5th European Particle Accelerator Conf., Barcelona, Spain, 6/10-14/96.

BNL-63252
CONF-960621--30

Performance of the TLS at SRRC

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Abstract

Three-year operation experiences of the 1.3 GeV synchrotron radiation facility at SRRC are presented. To date, two insertion devices, namely W20 and U10p, are installed in the storage ring and more are currently under construction. The single bunch instabilities were measured and ring impedance was calculated. Both transverse and longitudinal coupled bunch instabilities were observed and the corresponding feedback systems have been constructed. The transverse feedback system is now routinely operated. A fast global orbit feedback system is in the development stage. The lifetime is about 5 hours at 200 mA and plans to increase lifetime are proposed. At present, the machine can be operated at nominal design energy 1.3 GeV with full energy injection and ramped up to 1.5 GeV at 200 mA.

I. INTRODUCTION

The 1.3 GeV synchrotron radiation storage ring, Taiwan Light Source, of the Synchrotron Radiation Research Center has been operated for more than two years since its commissioning in 1993.[1-4] The storage ring is now equipped with two insertion devices: one is wiggler W20 (1.8 Tesla peak field, 20 cm period length, 25 poles) and the other is undulator U10p (1.04 Tesla peak field, 10 cm period length, 37 poles). More insertion devices such as U5 (4m), EPU5.6, U9 (4m), superconducting wavelength shifter, etc., are in either construction or design phase. There are six photon beamlines in use and several beamlines are currently under construction, as listed in Table I.[5] In 1996, the machine usually was scheduled from Monday morning to Saturday noon and two-third of beam time was for users and the other was for machine studies. The machine up-time was around 90% on a monthly basis.

The machine physics issues have been intensively studied and the improvement work for better light quality have been proposed or implemented. In this paper we report the transverse and longitudinal instabilities and cures, the suppression of the orbit vibration sources and a fast global orbit feedback system, the method for increasing beam lifetime and 1.5 GeV operation mode, as well as the beam loss monitors and the effects of the insertion devices.

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Work performed under the auspices of the U.S. DOE.

Table I. Beamlines at SRRC

Name	*Energy(eV)*	*E/ΔE*
In operation:		
Diagnostics		
1-m SNM	4-40	3k-6k
6m-LSGM	15-200	6k-15k
6m-HSGM	0.11k-1.5k	4k-10k
DCM	1k-9k	7k
X-ray(A)	4k-15 k	7k
In Construction:		
Dragon	0.2k-1.2k	5k-10 k
Micromachining	>1k	
Lithography	0.5k-1k	
X-ray(B)	4k-15k	0.3k-1k
X-ray(C)	1k-15k	7k
U5SGM	0.06k-1.5k	6k-15k
In design or planning:		
High flux	4-40	1k-20k
6m-SGM	0.01k-1.5k	6k-15k
U9(A)	4-100	20-40
U9(B)	4-40	>20k
EPU5.6	0.6k-1.5k	>6k
SCW	4k-30k	>5k

II. TRANSVERSE BEAM INSTABILITIES AND CURES

We have observed transverse beam instabilities since the commissioning started. In the multibunch mode operation, we can store beam more than 500 mA. However, we usually store beam current at 200 mA initially in the users shifts. The vertical beam instability threshold usually takes place around 50 mA and as a consequence the vertical beam oscillates and blows up. Before we installed a wideband vertical feedback system, we increased the vertical chromaticity to stabilize the beam.[6]

The wideband transverse feedback system can suppress the beam oscillation in both transverse planes. We have tried to use two beam position monitors as pick-up signals such that the betatron tune variation does not affect the system.

In April this year, we removed the damping antenna of the rf cavities and installed the second tuner in each cavity. We adjusted the second tuner positions to minimize the longitudinal beam instabilities while the transverse feedback system was applied. The longitudinal feedback system was not available yet. We observed that the strength of transverse coupled bunch modes depended on the second tuner position. Thus we believe that one of the main sources of the vertical beam instabilities was the transverse higher-order modes of the cavities.

Once the transverse feedback system was applied, the ring chromaticities could be set at slightly positive values to avoid the head-tail instability. Before the system was in operation, different sextupole strengths (chromaticities) was set to damp the transverse instabilities for different filling pattern and beam current. As a consequence, the closed orbit could be varied around 100 μm. Thus, the synchrotron light users needed to adjust their optical system every injection. With the help of the transverse feedback system this problem was solved.

