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Current status and progresses of SSRF project

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Abstract The Shanghai Synchrotron Radiation Facility (SSRF), a third generation light source, comprises a 3.5GeV electron storage ring, a full energy booster, a 150 MeV linac, and seven beamlines in Phase I of the project. Beginning at the end of 2004 with a groundbreaking ceremony, the accelerators were installed in ten months from November 2006, and were successfully tested and commissioned in the past a couple of months. On December 21, 2007, storing electron beams in the storage ring was realized, and the first synchrotron radiations were observed three days later on the front-end of Beamline BL16B of the facility. Now, it runs 3 GeV 100 mA beams with a lifetime of 8~10 hours. Meanwhile, construction of the first seven beamlines (five ID beamlines and two bending magnet beamlines) is progressing on schedule.

Key words SSRF, Synchrotron radiation facility, Linac, Booster, Storage ring, Insertion device, Beamline, Test and commissioning
CLC number O57

1 Introduction

The SSRF project, supported jointly by Chinese Academy of Sciences and Municipality Government of Shanghai, is to build a third generation light source of high performance/cost ratio and to provide powerful X-rays for users in China and other parts of the world in a variety fields of research. The SSRF complex (see Fig.1 for a schematic view of the facility) consists of a 150 MeV linac, a 3.5 GeV booster of 180 m in circumference, a 3.5 GeV storage ring of 432 m in circumference, and seven beamlines and experimental stations (Phase I of the project). Its design specifications are among the best synchrotron radiation facilities in the world.[1,2] With advanced insertion devices, the storage ring can run electron bunches of up to 300 mA in beam emittance of 3.9 nm·rad, and provide high intensity monochromatic 0.1~40 keV X-rays of 10^{20} photons / (s·mm^2·mrad^2·0.1%·BW) in maximum brilliance. X-rays in this energy region are the most frequently requested by users in either fundamental or applied researches in materials science, life sciences, environmental studies, physics, chemistry, pharmaceutics and geology [3-7], and are finding wide applications in industries of electronics, pharmacy, petrochemistry, bioengineering and micro- and nano-fabrication.[7-9]

On December 25, 2004, a groundbreaking ceremony started constructions of the SSRF project, towards a scheduled operation of the synchrotron radiation facility in April 2009. The main building to host the SSRF complex had been completed by the end of 2006, and constructions of auxiliary buildings, including utility buildings, a technical building, an administrative building, a cafeteria and a guest house, were completed a few months later. Fig.2 shows the SSRF campus in October 2007. In November 2006, installations of the accelerators began with the linac, which was tested and commissioned successfully in April 2007. In October, the booster was tested to accelerate the 150 MeV electron beams from the linac to 3.5 GeV. In December 2007, the electron beams were injected into and stored in the storage ring, and synchrotron radiations were observed at the front end

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of the BL16B beamline. All these are roughly four months ahead of schedule.

In the following sections, results of testing and commissioning the linac, the booster and the storage ring, and progresses in constructing insertion devices and beamlines, will be described in details.

