IMPROVED STABILITY OF THE RADIATION INTENSITY AT THE NewSUBARU SYNCHROTRON RADIATION FACILITY

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Abstract

The periodic fluctuations and drifts in the radiation intensity have been observed at the NewSUBARU synchrotron radiation facility. To clarify the cause of this problem we have measured temperatures of air, cooling water, equipments and building with a network-distributed data logger. And we found that temperature fluctuations in both air in the shielded tunnel and cooling water mainly affect the stabilities of electron beam orbit and optical axis.

To reduce temperature fluctuations, the experimental hall was partially thermal-insulated, and PID parameters of temperature controllers were optimized. As results, the periodic fluctuations almost disappeared, but some drifts were still remained, which are due to slow variations of equipment temperatures. By realizing the automatic COD correction, the drift in electron beam position could be suppressed and the fluctuations of radiation intensity observed at beam-lines became smaller than they used to be. For further stabilization, we recently introduced a XBPM in a beam-line to measure the vertical position of the radiation axis more precisely.

INTRODUCTION

The NewSUBARU synchrotron radiation facility [1] was constructed in the SPring-8 site by Japanese local government, Hyogo prefecture. The main aim of the facility is industrial applications of synchrotron radiation, such as EUV lithography, LIGA, nanotechnology, creation and analysis of new materials, and gamma-ray production by Compton scattering. The main parameters of a storage ring are shown in Table 1.

Table 1: Main Parameters of NewSUBARU Storage Ring

Ring Circumference	118.7m
Injection Beam Energy	1.0 GeV
Stored Beam Energy	1.0-1.5 GeV
Max. Stored Current	500 mA
Tunes (H/V)	6.30 / 2.23
RF Frequency	499.955 MHz
Harmonic Number	198
Natural Emittance	37 nm @1.0GeV
Beam Lifetime	12 hrs @1.0GeV, 100mA
Number of Beamlines	8

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In the NewSUBARU facility, both a periodic fluctuation and a drift in the electron beam position have been observed as shown in Fig.1. The measured intensity of synchrotron radiation was in synchronism with this variation. Its main cause was fluctuations in temperature.

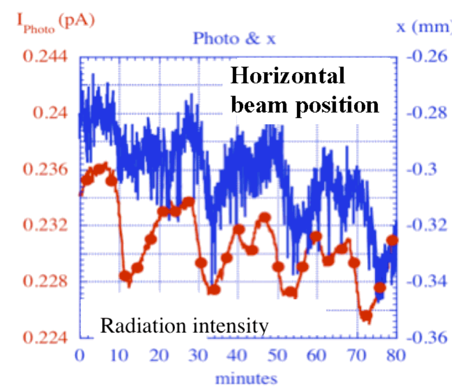

Figure 1: Horizontal position of stored electron beams measured by a BPM (beam position monitor) and the radiation intensity measured at a beam-line. A slow drift and periodic fluctuations can be observed.

Recently the stability of the radiation intensity was greatly improved, because of several kinds of grappling with this problem. In this paper we report the reduction of temperature fluctuations, the optimization of PID parameters of temperature controllers and realizing the automatic COD (closed orbit distortion) correction.

And also a XBPM system is recently introduced in a beam-line for a continuous measurement of the position of the radiation axis.

GRAPPLING WITH THE RADIATION STABILITY PROBLEM

To reduce fluctuations of the radiation intensity due to temperature variations, we have carried out:

- Enhancement of a data logging system.
- Stabilization of temperatures of air and cooling water.
- Introduction of an automatic COD correction system.

Enhancement of Data Logging System

We have reinforced the network-distributed data logging system based on National Instruments FieldPoint. Over 60 points of measurement data, including temperatures of air, cooling water, floor, and several kinds of equipments, are acquired by LabVIEW software and saved to the SPring-8 database system. We can know various temperature data at arbitrary date and time by accessing to the database.

Stabilization of Air Temperature in Tunnel

From the analysis of measured temperatures, it was found that the main cause of variations of the electron orbit and the optical axis of the synchrotron radiation is the change of air temperature in a shielded tunnel for the storage ring. The range of fluctuation was about one degree.

