BEAM PARAMETERS MEASUREMENT BY A PINHOLE DETECTOR

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Abstract

In order to index the photon stability at Taiwan Light Source (TLS), an Automatic Peak Tracking System (APTS) of photon intensity has been established. The incident photons were focused by a vertical focusing mirror and detected by a photodiode, which is positioned behind a 50 μm pinhole. The position of pinhole detector is driven by an automatic peak-current detecting program with compensation of motor's backlash. The intensity fluctuation, long-term or short-term, is one of the major gauges of the beam stability. Correlation between the parameters of storage ring and measurement results will be presented.

1 INTRODUCTION

The Taiwan Light Source (TLS) provides 200 mA, 1.5 GeV electron beam to generate photon source for academic and industrial research scientists. The storage ring is a six-folds symmetry Triple-Bend-Archomat (TBA) lattice with six straight sections. Four of the straight sections are occupied by conventional normal-conducting insertion- devices, U9, U5, W20 and Elliptical Polarized Undulator EPU5.6. One straight section is used as injection taken by 4 kickers. A 3-poles and 6.5 Tesla superconducting wavelength shifter was installed at downstream of the injection kicker #3 to provide high photon flux in x-ray regime. One RF straight section is for the Doris cavities and diagnostics instrumentation, e.g. current transform and excitation kicker for transverse feedback.

A double-cavities set with damping antenna attached to each Doris cavity's port, which did not provide sufficient damping mechanism for the excited Higher Order Modes (HOM) at storage ring. A plunger-type tuner with precision controlled cavity body temperature has been implemented for each cavity. These efforts with RF voltage modulation keep the stability of photon spectrum within acceptable range for general synchrotron users.

In order to index the short-term photon stability at TLS, an Automatic Peak Tracking System (APTS) of photon profile has been established [1]. To minimize the interference between normal beam line operation and tracking system, a dedicated diagnostic beam line is built next to Low-energy Spherical Grating Mirror beam line, LSGM. The incident photons are focused by a Vertical Focusing Mirror, VFM, and detected by a photodiode positioned behind a 50 μm pinhole. The size of the pinhole is a compromise between sensitivity and localization of detection. If a pinhole is larger than photon projection spot, photo-diode current will not be sensitive to photon flux fluctuation. If pinhole is too small, the stability calculation will be confined to a localized fluctuation or restrict by the light source diffraction limit.

The photo-diode assembly is attached to a stepping motor driven gear and controlled automatically to track to the maximum within preset time interval. Under the assumption of Gaussian distribution of flux intensity, the effective noise on measurement system will be reduced when the position of photo-diode centred to the peak of the Gaussian profile.

Through Ethernet connection, the device can be remotely controlled. An index of stability, ΔI/I, is defined and some experiments are taken to test its validation. All parameters, which is related operation status, can be accessed simultaneously by the control program. The measured photo-current, pinhole position and calculated data are also sent to the database for further analysis.

2 DEFINITION AND SETUP

We will simulate and make some assumptions to find out the relation between the photon fluctuation and pin hole misalignment. This will help us find out the accuracy of the system can reach.

2.1 Definition of ΔI/I

Assume I_0 is the photo-current detected by the photo-diode and ΔI is the current deviation due to the instability from electron beam, e.g. beam drift due to thermal effect [2], high-order-mode excitation [3], or ion effects [4], etc. Hence, I is function of time and is updated every half-second in our set up.

The tracking interval is about every 300 seconds, if include the motors moving dead time. It will take 256 seconds to take the I_0 data in 2 Hz sampling rate to have a good Fourier Transformation information. The definition of de-trended information is to eliminate the DC slope, which accounts for the Touschek effect decay of the beam current, of the I_0. The value of $\Delta I / I_0$ is calculated by a de-trended information with full width root mean square (FWRMS) divided by the average value, which can be represented as:

$$\Delta I / I_0 = 2 * \frac{\sqrt{\sum_{I=1}^{N} (x_i - \bar{x}) / N}}{(\sum_{i=1}^{N} x_i) / N}$$

where N is the number of data points, x_i is the de-trended data sampled at 2 Hz.

2.2 Hardware Architecture

The radiated photon flux from a bending magnet is wide spread in x-axis, the horizontal direction, from a beam port. The major concern of the beam intensity fluctuation is in the y-axis, the vertical direction.

The hardware set up of APTS, which is shown in Fig. 1, includes motor driver, pinhole, photo-diode and PC controller. The stepping motor is controlled by a PC through multi I/O interface cards.

