The Status of SRRC

Y.C. Liu
Synchrotron Radiation Research Center
No 1. R&D Rd VI, Hsinchu Science-Based Industrial Park, Hsinchu, Taiwan, R.O.C.
and
Department of Physics, National Tsing-Hua University, Hsinchu, Taiwan, R.O.C.

Abstract

The commissioning of the SRRC storage ring was rapid and successful. We had far exceeded the design goal of 200 mA stored beam in the multi-bunch mode and 5 mA in the single bunch mode. The beam lifetime was more than 6 hours at 200 mA. The photon beamline commissioning was at the final stage; experiments with synchrotron light have been carried out. The machine parameters are still being optimized in order to provide expected bright light source.

1. INTRODUCTION

The 1.3 GeV synchrotron radiation light source located in Hsinchu, Taiwan, the Republic of China, had completed its commissioning in October 1993 and has been put into routine operation to serve the users starting April 1994.

The project was initiated around 1980 to enhance the local science and technology in Taiwan. Since its establishment in 1983, SRRC went through the R&D phase from 1983 to 1988, the design and construction phase from 1988 to 1992, and the commissioning phase in 1992 and 1993. The facility consists of a 50 MeV electron linac, a 10 Hz, 1.3 GeV synchrotron booster and a 1.3 GeV low emittance storage ring, as shown in Fig. 1.[1]

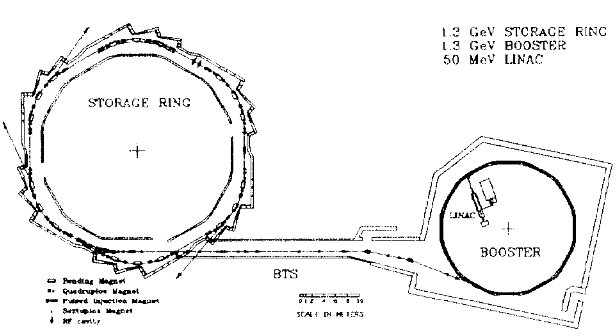

Figure 1. Layout of the SRRC accelerator system: 50 MeV Linac, 1.3 GeV Booster and 1.3 GeV Storage Ring.

A 1.8 Tesla 25-pole wiggler magnet will be installed in the ring by end of 1994 so that higher brightness in the x-ray region can satisfy the need of a large group of x-ray users in Taiwan. At present the storage ring can operate from 1.0 GeV to 1.5 GeV.

The injector reached the specified energy of 1.3 GeV electron beam in April 1992 and was transferred to SRRC by Scanditronix AB, Sweden in July 1992. The storage ring accumulated 1.3 GeV electron beam in April 1993. The beam current exceeded the design goal of 200 mA in August same year. Up to date, the recorded current is about 450 mA.

Three high resolution VUV photon beamlines were successfully commissioned and opened to public users.

2. MAIN PARAMETERS OF THE ACCELERATOR SYSTEM

The major parameters of the injector and storage ring are listed as follows:

A. Injector	
Linac Energy	50 MeV
Repetition rate	10 Hz
Booster electron energy	1.3 GeV
Natural horizontal emittance	1.1 10^{-7} m-rad
Circumference	72 m
RF frequency	499.654 MHz
B. Storage Ring	
Circumference	120 m
Number of super periods	6
Free length for insertions	6 m
RF frequency	499.654 MHz
Natural beam emittance ε_{x0}	1.92 x 10^{-8} m-rad
Natural energy spread	0.066%
Momentum compaction factor	0.00678
Damping time $\tau_x/\tau_z/\tau_s$	10.691/14.397/8.708 ms
Betatron tunes ν_x/ν_z	7.18/4.13
Natural chromaticities ξ_x/ξ_z	-15.292/-7.868
Synchrotron tune (RF@800KV)	1.15*10^{-2}
Bunch length (RF@800KV)	0.74 cm
Radiation loss per turn (dipole only)	72.28 keV
Nominal stored current M.B./S.B.	200 mA/5mA
Critical photon energy from bending	1.39 keV
Beam size (σ_x/σ_y, assuming $\varepsilon_y/\varepsilon_x$=1/100)	
BM1	0.135/0.048 mm
Insertion middle	0.447/0.024 mm

The brilliance of the SRRC storage ring is illustrated in Fig. 2. The proposed undulators U5 and U10 are given too.

