STATUS OF THE SHANGHAI SYNCHROTRON RADIATION FACILITY

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Abstract

The Shanghai Synchrotron Radiation Facility (SSRF) made its ground breaking at Zhang-Jiang High Tech Park on Dec.25, 2004 and moved into its construction phase with the plan of commencing user's operation from April 2009. The SSRF complex is based on a 3.5GeV storage ring optimized to operate with top-up injection, mini-gap undulators and superconducting RF system, the 432m circumference storage ring provides 18 ID straight sections (4×12.0m and 16×6.5m), and four of them will be used for the first SSRF beam lines. The SSRF project was proposed in 1995, and since then it has experienced the conceptual design stage, the R&D program and the design optimization phase. This paper presents the updated design specifications and the construction status of the SSRF project.

INTRODUCTION

The SSRF is an intermediate energy third generation light source founded by the Chinese central government, the Shanghai local government and the Chinese Academy of Sciences. The SSRF project passed its main approval milestones and its groundbreaking was carried out on Dec. 25, 2004. The early access to accelerator tunnels is foreseen in June 2006, then the linac commissioning is expected to be carried out from April to July 2007, the booster commissioning from October 2007 to March 2008, the storage ring and 7 beamlines commissioning from April 2008 to March 2009.

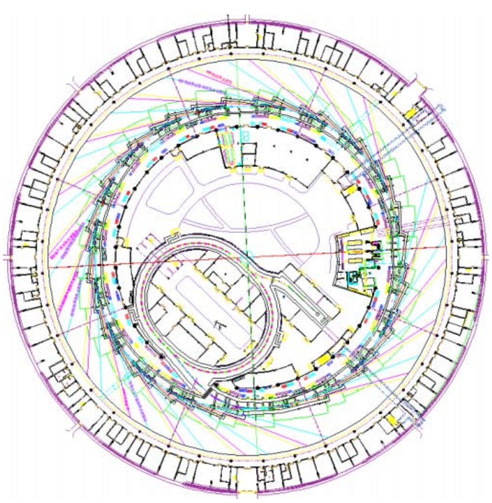

Figure 1: Layout of the SSRF.

The SSRF complex, as sketched in figure 1, consists of a full energy injector including a 100MeV linac and a 3.5GeV booster, a 3.5GeV storage ring and its associated synchrotron radiation experimental facilities. The design evolution and progress of the SSRF project as well as its R&D program has been regularly reported at particle accelerator conferences [1-5]. Since January 2004, the SSRF design optimization has been continued towards the finalization of its technical specifications. From June to December 2004, the SSRF feasibility study report and the SSRF preliminary design report were reviewed and approved. They are followed by the extensive engineering design efforts till September 2005, and then will start the equipment procurements and fabrications.

STORAGE RING

The SSRF storage ring design has been refined based on its existing optimizations since September 2004. The finalized SSRF storage ring lattice is a 20-cell double bend structure with 4 super-periods and a circumference of 432m. Each super-period contains 5 cells, including one 12.0m long straight section and four 6.5m standard straight sections. Each double bend cell is equipped with 2 bending dipole magnets of 1.27T, 10 quadruple magnets with maximum gradient of 20T/m, 3 chromatic and 4 harmonic sextuple magnets with maximum gradient of $500T/m^2$. The main change in this design refining is using flat bending dipoles instead of using gradient bending magnets in the double bend structure lattice, which results in that the storage ring natural emittance is increased up to 3.9nm·rad. Table 1 lists the main parameters of the finally optimized storage ring, and figure 2 shows the spectral brightness of the SSRF bends and typical IDs.

Table 1: Main parameters of the SSRF storage ring.

Energy (GeV)	3.5
Circumference (m)	432
Harmonic number	720
Number of cells/Super-periods	20/4
Nature emittance (nm·rad)	3.9
Beam current, Multi-bunch (mA) Single-bunch (mA)	200~300 >5
Straight lengths (m)	4×12.0，16×6.5
Betatron tunes, Q_x/Q_y	22.22/11.32
$\beta_x/\beta_y/D_x$ @12m straight (m)	10.0/6.0/0.15
$\beta_x/\beta_y/D_x$ @6.7m straight (m)	3.5/2.5/0.10
Momentum compaction	4.2×10^{-4}
Natural energy spread (rms)	9.9×10^{-4}
RF frequency (MHz)	499.654
RF voltage (MV)	4.0
Dipole radiation per Turn (MeV)	1.45
Damping times $\tau_x/\tau_y/\tau_s$(ms)	6.95/6.97/3.49
Bunch length (mm)	4.0
Beam lifetime (hrs)	>10