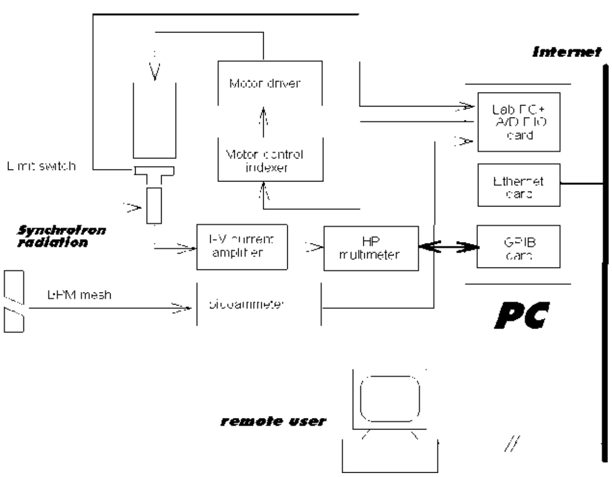

Figure 1. Hardware architecture for the automatic peak tracking system with capability of broadcasting to the network.

In order to improve the accuracy of readout from photodiode and A/D conversion, the photocurrent is amplified and connected to a HP multi-meter. The transformed digital output is read into PC through GPIB interface.

All programs are developed by Visual C++ under Microsoft Windows operating system. The measured photocurrent, pinhole position and calculated current deviation ratio were broadcasting to network for remote access and data archiving.

3 MEASUREMENT RESULTS

Simulation of beam fluctuation indicates that the calculated beam instability is proportion to deviation between pinhole center and the peak-flux position, if a pinhole tracking error occurred. At the same time, measured photon intensity variation is proportion to either fast or slow fluctuation of beam-profile centre, which is due to beam charge centre drift relative to the pinhole position or excitation by the coupled-bunch-instability.

3.1Beam Profile Measurement

The relationship between photon flux intensity and position of stepping motor is not reproducible due to mechanical backlash, as shown in Fig. 2. Retracing with cycling process is used to compensate the backlash offset and locate the peak position of beam profile. The backlash correction scheme with fast scanning mechanism makes the pinhole reading correlate to the beam movement in the storage ring possible.

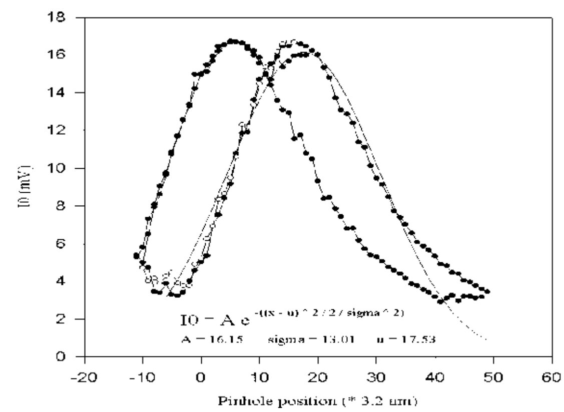

Figure 2. Backlash phenomena of motor movement and the correction scheme for the auto-peak-tracking system. The smooth line indicates the Gaussian-fit beam profile in y-direction.

Figure 2 also can be used as the beam profile measurement instrument. The intensity measurement vs. the pinhole position can be fitted by a Gaussian curve. The fitting parameters for the experiment were listed in Fig.2. The calculated beam size from the curve, with the correction factor of vertical focusing mirror, is 125 μm. A synchrotron light monitor, using a CCD camera to take the image of synchrotron light with image process, has been set up at TLS[5]. The measurement results, by the CCD camera, of the beam profile is estimated to be 115 ± 5 μm which is comparable to the results in this experiment.

3.2 Thermal Effect of Focusing Mirror

Figure 3 shows the mirror's temperature and corresponding pitch angles change in user's shift for the VFM. The induced surface deformation of the VFM at high beam current makes the reflection angle of the incident light drifting, the detected photo-current decaying, faster than expected, and calculated stability worsen accordingly. However, the APTS can trace and lock the peak of beam profile every five minutes as the system design. Figure 4 shows the variation of the VFM's pitch, roll and pinhole position during user's shift.