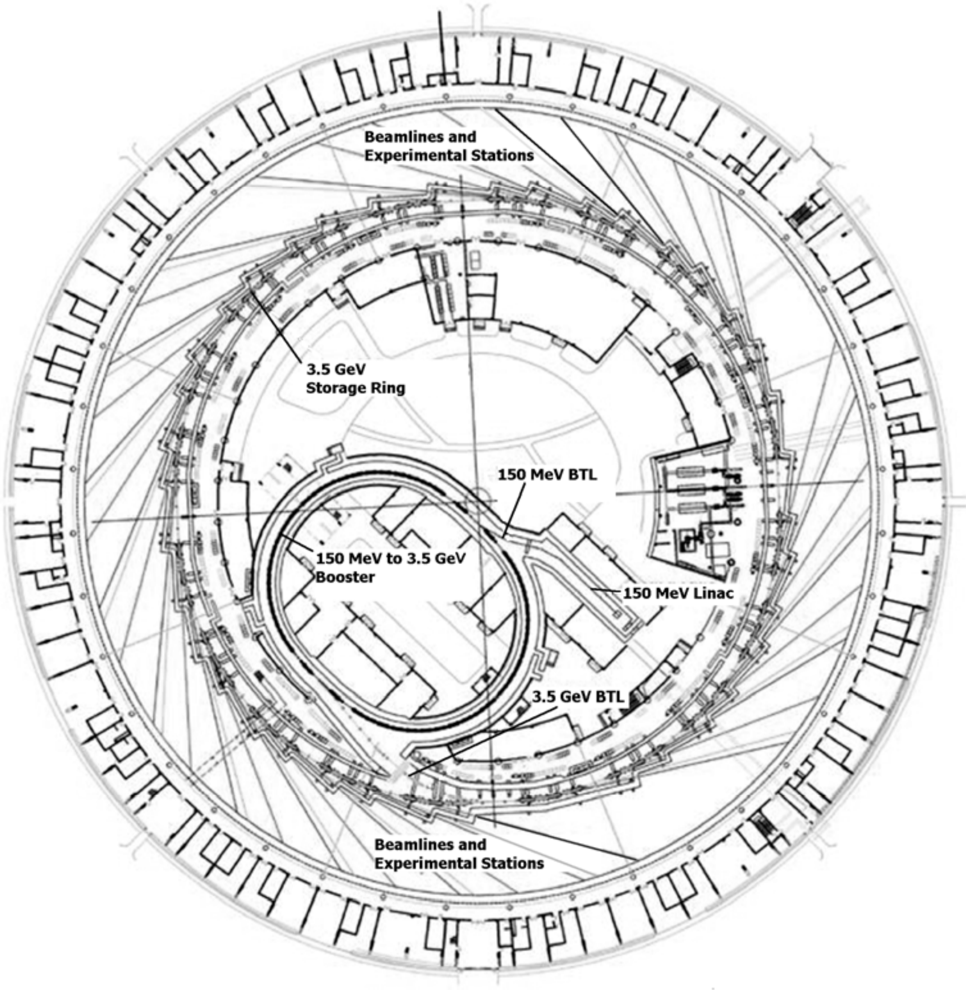

Fig.1 Layout of SSRF.

Fig.2 The SSRF campus in October 2007.

2 The linac

Installation of the linac was finished in six months. It was commissioned in July 2007, with all the linac parameters being fulfilled within the design specifications. It has two operation modes, i.e. the single bunch mode with 0.2 nC~1 nC in a 1ns pulse, or alternatively the multi-bunch mode with 3 nC in a macro pulse of 200 ns. Parameters of the linac are listed in Table 1. And Fig.3 shows the beam spot profile and signals on the wall current monitor (WCM) for the linac.

Table 1 Main parameters of the linac

Parameters	Single bunch mode		Multi-bunch mode	
	Designed	Achieved	Designed	Achieved
E / MeV	150	152	150	151
σ_E / % (rms)	0.5	0.2	0.5	0.4
Q / nC	0.2~1	0.2~1.06	3	3~10
σZ / ns	1	0.3	200	200
ε / µm·rad	50	37	50	47
f_{RF} / MHz	2998	2998	2998	2998

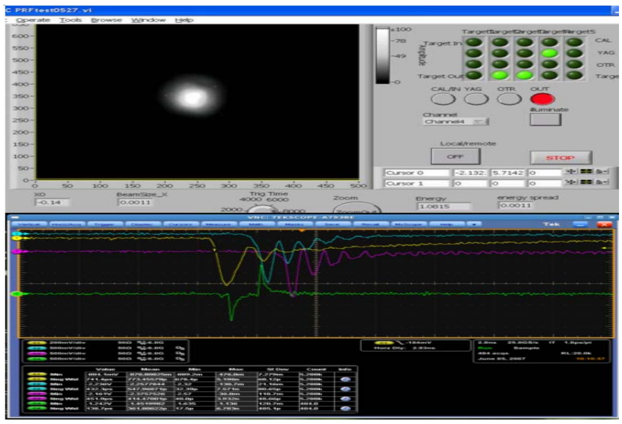

Fig.3 Beam spot profile and signal of WCM for the linac.

