STATUS OF THE SSRF STORAGE RING

Z.M. Dai, G.M. Liu, L.X. Yin, D.K. Liu, Z.T. Zhao
Shanghai Institute of Applied Physics, Shanghai 201800, P. R. China

Abstract

The SSRF storage ring is composed of 20 DBA cells with energy of 3.5GeV and circumference of 432m. The installation of the SSRF storage ring started on June 11, 2007, and finished in the beginning of December 2007. The system tests of hardware and software for storage ring were completed in the middle of December 2007. The commissioning of the storage ring started on Dec.21, 2007, and the 100mA stored beam was achieved for the first time on January 3, 2008. The design, installation and commissioning of the SSRF storage ring are described in this paper.

INTRODUCTION

The Shanghai Synchrotron Radiation Facility (SSRF) is a third-generation synchrotron light source, which is under commissioning [1]. The storage ring of SSRF is composed of 20 DBA cells with a low emittance of 3.9nm·rad and circumference of 432m[2,3]. There are 2 dipoles, 10 Quadrupoles, 7 Sextupoles, 4 H/V combined correctors, and 3 H/V air coils in each DBA cell. These magnets are mounted on three girders for each DBA cell.

All the 40 bending magnets are powered in series with one power supply, 200 quadrupoles are powered independently, 140 sextupoles in 8 families are elaborately optimized to provide ample dynamical acceptances, 80 correctors in each transverse plane[4].

To achieve high stable orbit stability, full digital controller as used in Switzerland Light Source (SLS) is adopted in all magnet power supplies, and the BPM system is fully equipped with Libera EBPM processors. The Libera EBPM processors provides raw ADC data, turn by turn (694kHz) data, fast application (10kHz) data and close orbit (10Hz) data at the same time, is the most powerful tools during the commissioning and machine study of SSR F storage ring[5]. Stainless steel Vacuum chambers with antechambers have been developed for SSRF storage ring [6].

The SSRF was ground broken on December 24, 2004. Installation of the SSRF storage ring was started on June 11, 2007, and finished in the beginning of December 2007. System tests of hardware and software for SSRF storage ring were completed in the middle of December 2007. The Phase-I commissioning of the storage ring at energy of 3.0GeV with three normal conducting RF cavities started on December 21, 2007 and the 100mA stored beam was achieved for the first time on January 3, 2008.

The SSRF storage ring has been shutdown to install two superconducting RF accelerating modules, and the Phase-II commissioning of SSRF storage ring at energy of 3.5GeV with two superconducting RF accelerating modules is planed to be stated at the end of July 2008. The beam current will be increased to 200~300mA.

Two wigglers and one EPU will be installed into the ring in September 2008, and two in-vacuum undulators will be installed in December 2008.

INSTALLATION & SYSTEM TEST

In order to check the overall design and confirm the installation procedure, a pre-test installation for a half arc sector using the prototype components and a full-test installation and system test for one arc sector using the first group components are respectively carried out at the SINAP site in middle of 2006 and in the SSRF tunnel and technical gallery at the end of 2006. Based on the experience, the installation of the SSRF storage ring was started on June 11, 2007. The pre-alignment of the Girder-magnet assembly and the pre-processing of the vacuum system were carried out in the experimental hall. Then the assemblies were sent to ring tunnel using crane for alignment. The installation of the storage ring was completed successfully at the beginning of December, 2007. Figure 1 shows the machine in the tunnel.

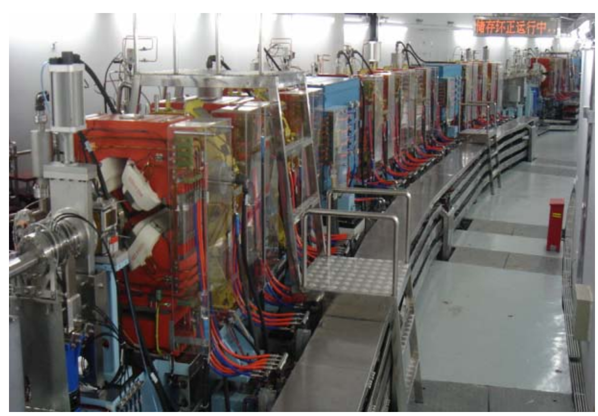

Figure 1: One sector of the machine in the tunnel

Quadruples and dipoles of the SSRF storage ring are fiducialized by laser tracker, and sextuples, all correctors, vacuum chambers (including BPM buttons) and SR absorbers of the ring are fiducialized by articulated arm. The magnets are installed on the girder and pre-aligned by use of the laser trackers in the experimental hall. All positions of the references of each girder and magnets on the girder were measured by laser tracker in respect to the SSRF alignment network. Standard deviations of the positions of mechanical centers of the magnets were

0.059mm and 0.033 mm in the horizontal and the vertical directions respectively.