III. LONGITUDINAL BEAM INSTABILITIES AND CURES

The strongest longitudinal higher-order modes of the cavities is 742 MHz, which cannot be suppressed with the damping antenna. We observed longitudinal coupled bunch instabilities(LCBI) with a current threshold as low as a few mA.[7] This results in an increase of the beam energy spread. The beam size thus becomes larger. The most damaging instability was the low frequency zigzag type synchrotron oscillation at high beam current above 170 mA, in which the sudden strong energy variation of the beam occurred occasionally and we observed the beam break-up on the synchrotron radiation monitor at one bend port. The photon flux through slits thus fluctuated in a large amount. Incidentally, the beam lifetime was reduced when this instability occurred due to smaller energy acceptance. To get rid of this instability, we removed the cavities' damping antenna and adjusted the second tuner positions and cavity temperature. We have succeeded in the remove of this zigzag instability thereafter in this April.

One of the cures for the LCBI is the bunch-by-bunch feedback system, which is currently under construction. We have succeeded in the test with one bunch operation using this device. Full operation is foreseen in one year.

The bunch length measured with a streak camera (Hamamatsu C5680) showed that the bunch was lengthened above the threshold of the microwave instability and was approximately in proportion to $I^{1/3}$, which is depicted in Fig. 1. From this measurement, an effective broadband impedance was estimated to be about 0.5~1.0 Ω.[8]

IV. ORBIT STABILITY

The orbit stability is one of the most crucial issue for the full benefits using such a third generation low emittance machine. Thus it requires not only the suppression of the orbit vibration sources but also the feedback systems.

We have launched a program to survey the vibration sources of the ring components, temperature variation, electric noises and fluctuation, etc. All detrimental sources will be removed if possible. On the other hand, some feedback systems are currently under construction.

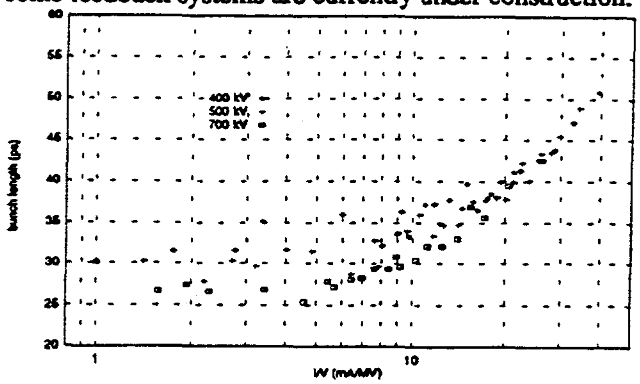

Fig. 1. Bunch length as a function of bunch current divided by RF gap voltage.

For example, a prototype orbit digital global feedback (DGFB) system has been tested and promising results have demonstrated.[9] The system utilized 18 vertical correctors and 26 BPMs (out of 49 BPMs) to form a measured response matrix in the time being. A single value decomposition methods was applied to invert the matrix and the close loop feedback with PID control employed. The orbit acquisition rate can be up to 600 Hz now. The cutoff frequency is about 80 Hz and 20 Hz in the vertical and horizontal plane, respectively, due to vacuum chamber. It demonstrated that the orbit change can be reduced to less than 20 μm during the insertion devices W20 and U10p gap change operation as given in Fig. 2.

We have established a feedforward orbit correction table for each insertion device to compensate for the ID field errors.[10] However, it was not easy to correct down to less than 10 μm for U10p. It became worse if the machine parameters changed. For example, the wiggler gap changing made the orbit drift larger. The DGFB helps to reduce the orbit change when ID gaps are varied.

Further development of the DGFB is planned to increase the throughput by adapting DSP boards and reflective memory, to increase the orbit acquisition rate to 1~2 kHz, to improve the loop performance to reduce the orbit down to a few μm and to include the horizontal plane. The resolution of the BPMs will be improved from 5 μm to 1 μm and the beam-based alignment techniques will be continuously carried out to find all BPM offsets.

Eventual goal is to use all feedback systems to correct the orbit change fast enough so that the users will be able to conduct extremely high resolution spectroscopy experiments.

