PRELIMINARY TUNE FEEDBACK STUDY IN THE TAIWAN LIGHT SOURCE

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Abstract

Tune is in important parameters play crucial roles to performance of a synchrotron light source. Tune change might caused by beam current dependent and operation of insertion devices in user operation. Top-up injection is a standard operation mode of many synchrotron facilities to keep constant heat load of vacuum chamber and beamline optics which is essential to achieve high beam stability. Keep working points are also important to achieve high beam stability. User controllable insertion devices will disturbed the optics of storage ring mainly on orbit and tune. The traditional feed-forward control is to correct orbit change and tune shift that isn't enough when difference type insertion devices are operated with various conditions [1]. The global orbit feedback solve global orbit problem. The tune feedback feed-forward is most common to compensate the tune change during insertion devices operation. However, it still hard to keep tune unchanged. Tune feedback was proposed and tested to prevent tune change during insertion devices operation. The tune measurement parasitic to the operation of the transverse bunch-by-bunch feedback system and preliminary tune feedback loop test are summarized in this report.

INTRODUCTION

A modern accelerator generally are designed to tolerance the fluctuations in tune, coupling and chromaticity and many factor. However, for a modern low emittance synchrotron light source, due to strong focus design, its optics are sensitivity to various factors. The main requirements are coming from the user side, where a tight control over coupling and beam tilt is important, especially in the view of the tendency towards small gap insertion devices. Perturbation sources are user configurable insertion devices and other beam lines, which create fluctuations in the beam optics, which need to be corrected locally. The document describes a measurement strategy and discusses new challenges requiring dynamic stabilization systems [2, 3].

The big impact is coming from high field, small gap insertion devices as wiggler, superconducting undulators and in-vacuum devices, where as the perturbation described above are relatively minor for the operation. These are typically adjustable by the user, so that a static correction of the nonlinear optics introduced by these devices is difficulty [4]. These user adjustments are performed in standard operation, so these action need to be transparent for the global ring optics as well as for other insertion devices and users.

To keep the tune constant for a synchrotron light source is an important issue.

TUNE MEASUREMENT

There are several approaches to measure the working points for a synchrotron light source during user service. Tune might change due to insertion devices operation, beam injection and beam current change.

Spectrum analyzer is the most traditional methods. But it might be unreliable if beam is stable enough. It is hard to delivery stable tune reading. Another method is to shake the beam by white (or pink) noise, the excitation level should allow the betatron peaks above noise floor 10 or more dB and measure the betatron sideband by the spectrum analyzer. Real-time spectrum analyzer can have fast update but it cannot be quickly readout.

Adopt turn-by-turn beam position acquired by the BPM electronics and perform the Fourier analysis or sophisticated extraction algorithm (extrapolate FFT or NAFF) is another methods. Beam excitation might still need. Tune measurement is by the residual kick of the injection pulse magnets in top-up operation. However, it happens in the time scale of several ten seconds and not always available.

Parasitic tune measurement accompany with the bunch-by-bunch feedback is also promising. User transparency is the most advantage of this approach. There are two possibilities to measure tune supported by the feedback system. The first method is use the notches happened in the turn-by-turn averaged bunch spectrum as shown in Fig. 1, these notched are derivate from the noise suppression natural of the negative feedback loop.

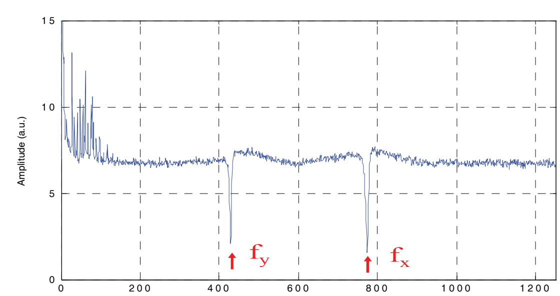

Figure 1: Tune measurement by the notches occurred in the bunch averaged spectrum due to negative feedback natural of the transverse feedback loop in the iGp of Dimtel.

Another method is performed peak identification of the Fourier analysis of the bunch data of a single excited bunch without disturbing the positional stability of the beam. Figure 2 shows the rms value of bunch without and with excitation in the bunch ID 20. It is easy to identify the tune from the Fourier analysis of the turn-by-turn data in the bunch ID 20 excitation which is shown a clean betatron oscillation peak. Excellent signal to noise ratio can achieve by using this method. Sine only a single bunch is excited, beam blow up is negligible, it is also a user transparency.

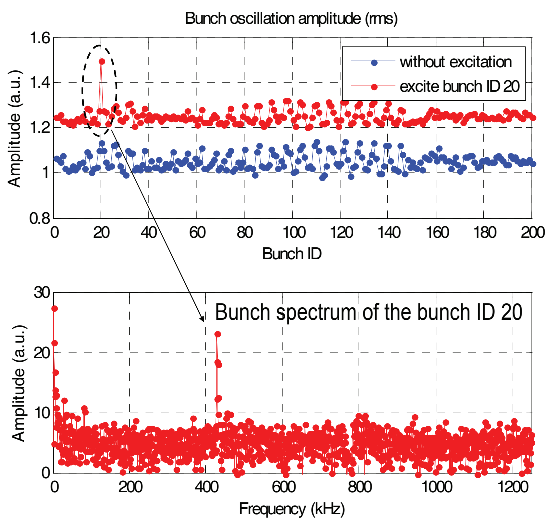

Figure 2: Tune measurement by single bunch excitation and Fourier analysis of its small bunch oscillation.

