

## CURRENT STATUS OF THE SSRF PROJECT

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### Abstract

The Shanghai Synchrotron Radiation Facility (SSRF) is an intermediate energy light source under design and R&D at Shanghai National Synchrotron Radiation Center (SSRC). It is based on a 3.5GeV electron storage ring with a circumference of 396m, a beam current of 200-300mA and a beam emittance of 5-12nm-rad. Since its R&D began in 1999, the design of the SSRF has been evolved smoothly towards a cost-effective machine required by its future users, and the prototypes of its key components have been manufactured and tested up to the design specifications. This paper reviews the design and R&D progress of the SSRF project and presents its current status.

## 1 INTRODUCTION

The SSRF was proposed by the Chinese Academy of Sciences and Shanghai Municipal Government in 1995, one year after that the SSRF Conceptual Design was completed and formally reviewed by an international review committee. The R&D program for SSRF project was approved with a budget of 80M Chinese Yuan in 1998 and was conducted at SSRC from January 1999 to March 2001. During this period, 41 prototypes of the main components of the SSRF accelerators and beam lines have been developed and tested up to their design specifications. In the mean time, the SSRF technical design has been carried out and timely reviewed by the international review committees and the SSRF Committee of Science and Technology.

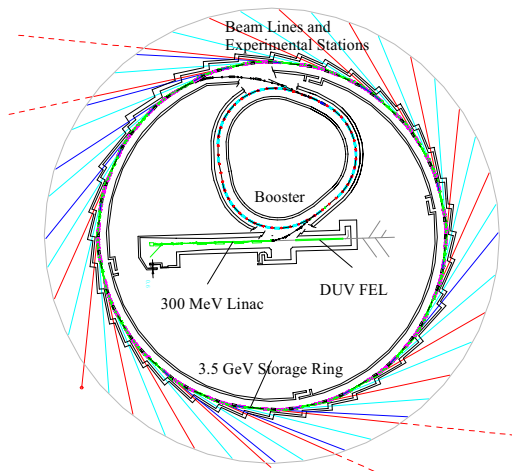


Fig.1 Layout of the SSRF

The SSRF complex sketched in Fig.1 consists of three

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main parts: a full energy injector including a 300MeV linac and a 3.5GeV booster, a 3.5GeV storage ring and the synchrotron radiation experimental facilities. The SSRF has been designed to produce high brightness and high flux X-ray in the photon energy range of 0.1~40keV, with the emphasis on 5~20keV. The current design of the SSRF storage ring does not pursue extreme low beam emittance but cost-effectiveness due to the user demands. The SSRF storage ring energy of 3.5GeV is determined by following the concept of using intermediate energy beam and advanced insertion devices to get the radiation for majority of the SR users.

Through a bidding process among 5 candidates, the Zhang-Jiang High-Tech Park in Pudong, Shanghai has been chosen to site the SSRF complex. The SSRF site is a 600m×300m green land and readily accessible now.

## 2 STORAGE RING

The storage ring is the core part of the SR light source. Its characteristics determine the source performance. The design of the SSRF storage ring has been evolved to a cost effective machine over the last 5 years [1] [2], its current specifications are featured with robust and flexible lattice configuration and advanced mature technology. Apart from brightness and flux, other essential issues of the storage ring are related to beam stability, such as ground conditions, girder vibrations, chamber mechanical stability and temperature control in the storage ring tunnel. Further more the top-up injection is also incorporated into the design considerations.

### 2.1 Magnetic Lattice and Performances

The latest SSRF storage ring lattice is composed of 20 double-bend achromat (DBA) cells with 396 meters in circumference. It provides ten 7.24m straight sections and ten 5.0m straight sections for accommodating injection components, RF cavities and insertion devices. Each asymmetrical DBA cell contains 2 bending magnets, 10 quadrupoles and 7 sextupoles. This lattice has normal beta and hybrid beta configurations, which can adjust the beta functions in the middle of the straight section in a wide range. The high  $\beta_x$  is 12m and the low  $\beta_x$  is about 1m, the tunes ( $Q_x/Q_y$ ) are 18.81/8.77 and 22.19/8.23 respectively. The non-zero dispersion in straight section is also employed in the low emittance lattice configurations, which gives a reduction factor of about 2.4 to the natural emittance.

The dynamic aperture of each SSRF ring lattice configuration has been examined with RACETRACK and MAD, both of the high beta and hybrid beta lattices have reasonably larger dynamic aperture and momentum acceptance with the effects of systematic and random

multipole errors of magnets. The influence of insertion devices upon dynamic aperture is also verified with and without magnet errors, the magnet errors dominate the ring dynamic aperture.

