Construction and Commissioning of the SRRC Storage Ring

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Abstract
A 1.3 GeV synchrotron radiation storage ring is currently under construction at SRRC. The installation activities had gone through about one year, from March 1992 to March 1993. The commissioning of the booster to storage ring (BTS) transfer line started from August 1992 soon after a 1.3 GeV synchrotron booster injector had been delivered in July 1992. The intensive activities of the storage ring beam tests began in April 1993. We had stored beam in April and some machine parameters have been measured

I. INTRODUCTION

To provide continuous, tunable and bright VUV and soft x-ray light sources for the researches ranging over physics, chemistry, biology, medicine, etc., a third generation dedicated synchrotron radiation facility was established in Taiwan. The SRRC accelerating system consists of a 50 MeV e^- linac, a 1.3 GeV synchrotron booster[1,2], a 70 m long BTS transfer line[1,3], and a 1.3 GeV storage ring[1,4,5], Up to now, the storage ring is in the commissioning stage. The stored beam was accomplished in April. We expect the designed current of 200 mA will be achieved soon after the vacuum vessels are baked in June. The design parameters and components are described in Sec. II. Installation activities are given in Sec III, and finally the early commissioning results are shown in Sec. IV.

II. DESIGN PARAMETERS AND COMPONENT

A. Lattice

The lattice structure is a combined-function triple-bend-achromat (TBA) type with 6-fold symmetry[1,4,5]. There are six dispersionless long straight sections, each 6 m, for the accommodation of injection elements, RF cavities, undulators and wigglers. Some major parameters are listed as follows:

Energy	1.3 GeV
Circumference	120 m
Natural emittance	19 nm-rad
Tune ν_x/ν_y	7.18/4.13
Momentum compaction	0.00678

The dynamic aperture of the single particle dynamics and collective effects of the particle beam were studied in detail. The acceptable tolerances of the magnetic properties and alignment errors were given accordingly[1,3,4].

B. Magnet and Power Supplies

There are 18 dipole magnets powered in series and four families of quadrupole magnets, each with 12 magnets powered in series. The chromaticities are corrected with 2 families of 24 sextupoles. In addition, there are 24 horizontal and 30 vertical corrector for orbit correction. Several skew quadrupoles were installed. The magnets were designed, constructed, measured, and analyzed with care. All magnets installed in the ring are within acceptable tolerances in terms of the multipole errors and integrated fundamental field errors[1,6]. The pulsed magnets such as septum and kickers also meet specification.

C. Vacuum

The most of the vacuum chambers were made of aluminum. Cares were taken as to provide ultrahigh vacuum, low impedance environments. The clearance of the material, tapering of the chamber, shielding of the bellows, the thermal load, deformation, rigidity and flexibility of the supporting frame, etc., were seriously considered to meet the requirements. Up to now, without turning on ion pumps, the vacuum pressure was about 10^{-8} Torr without beam and about 10^{-7} Torr with a few mA stored beam current. The bake-out of the vacuum chamber will be done in June. After turning on ion pumps, we expect the vacuum pressure can reach 10^{-11} Torr without beam.

D. RF system

In one of the long straight sections, two Doris I type cavities purchased from DESY were installed. Each cavity is with 60 kW maximum RF power provided by individual transmitter. The system can accelerate 1.3 GeV electron beam of more than 200 mA current in the presence of insertion devices. The nominal RF frequency is 499.654 MHz.

E. Survey and Alignment

Extremely tight requirements on the alignment of the magnet, especially quadrupole magnets in the ring in the transverse directions are necessary in order to reduced closed orbit distortions. The acceptable alignment errors in both planes are 0.15 mm rms and rotation errors are 0.5 mrad rms. The quadrupole magnets were prealigned in the girders and then moved into the tunnel. The final results of the alignments for dipoles and quadrupoles were 0.14 mm rms and 0.12 mm rms in the horizontal and vertical plane, respectively. The tilt errors was 0.2 mrad rms in dipoles and 0.06 mrad in quadrupoles. For sextupoles, the results were 0.20 mm rms and 0.15 mm rms in the horizontal and vertical plane, respectively. All were within acceptable tolerances.

