COUPLING DIAGNOSTICS AND CONTROL AT PLS STORAGE RING

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Abstract

The measurement and the control of the coupling are essential to maximize the synchrotron performance. Small coupling is required for small vertical size and high brightness. The Pohang Light Source has a 2.5 GeV storage ring and its coupling constants under various condition were measured. In addition to errors at quadrupole or sextupole, the condition varying of the insertion device affects the coupling. The coupling constants were measured by the resonance and controlled by a feedforward setting of a skew quadrupole in order to minimize the variation of the beam size.

INTRODUCTION

The equations of the motion of the electron beam in the storage ring are basically de-coupled between the vertical and the horizontal planes. Both equations can be coupled by mis-alignment or nonlinear higher order field. The coupling increases the vertical size of the beam while small size or emittance is desirable to produce high brightness radiation.

The coupling constant can be defined as the ratio of the transverse emittances. At third generation synchrotron, the ratio is about 1% and can be reduced below 0.1% by using codes like LOCO which measure the skew error distribution from the analysis of the orbit response matrices[1].

In the Pohang Light Source (PLS), the linear coupling constant was designed below 10% and measured as 0.8% without correction in 1996[2]. The coupling has been increased by the distortion of the storage ring and the Insertion Devices (ID). Especially, the Elliptically Polarized Undulator (EPU6) varies the coupling. When the gap of the EPU6 is changed, the vertical beam size varies a lot.

In this paper, coupling constants under various conditions and feedforward test of a skew quardrupole are presented.

MEASUREMENT

Under the influence of linear coupling, the coupling constant K can be defined as the ratio of the beam emittances in transverse planes:

$$K = \frac{\epsilon_y}{\epsilon_x} = \frac{|\kappa|^2}{|\kappa|^2 + \Delta^2/2}, \qquad (1)$$

where κ is the coupling coefficient and Δ is the distance from the resonance[3, 4]. The coupling increases with the strength of the coupling coefficient and complete exchange of the emittances appears at the difference coupling resonance while the sum of the emittances is conserved. The betatron frequencies in both planes are approaching to each other by adjusting quadrupoles, and the frequencies are exchanged at the coupling resonance. The minimum separation is the same as the coupling coefficient κ.

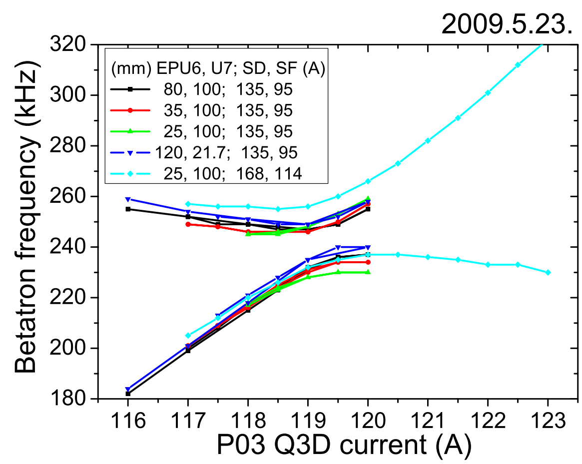

Figure 1: Measurements of betatron frequencies as a function of detuning for linear coupling. The effects of ID gaps and sextupole strength were tested.

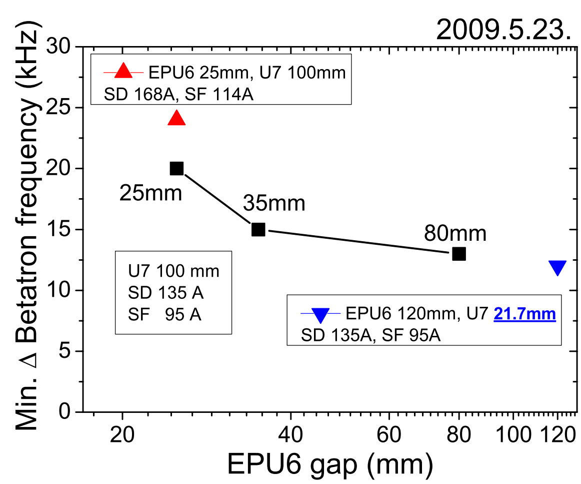

Figure 2: Distances from resonance as a function of EPU6 gap.

A quadrupole P03 Q3D was adjusted to make the coupling resonance as shown in Figure 1. The current of the quadrupole was increased to 123 A from 116 A and the resonances occur near 119.5 A. The various conditions are combined. The gaps of IDs, EPU6 and U7 undulator, are varied and the strengths of the sextupoles are changed. Figure 2 shows the summary of the measurement at 2009 spring. The frequency separations are 12∼24 kHz which correspond to the coupling constant 2∼7%. When the strengths of the sextupoles are reduced, the coupling decreased. It may be caused by mis-alignment at the sextupoles. The change of the EPU6 gap is the most dominant source, while the U7 gap shows little effect.