3 The booster

The booster is a synchrotron for accelerating electron beams from 150 MeV to 3.5 GeV in 250 ms, so as to meet requirements on energy, current intensity and phase space by the storage ring. It consists of the low-energy transport-line (LT), booster ring (BS) and high-energy transport-line (HT). The booster lattice is based on a FODO (Focusing–Defocusing) structure with missing dipoles, forming 28 cells with 8 straight sections of a 2-fold symmetry in its 180 m circumference. The booster is the first successful fast booster designed and constructed in China.

After nine months installation and pre-commissioning, the booster commissioning started on September 30, 2007. The first 3.5 GeV beam was observed on the WCM on October 5 (Fig.4), and the first extracted beam was obtained on October 29. All the design specifications were achieved (Table 2). Based on the progresses, we were able to start tests and commissioning of the storage ring in December.

Fig.4 The first 3.5 GeV beam measured on October 5 by WCM of the SSRF booster.

Table 2 Main parameters of the SSRF booster

Parameters		Values
Injection energy / GeV		0.15
Extraction energy / GeV		3.5
Beam current / mA	Single bunch	1.6
	Multi-bunch	10
Cycle rate / Hz		2
Circumference / m		180
Harmonic number		300
Lattice structure		2-fold FODO
Cell number		28
Natural emittance / π nm-rad		100
RF frequency / MHz		499.65
Betatron tune, ν_H / ν_V		8.18/5.23
Natural momentum spread		7.8×10^{-4}

4 The storage ring

The storage ring lattice is composed of 20 double-bend achromatic (DBA) cells in its 432 m circumference. Its lattice includes sixteen 6.5 m and four 12.0 m straight sections for accommodating injection components, RF cavities and insertion devices. Each DBA cell contains 2 bending magnets, 10 quadrupoles and 7 sextupoles. Performance of the storage ring is determined by the choice of betatron tunes and beta functions in the straight sections. The betatron tunes are chosen as Q_x=22.22 and Q_y=11.32, and the horizontal beta functions as 10 m and 3.6 m, the vertical beta functions as 6.0 m and 2.5 m, and the horizontal dispersion functions as 0.15 m and 0.105 m, in the middle of the long and short straight sections, respectively. The resulting structure has a natural horizontal emittance of 3.9 nm·rad. Main parameters of the SSRF ring are given in Table 3. Fig.5 shows a section of the storage ring.

Table 3 Main parameters of the SSRF storage ring

Parameters	Specifications
Energy / GeV	3.5
Circumference / m	432
Harmonic number	720
Natural emittance / nm·rad	3.9
Multi-bunch / mA	200~300
Single-bunch / mA	>5
Long straight lengths / m	4×12.0
Straight lengths / m	16×6.5
Betatron tunes, Q_x/Q_y	22.22/11.32
Momentum compaction	5.2×10^{-4}
RF frequency / MHz	499.654
RF voltage / MV	4
Energy loss per turn/ MeV	1.448
Beam lifetime / h	>15

Fig.5 One section of the storage ring.

On December 21, 2007, the commissioning of storage ring was started and electron beams were injected. The electron circulated the storage ring successfully from single turn to multi-turns at that night (Fig.6). On December 24, storing 3 GeV electron beam bunches was realized in the storage ring, and synchrotron radiations were observed at the beamline for synchrotron radiation diagnosis and the front end of Beamline BL16B (Fig.7). At present, the storage ring runs 3 GeV 100 mA beams with 8~10 h of lifetime.

