BEAM STABILITY AT SRRC STORAGE RING *

W.T. Weng †, H.P. Chang, J.R. Chen, Y. Cheng, K.T. Hsu, C.C. Kuo
J.C. Lee, K.K. Lin, Y.C. Liu, G.H. Luo, K.L. Tsang
Synchrotron Radiation Research Center
Hsinchu, Taiwan, Republic of China S.Y. Fu, I. Hsu, C.S. Hsue, J.S. Leu
National Tsing Hua University
Hsinchu, Taiwan, Republic of China

Abstract

To satisfy the need of users of the synchrotron radiation at SRRC, the photon flux at the end station has to be kept at a constant with minimum fluctuation. The sources of flux variation attributable to the electron beam in the storage ring have been carefully studied and the effects on the flux have been investigated. The sources include floor vibration, power supply ripples, cooling water, ion trapping and transverse instability. The cures attempted or in plan include removal of vibration sources, reduction of ripple, local orbit feedback, ion cleaning and damping. A special diagnostic beamline has been constructed and used solely for accelerator studies and improvements.

I. INTRODUCTION

The electron storage ring at the Synchrotron Radiation Research Center (SRRC) [1] was constructed and successfully commissioned in 1993 [2] and routinely operated for research in 1994 and 1995 [3]. All of the design parameters have been realized in the first two years of operation [4]. For reliable and useful operation for scientific research, most users demand a flux stability $\Delta I/I$ of about 0.5% at the end of the photon beam lines. Such a requirement puts a stringent stability condition on the stored electron beam over the useful lifetime, typically five to six hours for SRRC.

The reduction in photon flux has been calculated for a Gaussian beam with rms beam size $\sigma_y \approx 50$ μm passing through a slit with 50 μm opening. Normalized to the flux of beam without orbit deviation, the reduction in intensity as a function of deviation of the beam controid is shown in Fig. 1. It can be seen that to keep the flux reduction to less than 0.5%, the beam has to be kept at a constant position of about 10 mm in the storage ring. This calculation has also been confirmed by an experiment which records the reduction of photon flux as a function of controlled beam offset introduced by a local orbit bump in the storage ring. The found rate of reduction in the photon flux is about 1% per 10 μm offset [5]. In the absence of any feedback system for the photon beam line, any sources capable of generating more than 10 μm oscillation has to be identified and suppressed. Ideally, the beam oscillation can be damped by synchrotron radiation within one damping time. However, some sources of perturbation of a dynamical nature can create beam oscillation and hence flux reduction in the beam line. In this report, five possible sources of perturbation are identified and their effects on the beam stability have been studied.

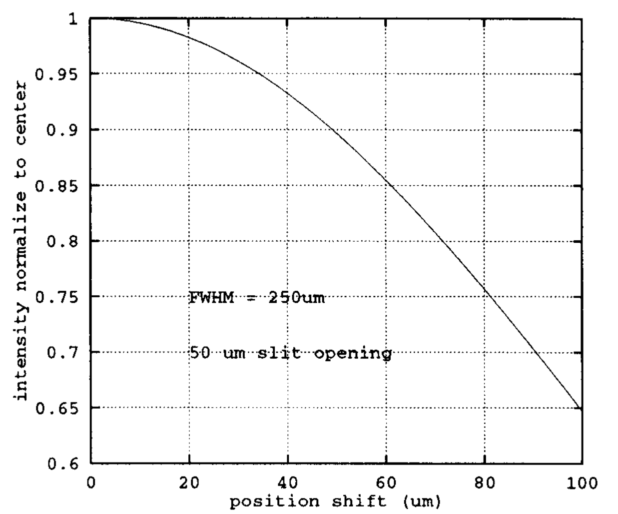


Figure 1. Intensity reduction as a function of beam centroid offset.

II. SOURCES AND CURES OF ORBIT OSCILLATION

A. Power Supply Ripple

The closed orbit correction system in the SRRC consists of 47 beam position monitors (BPM) and 24 horizontal and 30 vertical correction dipoles. The system is capable of correcting the orbit to about 0.15 mm in the vertical plane which is about the resolution of the current BPM system. The power supplies of the correctors have 60 Hz ripple to the order of about 200 PPM which in turn causes photon beam oscillation of about 60 μm. A crash program has been initiated to reduce the 60 Hz ripple to better than 50 PPM which reduced the corresponding photon beam vibration to about 13 μm [6]. In the mean time, the power supplies have also been modified to have bandwidth larger than 300 Hz for the anticipated local feedback application to be discussed later.

B. Vacuum Pump and Water Temperature

A vibration at 29.5 Hz with the amplitude of about 6 μm has been identified and its source traced to be Turbo pumps in the ring. This has been confirmed by turning off the pumps and observing that the spectral peak at 29.5 Hz disappears. Another os-

* Work performed under the auspices of the National Science Council, R.O.C.
† Permanent address: AGS Department, Brookhaven National Laboratory, U.S.A.

cillation at about 0.01 Hz with the amplitude of about 10 μm has been identified as shown in Fig. 2. This oscillation has been attributed to the water temperature variation in the cooling water system of the main magnet supply. Fig. 2 also shows that the ring BPM system is capable of resolution of about 2 μm which is required for future global feedback system.

