MEASUREMENT OF LATTICE PARAMETERS DURING THE ENERGY RAMPING AT STORAGE RING

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Abstract

The spectrum of the 1.3 GeV storage ring at SRRC can provide ultra-violet to soft x-ray radiation source to the potential users. Energy ramping of the storage ring can push the critical photon energy to the edge of hard x-ray. There are several ways to ramp the electron energy, for example, increasing the extraction energy to 1.5 GeV at booster directly, ramping the magnets' power supplies with synchronized function generators, or software ramping of magnets at storage ring, etc. The tune drifting, during the ramping procedure, is expected and should be minimized such that the beam can survive through the ramping process. The betatron frequencies and ramping function of magnets were carefully monitored in order to avoid the betatron tunes cross the resonance line. A successful ramping results and some lattice parameters was measured and discussed in this paper.

1 INTRODUCTION

The storage ring at SRRC is providing an ultra-violet to soft x-ray radiation source to the synchrotron light users. The energy ramping of storage ring will push the critical photon energy to the edge of hard x-ray. A short wavelength will assure the capability in seeing and writing of smaller feature size. The brightness of the radiated photons will also be improved significantly, due to the increased beam energy, at the edge of the x-ray regime. The likely beneficial research areas include the general x-ray users, micromachining, microscopy, lithography and LIGA application, etc. A successful ramping program will also provide a powerful instrument for the machine engineers and physicists to study the machine performance under different electron beam energy.

1.1 Basic Parameters

Some of the major nominal parameters for the storage ring operated at nominal energy were calculated and listed in Table I [1]. The change of these parameters for the 1.5 GeV operating energy was shown in Table II.

Table I. The nominal parameters for the storage ring

Nominal energy	1.3 GeV
Natural beam emittance [2]	1.92 x 10^{-8} rad m
Radiation loss per turn (dipole)	72.28 keV
Critical photon energy	1.39 keV
photon flux (at critical energy)	2.08x10^{12} (photons/s/mrad, 10% BW, mA)
betatron tune	7.18/4.13
bunch length (RF@800KeV)	7.4 mm

Table II. The machine parameters for the 1.5 GeV

Nominal energy	1.5 GeV
Natural beam emittance	2.56 x 10^{-8} rad m
Radiation loss per turn (dipole)	128.1 keV
Critical photon energy	2.14 keV
photon flux (at critical energy)	2.40 x 10^{12} (photons/s/mrad, 10% BW, mA)
betatron tune	7.18/4.13
bunch length (RF@800KeV)	9.2 mm

1.2 Basic Concept

The coordinate system of accelerator was setup as shown in Fig. 1. Considering a single particle case, the description of motion of electron at the storage ring can be written as following [3],

$$\frac{d^2x}{d^2s} + K(s)x = f(s)$$

where *x(s)* is the displacement in horizontal or vertical from the designed orbit. *f(s)* is the high-order perturbation terms. *K(s)* is the strength of quadrupoles and satisfies the periodicity relation

$$K(s+C) = K(s).$$

Here *C* is the circumference of the equilibrium orbit. A similar representation can be found for another transverse direction.

For a fixed position observation of the electron beam movement, the description can be rewritten as

$$x_j = a\sqrt{\beta_0}\cos(2\pi\nu j + \phi_0).$$

The $a\sqrt{\beta_0}$ is a constant and the successive passage number is represented by the index j. The initial phase is defined by ϕ_0 and ν is defined as betatron frequency. Hence the pickup signal by the BPM is a sinusoidal oscillation. The Fast Fourier Transform of the observed signal, betatron oscillation, gave us the information of the characteristic of the beam behavior at the storage ring.

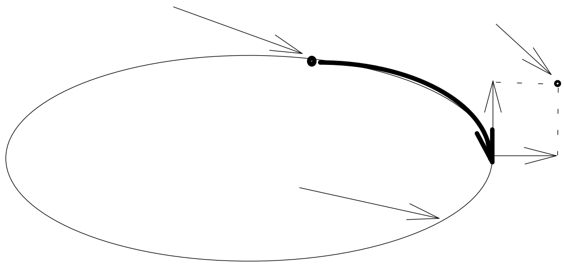

Figure 1. The coordinate system of the storage ring.

The betatron frequencies could indicate the characteristic of the ramping process. The betatron frequency is the major indicator of the following up situation for the quadrupoles and the dipoles.

2 PREPARATION AND SETUP OF EXPERIMENT

The non-linearity of the magnet response forces us to use several linear segments to approach the non-linear curve. The non-linear effects are different in each type of magnet, so that the bending magnets, quadrupole magnets must each follow a different current trajectory to control the accelerator tunes as function of energy. This asynchronized ramping process is a very slow ramping process, which will take 2 ~ 3 minutes to complete the energy ramping.

2.1 The Preparation of Experiment

The preparation works for the ramping experiments include the program coding, power supply stability test at high current, and temperature measurement of dipoles, quadrupoles, and sextupoles. The temperature measurements of dipoles and quadrupole were performed before the experiment of ramping process. The current of dipole and quadrupole magnets were driven to the maximum capacity of the power supplies. From the long term measurement data shows that the hottest point of the magnet will reach the heat balance around 55 °C. If the coils temperature exceed 70 °C, the magnet protection system will trigger the interlock to shut down the power supplies to prevent over heating of magnet coils. The temperature of the vacuum chamber will also protect by the interlock system. Several radiation survey meters also placed around the storage ring to monitor the radiation dosage constantly.