System tests of vacuum system, magnet power supplies, beam diagnostics, control system, et.al., for each DBA cell was carried out after installation and alignment of the cell. System tests of the storage ring started in August 2008 and finished in the middle of December 2008.

PHASE-I COMMISSIONING AND PERFORMANCE OF STORAGE RING

Phase-I commissioning of the storage ring has been carried out with three normal conducting RF cavities, which are lent from KEK PF, Japan. The Q0 and QL of the PF RF cavities are ~39000 and ~12000 respectively. The maximum accelerating voltage and feed RF power of each PF cavity are limited in 0.5MV and 60kW. Because the three normal conducting cavities can't compensate beam energy loss on the 3.5 GeV, beam energy of the storage ring is decreased to be 3.0GeV, while the beam current of the storage ring is limited to be 100mA.

On December 21, 2007, the Phase-I commissioning of the SSRF storage ring was started and electron beams were injected on the central orbit of the ring by an on-axis injection [2]. About three hours later, first turns of beam in the ring has been achieved. On December 24, 2007, beam storage was obtained in the storage ring. The first synchrotron radiation was observed at the beam line for synchrotron radiation diagnosis and the front end of Beam line BL16B [7]. Beam accumulations of 5 mA and accumulation of 100 mA were achieved on December 25, 2007 and January 3, 2008 respectively. After about one month for beam cleaning of the vacuum chamber, the beam lifetime at 100mA current could increase to be longer than 10 hours.

By use of beam based alignment (BBA), the offsets between quadrupoles and their closest BPMs have been accurately measured [8]. Based on the BBA and highly precise measured orbit response matrix, closed orbit deviations (COD) of storage ring were corrected sufficiently with SVD methods. In March, 2008, RMS COD of the storage ring has been successfully corrected to be less than 50 um in both transverse planes, with 137 digital BPMs and 80 H/Vcorrectors.

By use of the LOCO technique [9], the linear optics of the storage ring has been characterized and corrected. After fitting the linear optics magnet-by-magnet, the beta-beating between the machine and the designed mode was sufficiently minimized to ±1%. These results show an excellent agreement with the designed mode.

ORIBT FEEDBACK AND ORBIT STABILITY

A slow orbit feedback system (SOFB) and a fast orbit feedback system (FOFB) have been designed for the SSRF storage ring. Both of them will work together to stablize the beam orbit to micron or sub-micron level.

Without orbit feedback, the vertical orbit variation is less than 50μm, while the horizontal orbit variation is more than 300 μm resulted from the circumference variation due to temperature changing from day to night.

The slow orbit feedback system (bandwidth < 0.1Hz) with 80 H/V slow corrector magnets is based on Libera 10Hz data, EPICS CA protocol and MatLAB application [10]. SVD correction technique is also used in the slow orbit feedback system, including adjustment of the RF frequency to compensate the circumference variation due to temperature variation. It has been successfully test in the storage ring during Phase-I commissioning. At the beginning of June 2008, the slow orbit variation has been suppressed down to 1μm (rms) in both plane by use of the slow orbit feedback.

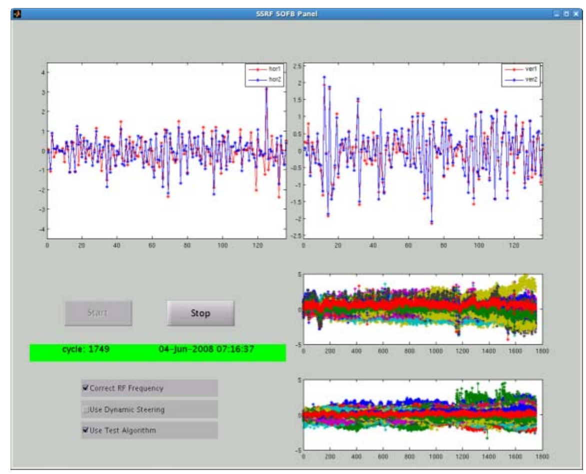

Figure 2: Orbit stability of SSRF storage ring in 5.5 hours with slow orbit feedback (2008.06.04)

The fast orbit feedback system (bandwidth 100Hz) using 60 H/V fast corrector coils, is based on Libera 10 kHz data, private optical network and VME feedback controller. This system will be installed in Sept., 2008 [5].

SUPERCONDUCTING RF SYSTEM

The RF system for SSRF Storage Ring consists of three RF stations, each of which has a klystron amplifier, a superconducting RF module and a low level RF feedback control. A 300kW klystron will feed the RF power to the superconducting cavity via a circulator and waveguides.

The CESR type 499.654MHz SRF module with tuning range +/-150kHz and external Q (1.7+/-0.3)×105 is chosen for the SSRF storage ring. Vertical testing results indicate the unloaded Q value higher than 1.0×109 at the cavity voltage of 2MV, and the maximum cavity voltage reached is 2.8MV. All three SRF modules have been passed the factory acceptance test and shipped to the SSRF site.