The measured closed orbit distortions were consistent with the simulated results and will be described in Sec IV.

F. Beam Diagnostics

There are seven destructive screen monitors for first turn beam observations in the ring. Two were used for injection launching adjustment. The number of button type beam position monitors (BPM) are 47 in total. Two stripline electrodes are also installed. One excitation electrode station can be used for the tune measurements as well as for the transverse instability damping. The fast beam signal can also be measured using fast current transformer and precise beam current are obtained from DCCT. Some other elements such as scraper, photon light monitor, etc., are described in ref.[7].

G. Control and Operation[8]

VAX workstations running VMS operating system are used for control computer system. Between database and the sub-system devices, several intelligent local controllers (ILC) were implemented. A friendly graphical user interface (GUI) operation panel was developed. The radiation safety interlock system is a self-protected subsystem and will be linked to the central control system.

III. INSTALLATION

The installation task of such a rather complicated system in deed need well planning and full cooperation among all sub-systems. A cell of 20 m long was installed in the shop by the end of 1991. We gained a lot of practical experience. The installation of the BTS started in March 1992 and completed in September 1992 except the septum magnet. The installation of the ring began from March 1992. By May 1992, the cabling work and magnet stands installation were finished. Power supplies and all magnets except pulsed magnets were installed by October 1992. Finally, the vacuum system including diagnostics elements, RF cavities, and RF low level system were installed by the end of 1993. In February 1993, we passed the full power tests of magnet power supplies and the ring chambers were connected as a closed form by then. The installation of the RF high power transmitter and four kicker pulsers were finished in March 1993. The alignment of the magnets reached the acceptable level in March. In the meantime, the subsystem tests with control computer and developments of the control system software were under way. The subsystem tests with beam were taken whenever necessary. The storage ring commissioning started in April and we had stored beam very soon.

IV. COMMISSIONING

A. milestones

The BTS beam tests started in August 1992 when the lower level section of the transfer line was completed. By September, the beam reached septum entrance point. After the pulsed magnets had been installed, the beam passed through septum and injected into ring in January 1993. In February 23, the first beam revolution for the first time was accomplished using one kicker for on-axis injection. The beam was observed in each screen monitor without using any corrector. It showed that many sub-systems were basically in good condition. The beam sizes in the screen were consistent with the theoretical values. The alignment errors proved to be barely acceptable in the horizontal plane and extremely good in the vertical plane. Due to the long half-sine base width of 1.6 μs (400 ns revolution time) of the kicker pulse and only one kicker available, the second turn observation was impossible. Soon after all four kicker were available in April, we have several hundred beam revolutions using a few correctors without RF power and beam was captured on April 13 after turning on RF power with minor adjustments of the magnet settings and RF frequency. The stored beam current was a few mA and beam lifetime was a few minutes under vacuum pressure of 10^{-7} Torr.

B. Closed Orbit

We performed the closed orbit measurements soon after the BPM system was operative and the orbit was corrected down to 0.5 mm and 0.3 mm rms in the horizontal and vertical plane, respectively, using on-line application programs[9]. Further suppression of the orbit distortions will be obtained as soon as the BPM system is well calibrated. The preliminary results of the closed orbit measurements without using corrector are fairly consistent with simulation results using existing alignment data. Figure 1 show the closed orbit before and after correction, and simulated results as well.