V. BEAM LOSS MONITOR

Around the ring, we installed 48 sets of beam loss monitors (BLM). This BLM (from Bergoz) consists of

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two PIN-diodes mounted face-to-face to form a coincidence detection which can reject low energy photon and only detect the high energy particles. The depletion area of the installed BLMs in SRRC is about 100 μm and the surface area is about 7.3 mm^2.

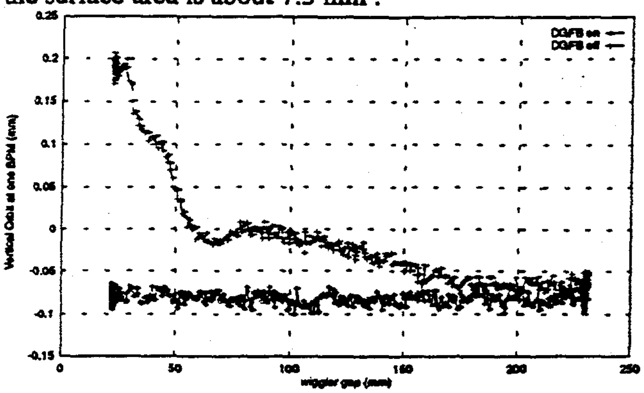

Fig. 2. The orbit change with and without DGFB during wiggler gap change.

The count rate of each BLM is depicted in a GUI panel. It is very helpful for machine operators to identify the hot spots of the real time beam loss. We found after the installation of the U5 chamber, a large amount of the particles were lost in the U5 chamber both during the injection and storage as shown in Fig.3. In the high bunch current operation condition, the beam loss became larger at some locations with rough structure of beam pipes.

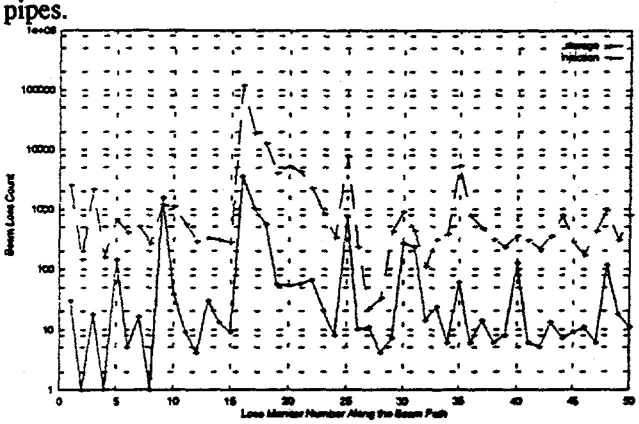

Fig. 3. Beam loss pattern during injection and storage. U5 chamber is located near loss monitor index 15-17.

VI. LIFETIME AND 1.5 GEV UPGRADE

The beam lifetime is an important factor of the successful operation of the storage ring and users require a longer lifetime, e.g., the interval between refills is no less than 5 hours. The study of lifetime showed that this machine is Touschek lifetime limited.[11] However, the smaller pipes for insertion devices of small magnetic pole gaps reduced the gas lifetime significantly. To increase lifetime, skew quadrupoles were excited to blow up the vertical beam size by a factor around 1.5. With skew quadrupoles on, the lifetime is about 5 hours at 200 mA.

Other studies such as adding another rf system or harmonic cavity are going on presently to know whether it is feasible to increase the beam lifetime and stability.

The 1.5 GeV operation is a major upgrade program. At this higher beam energy, we expect an intensity increase of high energy photon and a longer beam lifetime than that at 1.3 GeV.

In the first phase, it is to ramp the beam energy from 1.3 GeV to 1.5 GeV in the storage ring at 200 mA for the routine operation. The slew rate of the magnet excitation has been increased to shorten the time needed for the cycling process of the magnets. Some hardware systems have been strengthened to sustain the heat load and current increase. We have succeeded in ramping the beam energy from 1.3 GeV to 1.5 GeV using asynchronized process in a few minutes. We plan to operate the machine at 1.5 GeV in the users time later half of this year. The beam lifetime increase has observed during 1.5 GeV operation.

V. ACKNOWLEDGMENT

The authors would like to express their thanks for the support from all technical groups

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