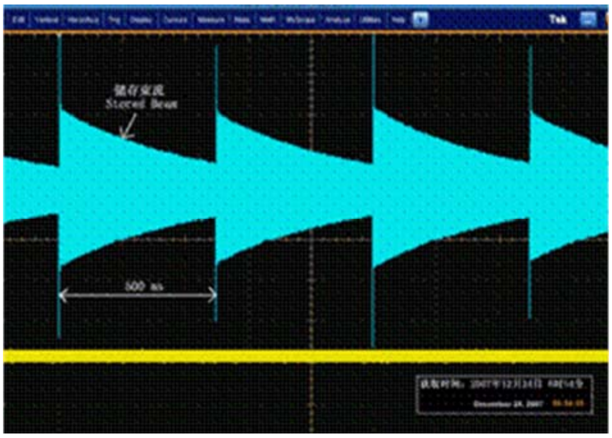

Fig.6 The first stored beam in the SSRF storage ring recorded on December 21, 2007.

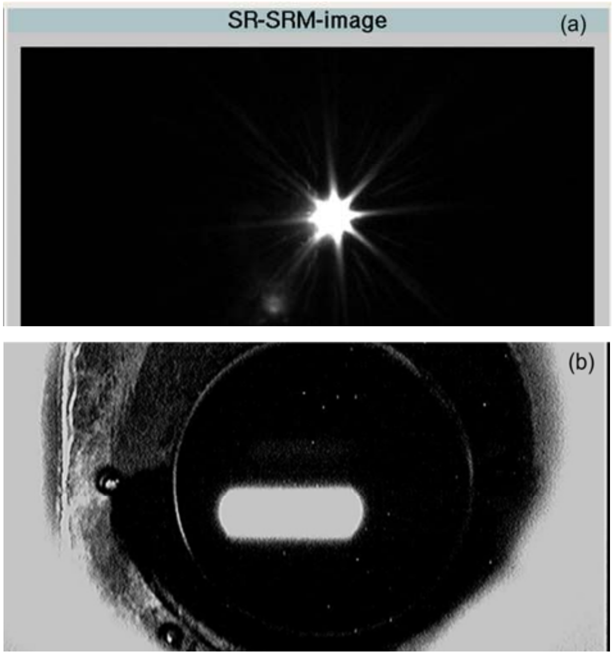

Fig.7 Synchrotron radiations observed on SSRF on December 24, 2007. (a)the visible light at the beamline for synchrotron radiation diagnosis, (b) X-rays on the fluorescence target in the front end of Beamline BL16B.

5 The insertion devices

Among the Phase I beamlines, five of them will use insertion devices. Table 4 shows the main parameters of the five insertion devices. Fabrication of two in-vacuum undulators was contracted to a US company. Two wigglers and one EPU undulator are being developed in China under joint efforts of SSRF and industries. It is scheduled to start their installations into the SSRF storage ring in September 2008.

Table 4 Main parameters of insertion devices (IDs) for Phase I beamlines

IDs	Type	Periods / mm	N	Minimum gap / mm	Peak field / T
IVU25-1	Hybrid	25	80	6	0.94
IVU25-2	Hybrid	25	80	6	0.94
EPU100	PPM	100	42	32	0.6 (B_y) 0.33 (B_x)
W79	Hybrid	79	19	14	1.2
W140	Hybrid	140	8	14	1.94

6 The Phase I beamlines

The SSRF Phase I beamlines include seven beamlines, among which five are ID beamlines and two are bending magnet beamlines. The main design features of Phase I beamlines are given in Table 5.