The SSRF liquid helium cryogenic system was designed for providing three SRF modules at 4.5K a cooling capacity of 600W with LN2 pre-cooling. A safety factor of 1.5 is used to estimate the heat load from the SC

RF module and the heat loss from the transfer lines. The helium refrigerator has successfully commissioned at the end of April 2008.

The site acceptance test (i.e., horizontal test) of the SRF modules started in May, 2008. The SRF module 3# has been successfully passed the site acceptance test at the beginning of June, 2008. It shows that unloaded Q value higher than 6.0×10^8 at the cavity voltage 2MV in horizontal test. The module 3# is being installed into the storage ring tunnel. The module 1# is being installed into the storage ring tunnel and will be site acceptance tested in the tunnel.

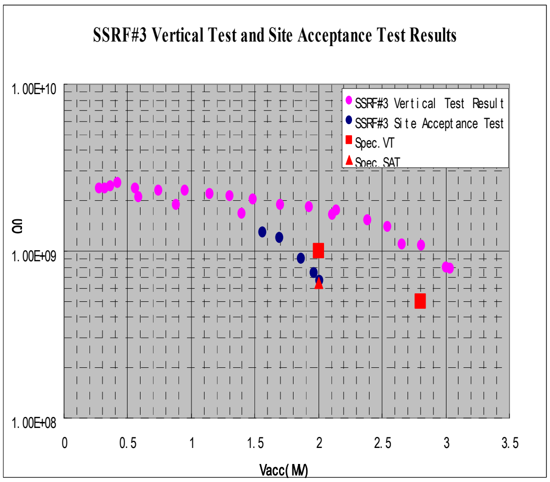

Figure 3. Vertical test and site acceptance test results of the third superconducting RF cavity for SSRF

A digital low level RF control (D-LLRF) system has been developed for the SSRF storage ring, in which a digitalized I/Q technology based on FPGA is adopted. Three sets of D-LLRF have been tested and operated about half year for the three normal conducting RF cavities during Phase-I commissioning. The amplitude stability and phase stability obtained are less than 1% and 1° respectively.

INSERTION DEVICES

There are five insertion devices for SSRF phase-I, including two In-Vac undulators (IVU25), one EPU (EPU10) and two wigglers (W80 and W140). Their main parameters are listed in table 1.

Table 1: Parameters of insertion devices for phase-I

Parameter	IVU25	EPU10	W80	W140
λu(mm)	25	100	80	140
Nu	80	42	19	8
Bu, max (T)	0.94	0.6	1.2	1.9
Gapmin (mm)	6	30	13	13

The first wiggler has been fabricated and assembled, and is being magnet measuring and shimming. The second wiggler has been fabricated and will be assembly in next month. The girder of EPU has been fabricated and assembly, and passed through the factory acceptance test in June 19, 2008. These two wigglers and one EPU will be installed into the storage ring in Sept., 2008.

The fabrication of the two in-vacuum undulators was delayed by about half year. And it plan to finish assembly and install into the storage ring at the end of 2008.

CONCLUSIONS

The design, fabrication, installation and system test of the SSRF storage ring have been finished within three years. And the first beam (light) has been achieved in the storage ring within three years after groundbreaking. By use of three normal conducting RF cavities, the Phase-I commissioning of the SSRF storage ring is quickly and some important specifications have been reached. Two superconducting RF modules are being installed into the storage ring tunnel and will be tested in July, 2007. The Phase-II commissioning of the SSRF storage ring with 3.5GeV and 200~300mA will be started in July, 2008. The five insertion devices will be also installed and commissioned this year.

ACKNOWLEDGEMENT

The authors would like to thank all of SSRF project team for their hard work, and thank the experts in the word for the discussion and the suggestion during the design, construction and commissioning of the SSRF storage ring.

REFERENCES

[1] ZHAO Zhengtang, Proceeding of this conference.
[2] LIU Gui-Min, et.al., Proceeding of this conference.
[3] LIU Gui-Min, DAI Zhi-Min, LI Hao-Hu et al. HEP&NP, Vol. 30, Supp. I, 2006, 144-146
[4] SHEN Tianjian, et.al., Proceeding of this conference
[5] LENG Yongbin, et.al., Proceeding of this conference
[6] JIANG Dikui, et.al., Proceeding of this conference
[7] XU Hongjie, ZHAO Zhentang, Nuclear Science and Techniques, 19 (2008), 1-6
[8] ZHANG Man-Zhou, HOU Jie, LI Hao-Hu et al. Chinese Physics C (HEP&NP), to be published
[9] J. Safranek, NIM A, 388 (1997), 27-36
[10] HOU Jie, TIAN Shun-Qiang, ZHANG Man-Zhou et al. Chinese Physics C (HEP&NP), to be published