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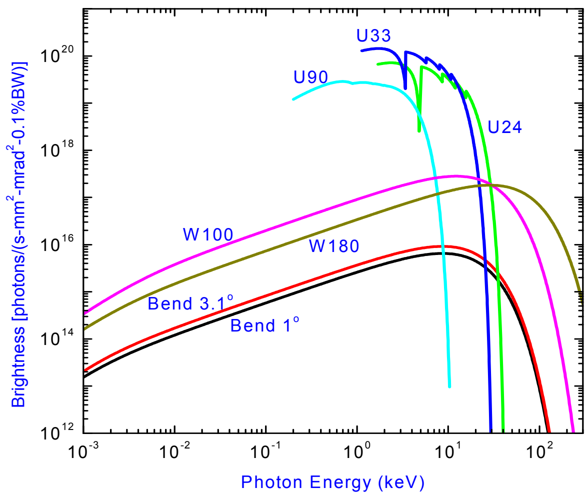

Figure 2: The SSRF Spectral Brightness.

There are 18 straight sections in SSRF available for accommodating insertion devices, including two 12.0m long straights for longer undulator or for multi-undulator installations. In phase one, one of the 6.5m straights will be used as beam instruments section for installing beam diagnostics elements and feedback kickers. The bending magnets at the upstream are used to provide synchrotron radiation to beam lines. Each upstream bending magnet can serve two beamlines at angles of 1°and 3.1°to the straight section. Table 2 shows the beam dimensions at the SSRF photon source points.

Table 2: Beam dimensions at the SSRF source points.

Source Point	σ_x (μm)	σ_x' (μrad)	σ_y (μm)	σ_y' (μrad)
Standard Straight (6.5m)	158	33	9.9	3.95
Long Straight (12.0m)	247	20	15	2.55
1°@upstream of SS	70	114	22	1.97
3.1°@upstream of SS	53	94	22	1.97
1°@upstream of LS	77	116	23	1.79
3.1°@upstream of LS	56	96	23	1.79

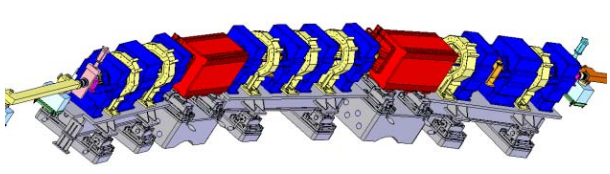

Figure 3: A storage ring cell assembly.

As sketched in figure 3, there are five girders in a storage ring cell. In which each bending magnet has its own independent girder and the 3 rest girders support all the quadrupoles, sextupoles and correctors. At time of this writing, the storage ring magnets, girders and vacuum chambers are under engineering design finalization, their fabrications are scheduled to start from this October.

The SSRF storage ring RF system consists of three superconducting RF cavities, a 4.2K liquid helium cryogenic plant, three 300kW klystron power amplifiers and digital low level RF control loops. The specifications of these technical equipments have been completed, and contracts with equipment suppliers are expected to award in the second half of this year.

The SSRF beam instruments system, including digital BPM system and orbit feedbacks, and EPICS based control system are under design finalization, they will also move to the equipment procurement stage from October 2005. The storage ring digital power supply prototype using PSI type regulator is under development, and the relevant engineering designs are scheduled to be finished in this September. Efforts to design the injection system including its septum and kicker magnets as well as their pulsers are being made, the engineering design is expected to be completed before this October.

LINAC AND BOOSTER

The SSRF linac has been re-designed as a dedicated pre-injector with an output energy of 100MeV. It includes a 80~100kV electron gun, a 499.654MHz sub-harmonic buncher, a 2997.924MHz fundamental buncher, four 3m SLAC type accelerating sections, a 45MW klystron and a 110MW modulator. This linac is designed to operate with both single bunch and multi-bunch modes for quick and top-up injections, Table 3 lists the main parameters of the SSRF linac. Its design is based on a newly developed 100MeV/2856MHz electron linear accelerator at SINAP, but its working frequency is modified to 2997.924MHz, which is harmonically related to the SSRF storage ring RF frequency for making precise single bunch injection.

Table 3: The main parameters of the SSRF Linac.

Nominal energy (MeV)		100
Beam charge (nC)	Single bunch	1.0
	Multi bunch	3.0
Pulse length (ns)	Single bunch	1.0
	Multi bunch	200
Pulse to pulse energy stability		0.5%
Energy spread (rms)		0.5%
Normalized emittance (mm·mrad)		<50mm
Operating frequency (MHz)		2997.924
Repetition rate (Hz)		1-10

The SSRF booster housed in an independent bunker, is optimized for top-up operation, its magnetic lattice is a two fold symmetric 28-cell FODO structure with 8 missing dipoles and a circumference of 180m. This lattice produces an emittance about 100nm·rad at 3.5GeV, which meets the requirement of top-up operation. It provides 8 2.9m straight sections for accommodating injection and extraction elements (septum and kicker magnets), 5-cell RF cavities and beam diagnostics elements. Figure 4 shows an SSRF booster cell and Table 4 lists the main parameters of the SSRF booster.