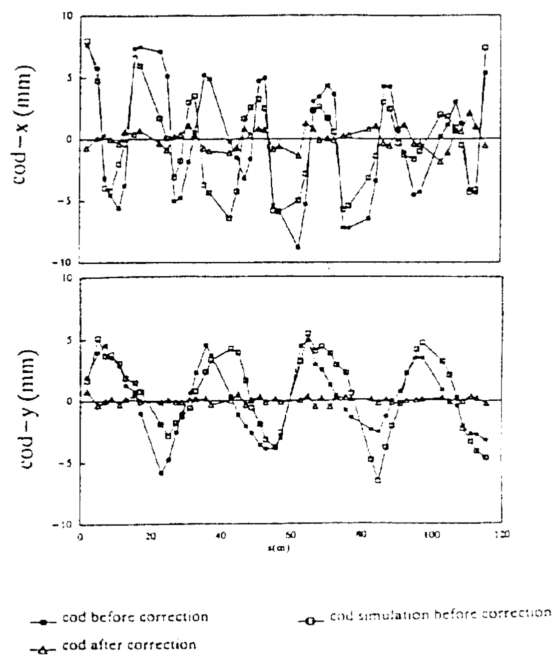

Figure 1. Closed orbit distortions before and after correction in both planes and the simulated orbit before correction are shown.

C. Synchrotron Tune and Momentum Compaction Factor

The electron beam signal was picked-up with a stripline electrode and analyzed with a spectrum analyzer. Synchrotron sideband was measured and the momentum compaction factor was extracted. The measured momentum compaction factor was 0.00663 and in good agreement with the design value of 0.00678.

D. Betatron Tune and Betatron Function

The turn-by-turn signal from one BPM electrode was FFT analyzed after electron beam was kicked using one of the kicker magnet with about 1 mrad in the horizontal plane. The betatron sidebands were observed. The measured tunes were ν_x=7.142 with nominal sextupole setting and corrected orbit. The vertical tune ν_y=4.170 was obtained from the orbit changes with vertical corrector setting. We will measure the tunes in both planes using the tracking generator and spectrum analyser system in the near future. Optimum working point will be searched soon. By varying the quadrupole strength and measuring the horizontal tune shift, we obtained the averaged betatron function at each family of quadrupole location. The results were in good agreement with the design value. From the orbit change with vertical corrector, it was found the vertical betatron function was in agreement with the design value[9].

E. Dispersion Function and Chromaticity

The dispersion function was deduced from the orbit difference with different RF frequency setting. In Figure 2 the measured horizontal dispersion functions as well as the design values are shown. The vertical dispersion is very small. The horizontal chromaticity was measured by observing the tune shift with the RF frequency change. It was found that the horizontal chromaticity was corrected to zero with nominal sextupole strengths.

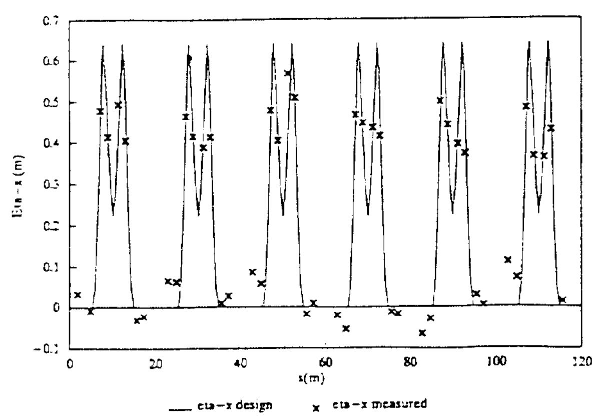

Figure 2. The measured and design dispersion function.

F. Beam Energy and Circumference

The injected beam energy was defined by varying the magnet setting and RF frequency. From the closed orbit distortions, one can obtain the energy deviation from the magnet settings. It was found that the injected beam was 1.3033 GeV. The accuracy is about 0.05 %. The circumference was less than 0.5 mm from the survey and alignment data, which was consistent with the closed orbit data.

G. Bunch Length

The electron beam signal picked-up with stripline electrode was analyzed with a fast digital sampling oscilloscope to obtain bunch length. The measured bunch length σ_ℓ of 42 ps at 300 kV RF peak voltage was in good agreement with the theoretical value of 37 ps.

V. ACKNOWLEDGMENT

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