2.2 Setup of Tune Measurement

Two sets of stripline type beam-position-monitor (BPM), which can pickup broad-band signal induced by the electron beam, have been installed at storage ring. The electrons pass through a pair of stripline type BPM will induce a voltage difference, if the beam is off the center of beam position monitor. The successive analysis of beam position at fixed BPM can give the information of fraction of betatron tune and bunch distribution of electron beam.

In order to measure the tune variation during ramping process, the transverse feedback system was turn off and the setting of chromaticity was adjusted to slightly negative such that coherent betatron oscillation can be maintained. The signal from stripline BPM was fed into a Hewlett-Packard 89440A spectrum analyzer. One of measurement results is shown in Fig. 2. The synchrotron side-band, up to quadrupole mode, around the betatron side-band in x-direction is clearly detected during the ramping process. It is an indication of very unstable beam during one of the ramping experiment.

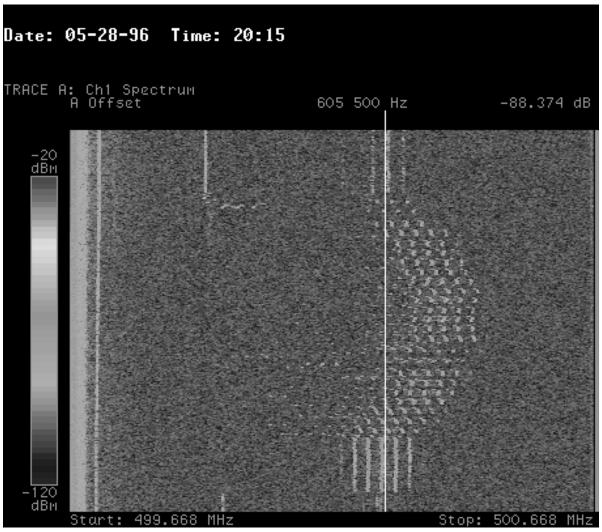

Figure 2. The diagram of betatron tune measurement using HP89440A spectrum analyzer with transverse feedback turned off and slightly negative chromaticity.

3 EXPERIMENT AND RESULTS

The ramping curves of each quadrupole were calculated based on the fitting curve of measured magnet field in order to keep working tune after ramping. The setting of correctors also ramp with beam energy to maintain the beam orbit. The normal operation lattice was used as our starting working point, (7.23, 4.10). The betatron frequencies were analyzed by HP89440A spectrum analyzer. The experiment also carried out with different working tune to test the ramping program.

The ramping function or curve has been checking with different working point with successful results. The tune differences, before and after the energy ramping, can maintain within 20 kHz in both x and y direction. The tune variation during the ramping process was observed around 80 kHz during the ramping process. Part of the reasons of the tune variation was due to the asynchronized ramping process.

A modified control program which will integrate the synchronization feature into the ramping process will cure part of the tune variation problem. The slow ramping is due to the waiting time for the setting process and waiting the power supplies to reach the setting current.

The excitation current of dipoles was shown in Fig. 3, which were taken from archived file. At time marker 1303 minute, the beam energy increased to 1.5 GeV. There is no significant beam lost during the ramping procedure except the beam lost due to the scattering effects.

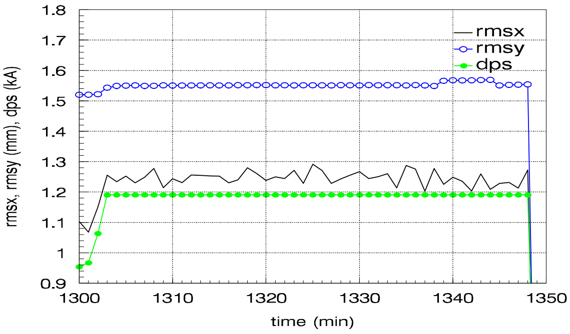

Figure 3. The rms values of the beam orbital in x and y-direction and the setting current of dipole magnets during the ramping procedure

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The change of root-mean-square (rms) value in x and y direction was shown in Fig. 3. The rms readings in vertical and horizontal direction were drifted by 40 µm and 150 µm respectively due to energy increment. At the time mark 1338, the wiggler gap is set to closed gap. The orbit drifted by 30 µm in vertical direction. The beam dynamic application program was applied to correct the closed-orbit to our target operation orbit.

The averaged radiation dosage rate was measured in the experimental hall at 1.5 GeV. Comparing with the case of 1.3 GeV, there is no significant increase of the averaged dosage rate. The wall shielding is safe enough for the 1.5 GeV operation at the beam current 200 mA.

According to simulation results, the chamber temperature will increase less than 5 °C. The average pressure will only increase about 20%. The measured data indicated that the average pressure increased slightly higher than 20%. The reasons of the increasing of the gauge reading were 1) due to the slightly change of closed-orbit and induce higher outgassing and 2) part of contribution coming from the increasing of the beam energy which will increase the photon stimulated desorption.

Photon beam intensity was measured at one of the white light beam line. The stability of the photon beam can sustain within 0.5%. Each of the two RF transmitters could deliver 60 kW power to the cavity. From the power loss estimation, these two transmitters could drive the 1.5 GeV electron beam at beam current as high as 300 mA, if beam instability and beam loading problem is not in our major consideration.

4 CONCLUSION

The energy ramping from 1.3 GeV to 1.5 GeV has been successfully tested. The testing beam current is set at 220 mA. During the ramping process, there is no significant beam lost except the scattering lost. Some of the critical components have been checked and tested. The beam line performance will be tested in the near future to verify the resolution and photon flux changing. The normal operation of storage ring at 1.5 GeV is possible at SRRC.

A further shorten of the ramping time to seconds is a goal for the ramping program. The tool for this goal is to modify the control program of the power supplies and make the synchronized ramping possible.

5 ACKNOWLEDGMENT

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6 REFERENCE

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