the end of 2004. In the middle of 2006, the prototype of key devices, such as dipole magnet, 2Hz dynamic dipole power supply, kicker and septum, fast pulse generators etc., had been developed and tested. In the beginning of 2007, the mass production of magnets was nearly completed, and according to schedule, the installation of booster was then started.

The installation of utilities in booster tunnel and technical halls was started from January, 2007. In the middle of April, the pre-installation of all booster cells finished, cells tunnel installation was then started (Figure 8).

Figure 8: The first booster unit started installation

Up to September 2007, all mechanical and electrical installation for booster (except HT) was completed. From August 2007, system test and pre-commissioning was taken.

The SSRF booster beam commissioning was started on Oct. 30 evening, 2007. Four days later, with in less 60 hours effort, the 3.5GeV ramping was successful on Oct. 5th morning (See Figure 11). The beam extraction and commissioning of HT succeed before Oct. 20, 2007.

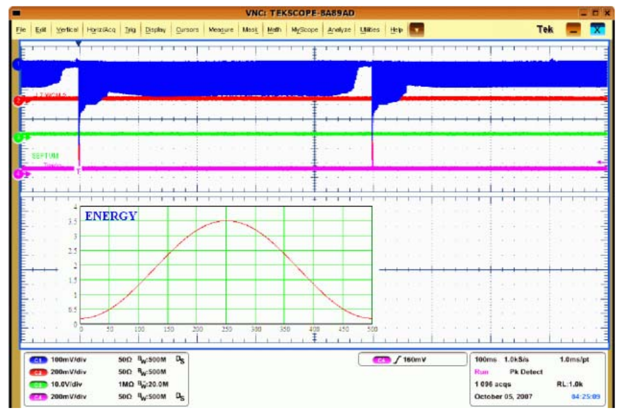

Figure 11: First succeed 3.5GeV ramping of booster

The details of beam commissioning will be described in [4]. Here are main beam commissioning milestones:

- SEP. 30, 20:20: Start;
- OCT. 1, 17:00: Cycling success；
- OCT. 5, 04:20: Success of 3.5GeV ramping；
- OCT. 29： Extraction successful;
- Dec. 21: Storage ring injection succeeds;
- Up to now: Booster works as injector.

CONCLUSION

Because the SSRF booster is the first Hz level electron synchrotron in China, the most of designs and methods were learn from other laboratories in the world. In past years, some special technologies, such as digital power supply, magnets special vacuum chamber, pulsed magnet and pulsed power generators, have been developed in our county. Up to now, this machine has been properly run over a half year, that shows the construction, commissioning, and project management of SSRF booster is successful.

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