The main parameters of the SSRF ring are shown in Table 1. And the corresponding photon brightness is depicted in Fig.2.

Table 1. Main Parameters of the SSRF Storage Ring

Energy (GeV)	3.5
Circumference (m)	396
Harmonic Number	660
Nature Emittance (nm-rad)	4.6~12.1
Beam Current, Multi-Bunch (mA)	200~300
Single-Bunch (mA)	>5
Straight Lengths (m)	10×7.24, 10×5
Betatron tunes, $Q_x/Q_y$	18.81/8.77, 22.19/8.23
Momentum Compaction	$6.9 \times 10^{-4}$
RF Frequency (MHz)	499.65
RF Voltage (MV)	4
Dipole Radiation per Turn (MeV)	1.256
Bunch Length (mm)	4.59
Beam Lifetime (hrs)	>20

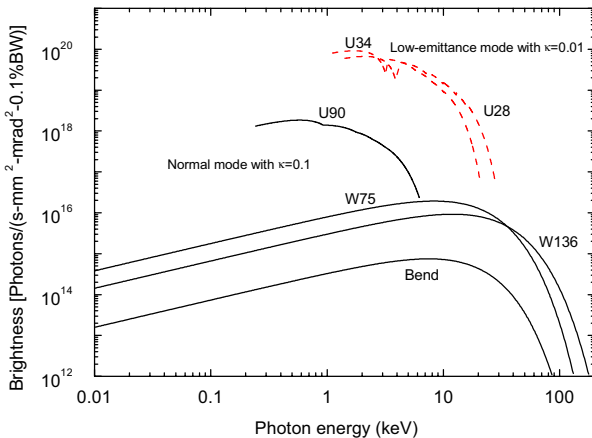


Fig.2 Spectral Brightness of SSRF

The new developments in insertion devices, such as high harmonic operation, in-vacuum IDs, mini-gap IDs and etc., will enhance the SSRF performance. The photon brightness of the SSRF sketched above can be further improved by employing advanced insertion devices.

## 2.2 Magnet System

The SSRF storage ring has 40 C-shape straight dipoles, 200 Collins-type quadrupoles, 140 C-shape sextupoles and 78 horizontal and vertical combined dipole correctors. All magnets have been designed at SSRC, the 1.66m dipole has a good field region of  $\pm 40.3$ mm in horizontal plane for accommodating the 32.6mm beam sagitta. The 56mm dipole gap, 72mm quadrupole diameter and 88mm sextupole diameter were determined by the required

minimum beam chamber aperture. The dipole field is 1.105T, the maximum quadrupole gradient is 18.5T/m and the maximum sextupole gradient is 500T/m<sup>2</sup>. The prototypes of a dipole, a quadrupole and a sextupole have been built and magnetically measured up to the specifications. Their corresponding harmonic contents of the integral fields in the good field regions, normalised to the main field components, are less than  $4 \times 10^{-4}$ ,  $5 \times 10^{-4}$  and  $3 \times 10^{-3}$  respectively.

One SSRF ring arc contains 3 six-strut type girders. Each girder supports one vacuum chamber with equivalent length. A 5.8m long girder was designed and built in Shanghai with adjusting precision of 0.01mm in three directions. This girder's lowest frequencies were measured with 5.88Hz, 6.88Hz and 27Hz to longitudinal, horizontal and vertical vibration modes.

## 2.3 Vacuum System

The SSRF ring vacuum system is designed to reach the mean dynamic pressure less than 1ntorr at beam current of 300mA. Each storage ring arc has 3 machined antechamber sections made of aluminium A5083-H321, 3 horizontal and 5 vertical photon absorbers as well as 2 bellows. The prototypes of the 6m long antechamber, the RF shielded bellows, the copper absorbers and the TSP and NEG pumps were designed and constructed during the last two years. A 6m antechamber vacuum system was assembled at SSRC with vacuum pumped down to 0.05ntorr by TSP. The PSD test of the horizontal photon absorber was carried out on a KEK PF beam line, and the bellow was tested with high RF power at KEK.