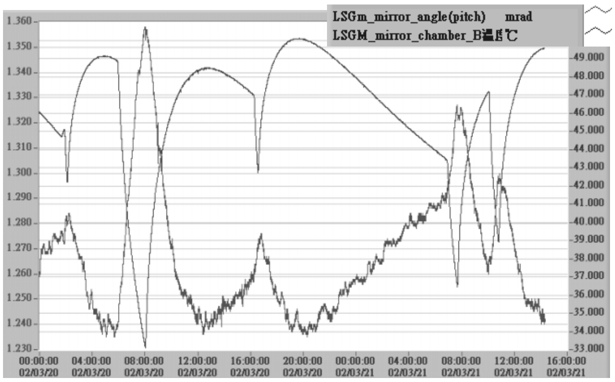

Figure 3. Mirror's temperature verse mirror's pitch angle.

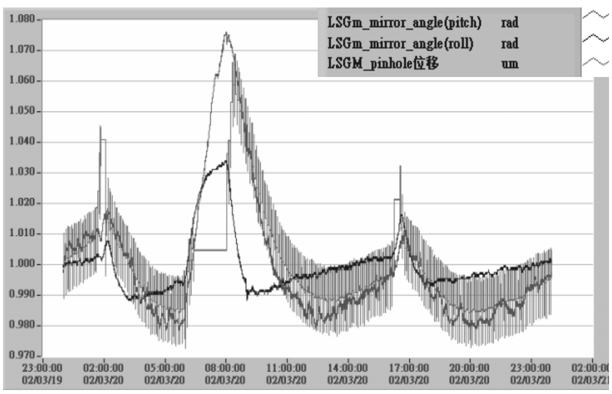

Figure 4. The pinhole position is tracked by APTS during the user's shift. Variation of VFM's pitch and roll is due to the deformation of VFM at different beam current or heat loading.

One of typical archived parameters, by ATPS, shows in Figure 5. The thermal balance of the VFM is reached at low current, around 150 mA. Once the optical component, VFM, reached thermal balance, measured photo-current is function of stored beam current only. The motor position remains unchanging after retracing. The calculated beam stability, 0.1%~0.15%, reflects the very stable synchrotron radiation at TLS.

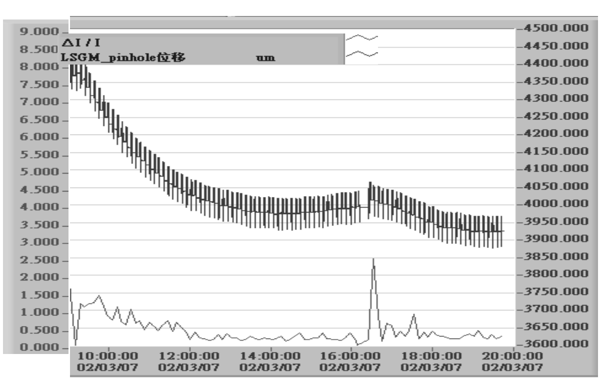

Figure 5. Archived I_0, pinhole position and the calculated ΔI/I for normal user's shifts.

4 DISCUSSIONS

The backlash of pinhole position and optic-axis drifting problems are compensated by the peak-tracing algorithm. The intensity distribution of beam profile can be determined by a Gaussian fitting program using the APTS. From beam bump creating experiments, we found the photo-current is much sensitive to the angular change of optic axis, which mainly caused by the thermal effect of the VFM, than beam position offset.

The APTS is the one of the major indicator for the figure of merit of the beam quality during the users' shift. It also provides a convenient tool for machine study and the diagnostic instrument for the beam line. For example, a low frequency spectrum of photon intensity is taken to identify the mechanical oscillation of ventilation system as shown in Fig. 6. A precision driving mechanism of the pinhole position and water-cooled VFM is planned to enhance the measurement reliability and accuracy of the APTS.

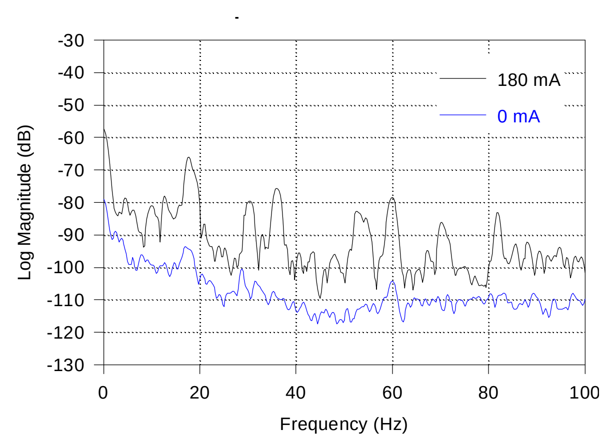

Figure 6. A photon-spectrum is taken from the pinhole detector. The first peak and its harmonic is correlated to mechanical vibration from ventilation system.

5 ACKNOWLEDGMENT

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