The air temperature in the tunnel is controlled using fan coil units with two cascade-connected controllers (Yamatake SD35). We connected a PC to these controllers via USB. The PC can be controlled from a remote PC through a network. Thus we can easily optimize PID parameters of the temperature controllers from our own room.

By the optimization of PID parameters, the periodic fluctuations disappeared and we could successfully maintain a constant temperature within 0.1 degree. PID parameters should be frequently optimized in accordance with the season, because of a change in circumference temperature.

Stabilization of Temperature of Cooling Water

After the optimization of air temperature, the next major issue was fluctuations in temperature of cooling water. Using the similar way to air, PID parameters for cooling water were optimized and the range of temperature fluctuation is less than 0.2 degree. The more precise control of water temperature may be required for further stabilization of the optical axis.

Stabilization of Air Temperature in the Experimental Hall

The change in temperature at the experimental hall is larger than that in the tunnel. Especially in winter there was about a four-degree difference in temperature between daytime and nighttime. Such a large change may have a great influence on the beam-line equipments in the experimental hall and the optical axis of synchrotron radiation.

To reduce the difference in temperature, we set up the thermal insulated curtain near a carrying door with a slight opening around it. Looking with a thermal view camera, the curtain was obviously effective for thermal insulation.

Figure 2: A thermal insulated curtain at a carrying door in the experimental hall.

Realizing of Automatic COD Correction

Although periodic variations of electron beam positions and an optical axis almost disappeared by optimizing PID parameters of temperature controllers, slow drifts were still observed. The cause of the drifts is slow changes of temperatures of vacuum chambers, magnet yokes, beam-line equipments, floor, building and so on.

The operation of the ring usually starts at 9 AM and stops at 9 PM. During night power supplies for magnets and a RF klystron are stopped. It needs over ten hours for temperature of a bending magnet yoke to reach a constant value. Thus the slow drifts due to temperature variations of equipments in a day cannot be avoided in our facility.

To suppress these drifts, the automatic COD correction system has been developed, where COD is measured every one minutes and is corrected if a RMS value of 18 BPMs is larger than a threshold. By the automatic COD correction, electron beam positions measured by BPMs are kept within 20 microns as shown in Fig. 3.

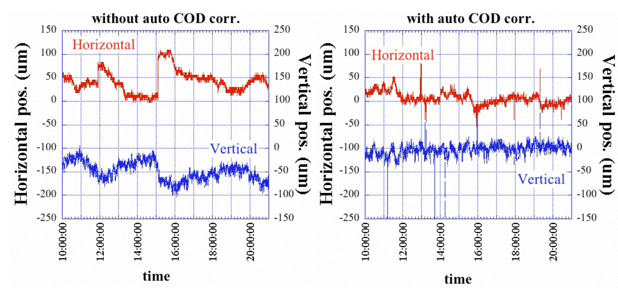

Figure 3: Horizontal and vertical positions of electron beams without (left) and with (right) the automatic COD correction.

STABILITY OF RADIATION INTENSITY MEASURED AT BEAMLINE

We measured the intensity of synchrotron radiation at the beam-line BL10, where users require a high stability on the radiation intensity. The radiation intensity normalized by a stored beam current without the COD correction is shown in Fig. 4.

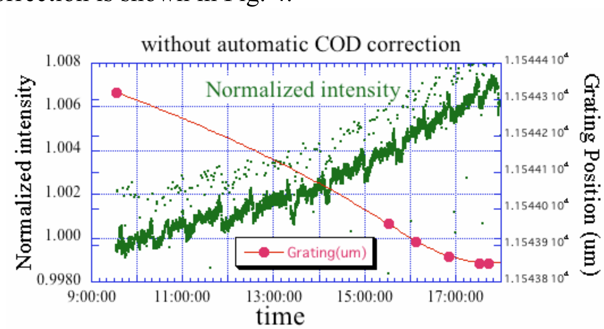

Figure 4: Normalized radiation intensity observed at the upper of BL10 without the automatic COD correction. The position of the grating mirror in the beam-line is also shown.