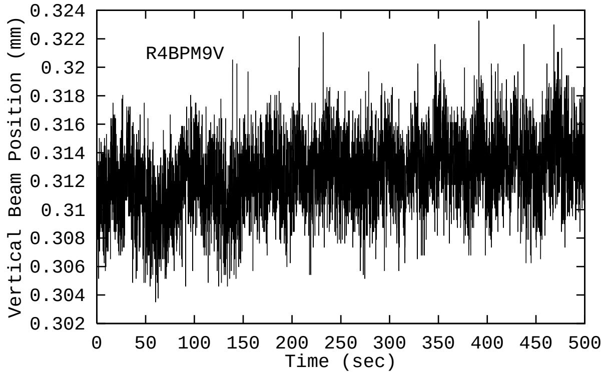


Figure 2. Orbital fluctuation from the beam position monitor system.

C. Local Feedback System

To decouple the photon beam stability from the beam oscillation inside the storage ring, a local feedback system has been constructed. Such a system consists of x-ray Photon Beam Position Monitor (PBPM) with resolution of about 1 μm and Local Bump Control and Optimization System. The vibration of the photon beam can be reduced by steering a local bump of the electron orbit. In case that the local bump is not well matched, residual oscillation in other part of the storage ring, hence other beam lines, can be generated. Such a leakage can cause cross-talking of various local bump controls. To reduce the cross-talking, the correlation will be calculated by a digital signal processing (DSP) technique with a gain- bandwidth of 300 Hz [7].

A test of the effect of the prototype system has been carried out in April 1995. The reduction of photon beam by about factor of three vibration and the spectral peak at 29.5 Hz can be seen in Fig. 3.

A final system will be perfected and installed at every photon beam line which requires better than 1% stability. The resolution of the PBPM system is about 1 μm implying that the ultimate beam stability achievable by the local feedback system is about 0.1%. When the cross-talk among various beam line becomes too large for local feedback system to be effective, a global feedback system will be provided.

D. Transverse Oscillation and Damping System

Vertical coherent oscillation has been observed since the commissioning time in 1993. When the storage ring current is more than 100 mA and the gap of electron is smaller than 100 bunches, the coherent oscillation can be excited [8]. The strength and threshold of this oscillation depends on gap size, vacuum condition and chromaticity of the ring. For stable operation, large positive chromaticity has to be introduced in both vertical and

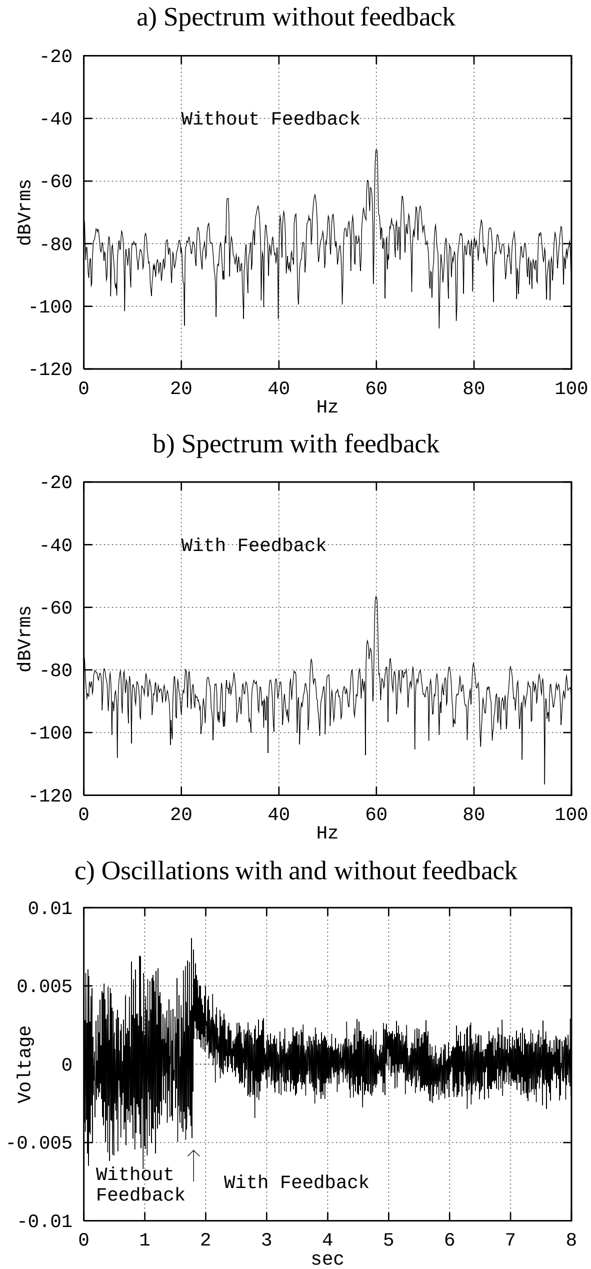
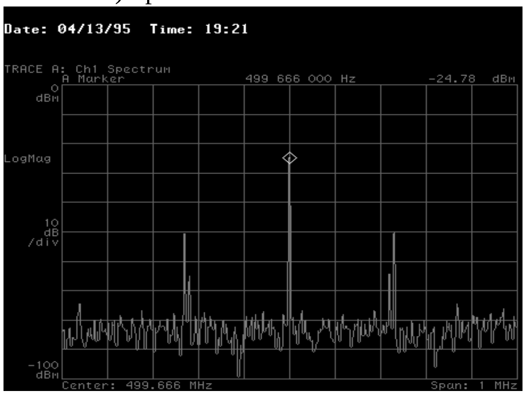