The engineering design of the SSRF booster systems is in progress and will be finished before October 2005. The

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procurements of the booster magnets, power supplies, RF cavities, girders, vacuum chambers and etc. are scheduled to start in the second half of this year. The schedule of the booster injection and extraction systems is now on the critical path since their designs have not been finalized.

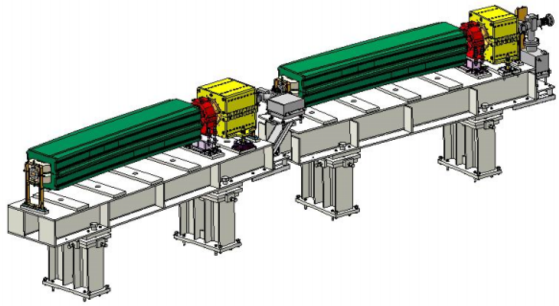

Figure 4: An SSRF booster cell Assembly.

Table 4: Main parameters of the SSRF booster.

Injection energy (MeV)		100
Output energy (GeV)		3.5
Circumference (m)		180.0
FODO cells/Super-periods		28/2
Harmonic number		300
Natural emitance (nm·rad)		110 (@3.5 GeV)
Beam current (mA)	Single bunch	1.6
	Multi bunch	15
Betatron tunes		8.18/5.23
Momentum compaction factor		0.0185
Natural energy spread		7.799×10^{-4}
Maximum straight length (m)		2.904
Energy loss per turn (MeV)		0.915
RF frequency (MHz)		499.654
RF voltage (MV)		1.8
Synchrotron Tune		0.0219
Repetition Rate (Hz)		2

BUILDINGS AND FOUNDATIONS

The SSRF complex is being built on a piece of green land, which occupies an area of 600m×300m at Zhang-Jiang High tech Park. The SSRF buildings include a main building to house accelerators and beamlines, utility buildings, an office building, a technical building, a guest house and a cafeteria. The SSRF building designer, Shanghai Institute of Architectural Design and Research, was appointed in April 2004. Since then the facility and the building designers have interacted closely to finalize the SSRF building specifications and the scheme designs, and detailed designs of the SSRF buildings have been completed. The SSRF building construction contractor, Shanghai Construction General Co., was appointed in November 2004, and then the SSRF ground breaking was made last December.

The SSRF site at Zhang-Jiang High Tech park is only about 4m in altitude, the site soil is soft and the rock layer is about 300m under ground. To achieve the differential settlement specifications of 0.1mm/10m/year for the storage ring tunnel slab and 0.25mm/10m/year for the experimental hall slab, a pilling scheme was chosen in the foundation design. The 0.6m diameter pile is 49m long poured from the ground surface down to the harden sand layer, and there are totally about 1000 piles under the storage ring tunnel and experimental hall slabs, which are 1.35m and 1.45m thick respectively and joined together. The foundation for injector and foundation for supporting the main building roof are independent ones to avoid their influence to storage ring and beamlines. 37 test piles and 2 test slabs were successfully made during March to April 2005, now the pile construction is ready and expected to be completed before October 2005.

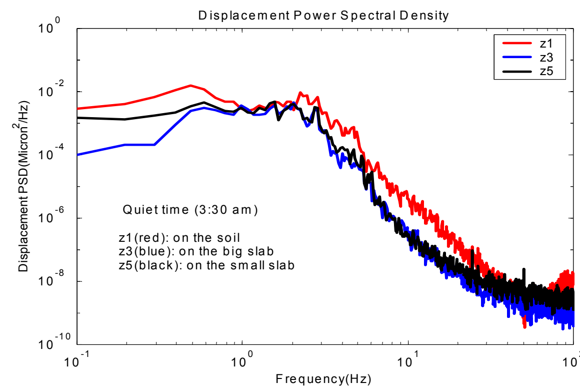

Figure 5: PSDs of vertical vibrations on ground and slabs.

The most critical problem of the SSRF site is its vibration behaviour. Since September 2004, extensive ground vibration measurements have been done on the SSRF site. The measurements show that the horizontal and vertical ground vibration amplitudes are few times higher than that in other light source sites. And there is a main peak around 3Hz, which seems caused mainly by the road traffics, particularly by the heavier trucks. The measurements have been made and compared at various conditions, including day and night, different depths from ground surface down to 49m under ground, controlled and uncontrolled road traffics. The measurements have been made with piles and the test slabs, which indicate that the slab and pile structure can damp the vertical ground vibration by a factor of about 2. Figure 5 shows the measured power spectrum densities (PSDs) of the vertical vibrations on the ground and slabs. In the meantime, some other methods, such as discontinuous foundation barriers, are being considered to adopt based on their technical feasibility and cost effectiveness.

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