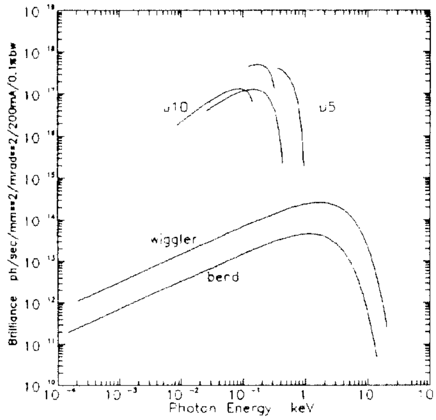

Figure 2. Brilliance of the SRRC storage ring.

3. MACHINE PERFORMANCE

Commissioning of the storage ring started in February 1993 and the first revolution of 1.3 GeV electron beam was immediately achieved on February 26 without using any corrector. Both the alignment and magnet system proved to be in good condition. We had one RF system and four kicker pulsers ready by end of March 1993. Improper function of the kicker system once caused the commissioning in difficult situation. Frequent drift of the pulser timing and amplitude as well as failure of the pulser electronics were the main obstacles. Nevertheless, we had several hundred turns on April 8 with a few horizontal correctors, and beam was stored on April 13 with the RF power.

Once the BPM system became workable, some machine parameters were measured and compared with the theoretical values.[2] While the ion pumps were not all turned on and the vacuum chambers had not been baked yet (not until end of July), the stored beam current could only be kept in a few mA. Higher beam current would cause the RF to trip off due to too high vacuum reading.

In mid-May to end of July 1993, the vacuum chambers were baked and three photon beamlines were installed. After we resumed beam test, the stored beam exceeded 200 mA in two weeks. The synchrotron light cleaning was very effective. The accumulated beam dosage as of June 1994 was 150 A-hr. The average base pressure was about 0.4 nTorr and the dynamic pressure was about 1.2 nTorr with 200 mA stored beam current. The beam lifetime was limited by Touschek scattering. Usually, at 200 mA the lifetime is about 6 hours. The emittance coupling $\varepsilon_y/\varepsilon_x$ was about 5%. The preliminary measured horizontal emittance was twice of the design value. Improvement on the measurement system was needed. The measured stopband width of the coupling resonance was 2.8 10^{-3} and two families of skew quadrupoles used for correction had been tested. It showed that the stopband width could be reduced to less than 4 10^{-4}. Further investigation of the correction will be conducted.

3.1 Operation

Although the machine has been opened to outside users starting April 1994, it is still considered as a test-run period. At present, the machine time is equally shared by users doing experiments and the SRRC technical staff conducting machine studies. Usually, we schedule two shifts (16 hours) per day, 5 days a week. The total machine up-time from October 1993 to June 1994 is 1200 hours. At first, failure of the kicker system resulted in a large amount of down-time. Now the system has been improved. In May 1994, 95% of the machine up-time was recorded.

3.2 Injection

There are two modes of injection, namely, the multi-bunch and single bunch mode. In the multi-bunch mode, a bunch train of about 100 ns with approximate 7.5 10^9 particles per second were extracted from the booster. The injection efficiency was about 35%, therefore it took about 25 second to inject 200 mA into the storage ring. Usually, the injection interval was about 8 hours.

Due to timing jitters of the booster extraction kicker, the extracted bunch train sometimes had bad distribution. The filling gap, which was controlled by an injection filling program, was out of control. Further improvement of the system to get uniform bunch distribution and bunch gap is needed. In the single bunch mode, the best condition was that two bunches of intensity ratio of 1:10 were stored in the ring. No bunch purification system was implemented yet. The injection rate of the single bunch could be up to 0.5 mA/s.

3.3 Machine Parameters

The machine parameters, such as tunes, betatron and dispersion function, chromaticity, bunch length, bunch size, broadband impedance of the ring, etc. were measured or deduced. To increase injection efficiency, the working point was changed to ν_x=7.24, ν_y=4.08. Beam lifetime at this working point was better than the neighbour points. The present lattice has a theoretical natural emittance of 2.02 10^{-8} m-rad.

The measured betatron function, either from the perturbed quadrupole settings (family or individual) or from the closed orbit change, showed that the optics were consistent with the theoretical values and were rather symmetric (no insertion devices were installed yet). The dispersion function was consistent with the theoretical value. The residual vertical dispersion was very small.

The natural chromaticities were close to the theoretical values and could be corrected to desired values. Usually, we set to more than +3 in the horizontal plane and more than +1 in the vertical plane at 200 mA to damp the coherent betatron oscillations. The higher the beam current and the narrower the empty bunch gap were, the higher the chromaticities were required to stabilize the electron beam.