## 2.4 Injection System

The storage ring injection system has 4 kickers, 1 eddy current septum and 1 DC septum. Two kickers at both ends of the injection chain are located in the neighboring achromatic arcs across the dipoles. The DC septum, the eddy current septum and two central kickers are placed in a 7.24m straight section. In the SSRF R&D phase a kicker system including kicker magnet and its pulser was prototyped, the window frame type kicker magnet with a Ni-Zn ferrite core in air produces 0.12T peak field in amplitude and 4 $\mu$ s bottom width in half-sine-wave pulse, its jitter is less than  $\pm 6.5$ ns. The eddy-current septum and its 60 $\mu$ s half-sine-wave pulser have been developed. Its main field peak is 0.62T with the stability better than  $\pm 0.1\%$ . The peak strength of stray field on the bump orbit is less than 0.02% of main field.

## 2.5 Magnet Power Supplies

There are more than 480 various power supplies for the SSRF storage ring magnets. All the main power supplies have been designed at SSRC, and the power supply prototypes of dipoles, quadrupoles and sextupoles were developed at SSRC. A dipole power supply prototype was tested with the stability of  $\pm 1 \times 10^{-5}/24$ hrs and the output current ripple less than  $6 \times 10^{-6}$ . The switch mode power

supplies for quadrupoles and sextupoles were also tested up to their specifications.

### 2.6 RF System

In the current RF system design, 8 normal conducting RF cavities are used to provide 4MV RF voltage to the beam, each cavity will be powered by a 180kW klystron power amplifier. In the R&D phase a cold test copper cavity was designed and fabricated with spin forming and electron beam welding techniques. And a high power RF system has been established, which contains a klystron and its power supply from THALES and THOMCAST, a circulator from AFT, a copper cavity borrowed from PF/KEK and low level RF control loops developed at SSRF. The high power RF system and the low level control loops have been tested separately. The high power test of the whole system with PF cavity and the control loops is under way. Recently the superconducting RF system for SSRF is being considered in cooperation with the BEPC-II project of IHEP in Beijing.

### 3 INJECTOR

The SSRF injector comprises a 300MeV electron linac followed by a 1Hz booster, which accelerates the electrons to 3.5GeV. As pre-injector, the linac has two operation modes: single bunch mode with pulse length of 1ns and pulse current of 1.2A, or alternatively multi-bunch mode with pulse length of 300ns and macro pulse current of 180mA. In addition, the linac is also designed as an injector for the proposed DUV FEL facility, and the energy of this linac is therefore chosen for this purpose.

The full energy booster with circumference of 158.4m has 24 FODO cells in 3 super periods. This kind of configuration makes the injection, RF acceleration and extraction separate from each other in space, therefore easier for mechanical installation. The main parameters of the SSRF booster are listed in Table 2.

Table 2. Main Parameters of the Booster

Injection Energy ( MeV)		300
Output Energy (GeV)		3.5
Circumference (m)		158.40
Natural Emitance (nm-rad)		203 (@3.5 GeV)
Beam Current (mA)	Single Bunch	0.5
	Multi Bunch	20
Repetition Rate (Hz)		1
RF Frequency (MHz)		499.65
RF Voltage (MV)		2.0
Energy Loss per Turn (MeV)		1.159
Super period Number		3
FODO Cell Number		24
Cell Length (m)		6.600
Betatron Tunes		7.253/4.214
Synchrotron Tune		0.0219
Momentum Compaction		0.02443
Bunch Length (cm)		2.46

During the last two years, a 100kV DC electron gun, a pre-buncher and a buncher were developed and tested up to their specifications. The prototypes of the booster dipoles, quadrupoles and sextupoles and their power supplies were constructed within their specification requirements. The 3m stainless steel booster vacuum chamber was prototyped with satisfying performance both in vacuum and mechanical deformation.

### 4 BEAMLINES

Through close interaction with the existing and potential SR users in China, the following 7 beam lines for the first phase were selected from the 70 proposals by more than 20 universities and research institutes.

- Macromolecular Crystallography (ID)
- High Resolution X-ray Diffraction and Scattering
- X-ray Absorption Spectroscopy (ID)
- Hard X-ray Micro-Focusing
- Medical Application (ID)
- Soft X-ray Coherent Microscopy (ID)
- LIGA

In the SSRF R&D phase, a front-end for the ID beamline and a double focusing monochromator were developed and tested off-line. A new type of long trace profiler has been built and used for the measurement of the crystal surface.

### 5 CONCLUSION

The SSRF specifications have been detailed with the completion of the technical design, and the prototypes made under the SSRF R&D program are qualified for formal construction by minor modifications. While waiting for the final project approval of the central government, we are going to construct a 300MeV electron linac from the second half of this year.

### ACKNOWLEDGEMENTS

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- [2] S.Y. Chen, H.J. Xu and Z.T. Zhao, "Shanghai Synchrotron Radiation Facility," PAC'99, New York, March 27 - April 2, 1999.