Figure 3. Effects of local feedback system.

horizontal plane. Cleaning electrode and RF-knockout method have been tried to show some effects on the instability.

Although large chromaticity has been shown to be effective in controlling the oscillation, it is not compatible with the injection process. It reduces the dynamical aperture of the stored beam, and finally is not sufficient for higher current of 400 mA anticipated for future operation. Therefore, an active transverse damping system has been introduced to damp the oscillation. Preliminary test of the damping system shows that the beam can be effectively stabilized and also has longer lifetime. In Fig. 4, the sidebands created by transverse oscillation were effectively eliminated with damping system on. In the future operation, the transverse instability will be controlled by the damping system and sextupoles will be used to optimize the lifetime and injection requirement. Gap between the electron train will be reduced to minimum for the reduction of single bunch intensity and the increase of the total current.

a) Spectrum without feedback



b) Spectrum with feedback

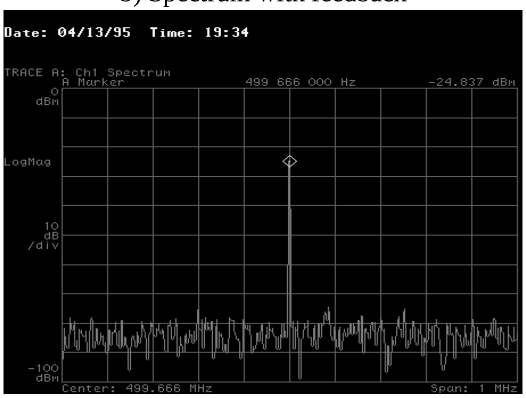


Figure 4. Effect of transverse damping system.

III. OTHER PERTURBATIONS AND FUTURE PLANS

In the longitudinal plane, both the single bunch and couple-bunch instabilities and the beam growth have been observed [9], [10]. Effective method of preventing the single bunch growth is harder to achieve. Fill up the ring with as many bunches of electrons as possible is the operational strategy to stay below the threshold by reducing the single bunch intensity. An active damping system will be constructed to suppress the longitudinal coupled-bunch effect which causes a factor of two growths in momentum spread and hence horizontal emittance and will also spoil the spectral distribution of the future undulator beam line.

At stong users' request, the SRRC intends to raise its operation energy from 1.3 GeV to 1.5 GeV. Besides the hardware and equipment upgrades in order to operate the storage ring at 1.5 GeV reliably, all the beam stabilization methods have also to be able to operate at higher energy.

At present, the SRRC has three bending magnet beamlines. An 1.8 Tesla permanent magnet wiggler was installed and commissioned in March 1995. Three additional x-ray beam lines will be completed in July 1995. Two dedicated beam lines for x-ray lithography and micromachining will also be available in the fall of 1995. The U5 and U10 undulators and their associated beam lines will be completed in two to three years. By that time a self-consistent, user friendly orbit correction, local feedback and global feedback system should be in place to assure beam stability for all users.

IV. ACKNOWLEDGEMENT

The authors would like to thank the assistance given by all staff of the Technical Division of SRRC during the performance of this work.

V. REFERENCES

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

[2] E. Yen, "Present Status of SRRC", 1993 IEEE PAC Conf. Proc., p. 1460.

[3] Y.C. Liu, "The Status of SRRC", 1994 EPAC Conf. Proc., p. 110.

[4] C.C. Kuo, et al., "Performance of the SRRC Storage Ring and Wiggler Commissioning", these proceedings.

[5] Ian Hsu, et al., "The Electron Beam Orbit Sensitivity of the Photon Flux of the Photon Beam Line", these proceedings.

[6] Y. Cheng, private communications, 1995.

[7] Y. Cheng, "High Resolution Photon Beam Position Monitor", 1994 EPAC Conf. Proc., p. 1566.

[8] J.C. Lee, et al., "The Study of the Trapped Ion Effects in the SRRC Storage Ring", 1994 EPAC Conf. Proc., p. 1159.

[9] Ch. Wang, et al., "Bunch Lengthening in SRRC Storage Ring", these proceedings.

[10] W.K. Lau, et al., "Study of Longitudinal Coupled Bunch Instabilities in the SRRC Storage Ring", these proceedings.