The bunch length was measured from an optical sampling oscilloscope. The bunch lengthening threshold was about 3 mA bunch current. We also measured the tune shifts as a function of bunch current. From the measurements, we obtained an effective broadband impedance of about 2 Ω. One of the major contributions came from the chambers of seven screen monitors. We plan to replace the screen monitor chambers with those of small impedance types in the future.

To monitor the beam shape and the beam position, a beam profile monitor was installed in one of the bending ports. The extracted emittance was about 48 nm-rad and 2.0 nm-rad in the horizontal and vertical plane, respectively.

3.4 Beam Current Limits

The nominal design beam current in the multi-bunch mode was 200 mA, but efforts have been made to increase the beam intensity. Although a maximum beam current of 450 mA had been stored, an abrupt beam loss prohibited further increase. Beam loading and coupled bunch instabilities which prevented maximizing the storage current are under study.

In the single bunch mode, short lifetime limited the stored current to 30 mA.

3.5 Vacuum, Ion effects and Lifetime

The ring vacuum chamber was made of aluminum alloys. The anti-chamber structure with a configuration of concentrated pumping in the photon ports and distributed ion pumps in the bending magnets enabled fast remove of the desorbed gas. As of June 1994, the base pressure was 0.4 nTorr and the dynamic pressure was about 1.2 nTorr at 200 mA storage current. The residual gases were mainly composed of H_2 (90%), CO, CO_2, and CH_4. The oil-free and dust-free processes and the turn-on action of the ion pumps in a good vacuum condition (< 10 nTorr after chamber baking) enabled the system to be a dust free environment. The dust trapping was reduced from 1 event per hour at a beam dosage of ~ 20 A-hr to 1 event per 100 hours at ~ 60 A-hr beam dosage.

The ion trapping phenomena were investigated. It was observed that at a higher beam current, smaller empty gap and higher vacuum condition (by deliberately turning off some pumps), the coherent betatron oscillations were excited, especially in the vertical plane. When the stored beam current increased, the horizontal tune also increased but the vertical tune decreased. An electron beam blow up was observed due to ions. Further study is going on.

Due to good dynamic vacuum, the beam lifetime was dominated by the Touschek scattering. Coulomb scattering was not the major concern. One would like to fill a uniform and long bunch train with small gap so that the bunch current is small and the lifetime is long. However, if the empty gap is too small, we need to increase the sextupole strength to suppress the coherent betatron oscillation, hence the dynamic aperture becomes smaller and lifetime is no longer as high as expected. Usually, we obtained a lifetime of about 6 hours at 200 mA.

3.6 Closed Orbit and Beam Stability

The closed orbit distortions (COD) were measured and corrected down to 0.23 mm rms and 0.13 mm rms in the horizontal and vertical plane, respectively. Further reduction of distortions can be achieved once the BPM system is improved (e.g. the electrode signal noise suppression, the attenuation of the front end signal to avoid the nonlinear response and offset corrections). It was found that the CODs change from time to time, in particular after the strong earthquake, and continuous correction will be a routine procedure.

The size and angle of a third-generation, low emittance synchrotron light source are very small and the beam stability is required to be less than 10% of the beam size, i.e., less than 10 μm. Our users require that the intensity fluctuation in the photon beamline after passing through a 10 μm slit be less than 0.5%. It will be our major task in the coming years.

From the spectrum of the photon beam, we could identify the vibration sources below 200 Hz. The narrow band sources included a 60 Hz and higher harmonics power supply ripple, a 29.5 Hz vacuum pump, and a 25.5 Hz ventilator. The broad band sources raised from a 40 ~ 45 Hz cooling water, a 20 ~ 25 Hz and a 35 ~ 40 Hz girdle vibration. In addition, if the chromaticities were not large enough at high beam current, we could observed the pulse of the synchrotron light in an interval ranging from a few second to ms and the coherent betatron oscillations showed up too. Moreover, we observed the photon intensity fluctuation in the photon beamline with a period of about 1 minute. This frequency was close to the water temperature regulation cycle of the facility. More investigation is going on to find if there is any correlation.

Other than the vibration sources, the longitudinal and transverse coupled bunch instabilities ought to be identified and damped. We found that the threshold of the longitudinal coupled bunch instabilities was as low as a few mA. At present, no any damping system is in use.

In the near future, we will employ all possible means to stabilize the electron beam. For example, the local and global orbit feedback systems, transverse and longitudinal damping systems, etc.

4. ACKNOWLEDGMENT

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5. REFERENCES

[1] "SRRC Design Handbook", SRRC, 1989

[2] Y.C. Liu, J.R. Chen, and C.C. Kuo, "Construction and Commissioning of the SRRC Storage Ring", IEEE PAC93, pp.1635-1638.