Table 5 Main design parameters of Phase I beamlines

No.	Beamline	Source	Main design parameters
1	Macromolecular crystallography	IVU25	Energy range: 5~18 keV Energy resolution: < 2×10^{-4} Flux at sample: ~10^{12} photons·s^{-1}(100mA)$^{-1}$ @12 keV Focal beam size: 120 μm×30 μm Beam divergence: 0.3 mrad × 0.1 mrad
2	XAFS	W79	Energy range: 3.5~22.5 keV, focused;3.5~50 keV, unfocused Energy resolution: 5×10^{-5}~2×10^{-4} Si(311)/Si(111) Flux at sample: 2×10^{13} photons·s^{-1} @10 keV@ Si(111) Focal beam size: 0.25 mm×0.25 mm
3	Diffraction	BM	Energy range: 4~22 keV Energy resolution: ~10^{-4} Flux at sample: 5 ×10^{11} photons·s^{-1} @8 keV Focal beam size: ~0.25 mm
4	Hard X-ray micro-focusing	IVU25	Energy range: 3.5~22 keV Energy resolution: < 2×10^{-4} Focal beam size: 0.2~2 μm Flux at sample: 10^{11}~10^{12} photons·s^{-1}
5	X-ray imaging and biomedical applications	W140	Energy range: 8~72.5 keV Energy resolution: ~10^{-3} Beam size(unfocused): 90 mm(H)×7 mm(V) @30 m@20 keV Flux: 3×10^{10} photons·s^{-1}·mm^{-2}@20 keV 2×10^{8} photons·s^{-1}·mm^{-2}@70 keV
6	Soft X-ray spectromicroscopy	EPU100	Energy range: 250~2000 eV (C~Si, K-edge) Focal beam size: ≤50 nm Spectral resolution($E/\Delta E$): >1000 Flux at sample: >10^{9} photons·s^{-1}
7	SAXS	BM	Energy range: 5~20 keV Energy resolution: < 5×10^{-4} Focal beam size: ~0.3 mm Flux at sample: ~10^{12} photons·s^{-1} Small angle resolution: ~0.4 mrad/300 nm @8 keV

The Phase I beamlines were decided based on extensive discussions in the Chinese scientific community.They are expected to facilitate researches in a number of fields of research, with emphasis on structural biology, environmental studies, materials science, nano-sciences and biomedical applications. Construction of the Phase I beamlines has been proceeding on schedule. The front-ends for seven beamlines have been in their tests and commissioning. Fabrication of the beamline components is in full swing. The beamline components for BM beamlines are scheduled to be completed before April 2008, and the BM beamlines are expected in commissioning in June 2008. All the seven beamlines will have been commissioned and ready for test experiments by early 2009. Fig.8 shows the front end of an undulator beamline in pre-installation.

Fig.8 Pre-installation of a front-end for an undulator beamline

7 Conclusion

The SSRF project has been in fast progresses. After two and a half years of building construction and equipment installation, the third generation light source was tested and commissioned successfully in the past a couple of months. At present, the storage ring runs 3 GeV 100 mA beams with a lifetime of 8~10 h, and the first beamlines are to be installed in first half of 2008. Also, we expect to construct 3 or 4 new beamlines annually in the future, so as to meet domestic and international demands for synchrotron radiation applications, and some new beamlines have been proposed to conduct relevant studies by users in China and other countries. SSRF is capable of having over 60 beamlines, which include 26 ID beamlines, 36 bending magnet beamlines and several IR (infrared) beamlines. SSRF will be an important platform in China for interdisciplinary studies and hi-tech developments.

References

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

2 Liu G M, Dai Z M, *et.al*. High Energy Physics and Nuclear Physics, 2006, **30**: 144-146.

3 Winick H. Synchrotron Radiation Research, ISBN-10: 0306403633, September 30, 1980.

4 Conceptual Design Report of NSLS-II (Chapter 3 Science at NSLS-II), 2006

5 Shenoy G, Viccaro P J. J Synchrotron Rad, 2005, **12**: 123.

6 Sham T K. Chemical applications of synchrotron radiation ISBN 978-981-02-4480-4, 981-02-4480-0(set) , Jun 2002

7 Ari I E. Applications of Synchrotron Radiation: Micro Beams in Cell Micro Biology and Medicine, (Biological and Medical Physics, Biomedical Engineering), ISBN-10: 3540464247 ISBN-13: 978-3540464242, April 12, 2007

8 Rack A. Synchrotron Radiation Based Imaging Methods for Industrial, DIR 2007 - International Symposium on Digital industrial Radiology and Computed Tomography, June 25-27, 2007, Lyon, France

9 Pantos E. Applications of Synchrotron Radiation to Archaeological Ceramics, Modern Trends in Scientific Studies on Ancient Ceramics, BAR International Series1011, 2002. 377-384