The normalized intensity should be constant, but it had periodic fluctuations and increased with the passage of time. The periodic fluctuation with small amplitude is due to fluctuations in the cooling water temperature. The slow drift comes from both the drift of electron beam positions and the fluctuation in temperatures of equipments for beam-lines such as a grating mirror. In Fig. 4 the position of a grating mirror is also shown. Fig. 5 shows the horizontal electron beam position measured by a BPM. The horizontal beam position shifts about 130 microns after 8 hours without the automatic COD correction.

The normalized radiation intensity with the automatic COD correction is shown in Fig. 6, where no drifts were observed in both the radiation intensity and the horizontal beam position. The normalized intensity measured at the upper of the beam-line is kept within 0.2%, but the intensity at the lower has a fluctuation of 3%, which comes from the temperature variations of beam-line equipments as a grating mirror.

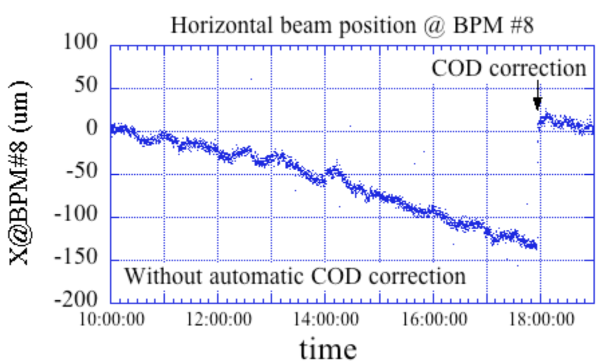

Figure 5: Horizontal position of electron beams measured by a BPM without the automatic COD correction. At 18 o'clock COD was corrected manually.

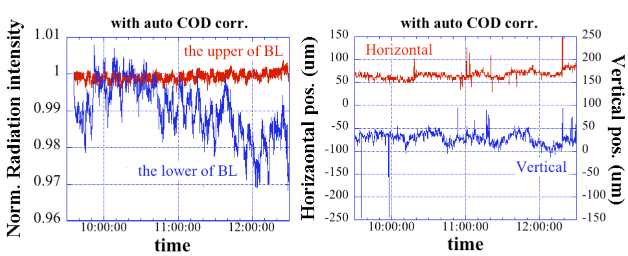

Figure 6: Radiation intensities observed at BL10 (left) and electron beam positions (right) with the automatic COD correction. The intensity measured at the lower of the beam-line has larger fluctuations than that at the upper.

INTRODUCTION OF XBPM SYSTEM

For the continuous measurement of the vertical position of the radiation axis at the upper of BL10, we designed a XBPM that can directly measure the radiation axis form a bending magnet without the effect of beam-line equipments. The XBPM shown in Fig. 7 was installed in this spring and is now under commissioning.

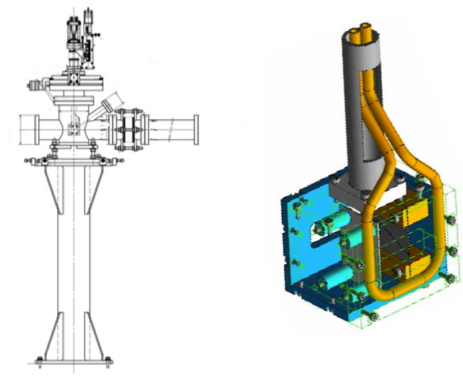

Figure 7: XBPM system installed at the upper of BL10: a chamber side-view (left) and an aperture (right) in which vertical electrodes are included.

SUMMARY

We have measured various temperatures in the NewSUBARU facility using a network distributed data logger and found that fluctuations of the radiation intensity were mainly caused by the fluctuations in temperatures of air and cooling water.

By optimizing PID parameters of temperature controllers, the range of temperature fluctuations became very small and the periodic variations of the radiation intensity have almost disappeared.

Slow drifts of electron beams and radiation intensity, which were caused by slow changes in temperatures of equipments, could be suppressed by the automatic COD correction. The fluctuation of radiation intensity observed at beam-lines became smaller than they used to be. For further stabilization of the radiation axis, a XBPM was installed at BL10 and is under commissioning.

The improved radiation intensity is necessary for industrial applications of synchrotron radiation in our facility such as a high precision reflectivity measurement in EUV lithography, making a standard database of various kinds of DLC (diamond-like-carbon) and so on.

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