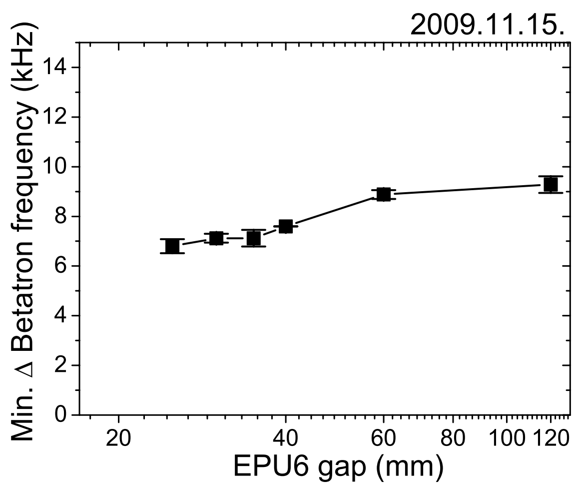

Figure 3: EPU6 dependency of coupling after 2009 summer re-alignment and new reference orbit.

After 2009 summer shutdown for some machine maintenence, the coupling is reduced as shown in Figure 3. The major enhancement during summer is re-alignment, especially at the injection section. There was 2 mm vertical drift that was large source for vertical dispersion. At 28 mm EPU6 gap, the tune separation is 0.0056 which corresponds to 0.5% coupling constant, and the tune separation 0.0112 (coupling constant 2%) at 48 mm gap.

Control by feedforward

During gap change of EPU6, the coupling constant varies from 2% to 7% before 2009 summer, 0.5∼2% after 2009 summer. The variation of the coupling leads to the change of the vertical size which can affect the brightness of the radiation. Only four skew quadrupoles for coupling correction are available at present in PLS. The resources are limited because the upgrade project PLS-II is on progress. With the limited condition, the coupling correction based on the orbit response and the dispersion was not enough to maintain the vertical beam size.

The feedforward control of a skew quadrupole is designed to keep the same vertical size. Figure 4 is the current setting of the skew quadrupole placed at Cell #2. It is similar to the coupling which has a minimum value at 28 mm gap. The skew quadrupole increases the coupling to the maximum during change of the EPU6 gap.

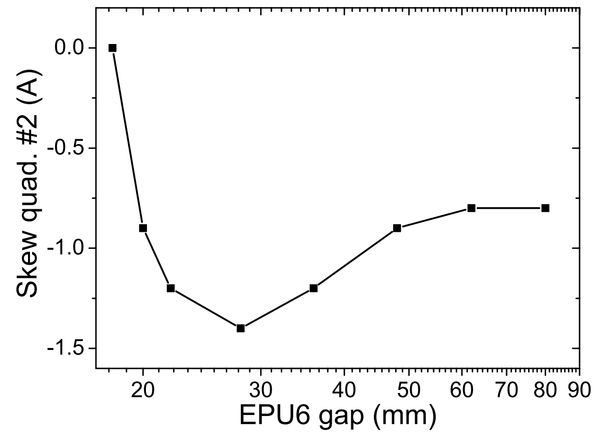

Figure 4: Current setting of a skew quadrupole for feedforward control.

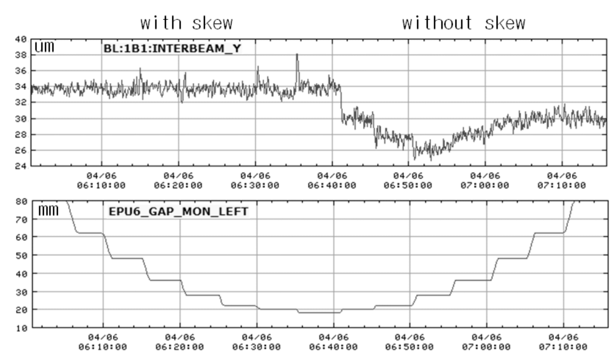

Figure 5: Effect of feedforward correction on vertical beam size when EPU6 gap moves.

The vertical beam size is measured at diagnostics bending beamline by an interferometer[5]. That interferometer system is still improving, and the exact value is expected larger at present. But it is enough to show the tendency. It varies from 26 μm to 34 μm when the EPU6 gap moves from 80 mm to 18 mm. The feedforward control of the skew quadrupole suppresses the varying of the size. It will be helpful to stabilize the beam before PLS-II upgrade. After upgrade, 24 skew quadrupoles will be installed to compensate the variation of the coupling and each ID will have the correction component.

CONCLUSION

The coupling constant of the PLS was measured under various situation. It was 2∼7% at 2009 spring and 0.5∼2% at 2009 autumn. U7 undulator has small effect and the gap of the EPU6 undulator is the dominant source. To minimize variation of the vertical beam size when EPU6 gap moves, a feedforward control of a skew quadrupole was designed and successfully tested in point of the vertical beam size at the diagnostics beamline.

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