PRELININARY TUNE FEEDBACK TEST

The functionality of the tune feedback experiment is shown in Fig. 3. Tune feedback experiments have been done. The tune value comes from the transverse feedback system directly with 2.5 x 10^{-4} resolution with 1 Hz update rate. The measured tune value (ν_x, ν_y) is subtracted form desired tune value (ν_{xREF}, ν_{yREF}) obtain tune error (ν_x, ν_y). PI control rule is applied to multiply the tune error and the inverse of the tune transfer matrix to get the correction current setting value. The result will state to the quadrupole trim coils.

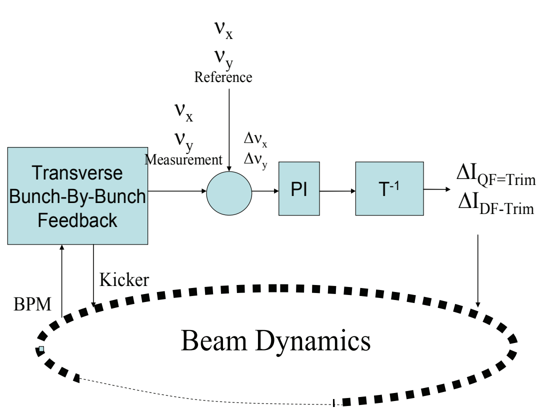

Figure 3: Functional block diagram of the tune feedback experiment.

Quadrupole trims are adopted for the test without disturbed the routine operation, which the global tune feed-forward setting was applied. Transfer matrix is between current change of quadrupole trim coils and tune which are performed by measurement as following relationship:

$$\begin{pmatrix} \Delta\nu_x \\ \Delta\nu_y \end{pmatrix} = (T) \begin{pmatrix} \Delta I_{QF-Trim} \\ \Delta I_{DF-Trim} \end{pmatrix} = \begin{pmatrix} t_{11} & t_{12} \\ t_{21} & t_{22} \end{pmatrix} \begin{pmatrix} \Delta I_{QF-Trim} \\ \Delta I_{DF-Trim} \end{pmatrix}$$

Control rules are applied to the different tune to achieve a smoothly control of the power supplies.

Figure 4 is the vertical tune vale during elliptical polarized undualtor EPU56 gap change with and without tune feedback. Tune variation can be keep almost constant. Figure 5 is the vertical tune vale during undualtor U90 gap change with and without tune feedback. Tune variation can be keep almost constant.

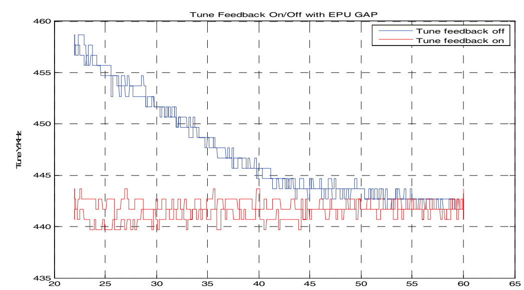

Figure 4: Vertical tune status corresponding to undulator EPU56 gap without (blue curve) and with (red curve) tune feedback.

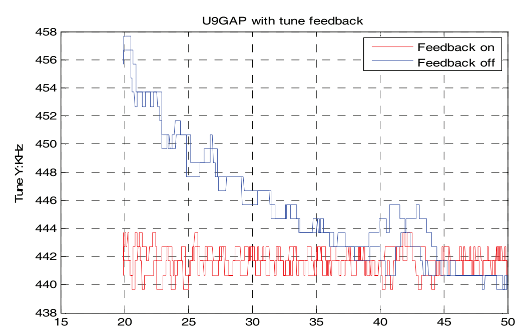

Figure 5: Vertical tune status corresponding to undulator U9 gap without (blue curve) and with (red curve) tune feedback.

Tune fedback was tested at user beamtime. Undulator gap can be changed during user serviuce, it will affect the tune in both planes. The undulator U90 have a global feed-forward tune compensation. However, it can only reduce the tune variation to about a few parts of 10^{-3} level. While the other undulators ; U50 and EPU56; are vnot implemented tune compensation scheme. Figure 6 shown undulator gap change during a typical user beam time for one day with only U90 feed-forward tune compensation is activated. Horizontal tune and vertical tune change mainly due to EPU56 gap change. When tune feedback loop closed, the tune can keep constant as shown in Fig. 7.

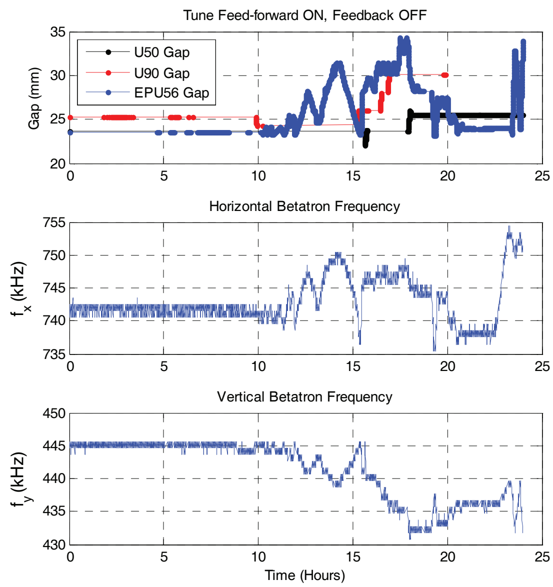

Figure 6: Tune change in one day period during user service. Tune values are varying when gap change of undulators even tune feed-forward compensation are applies.

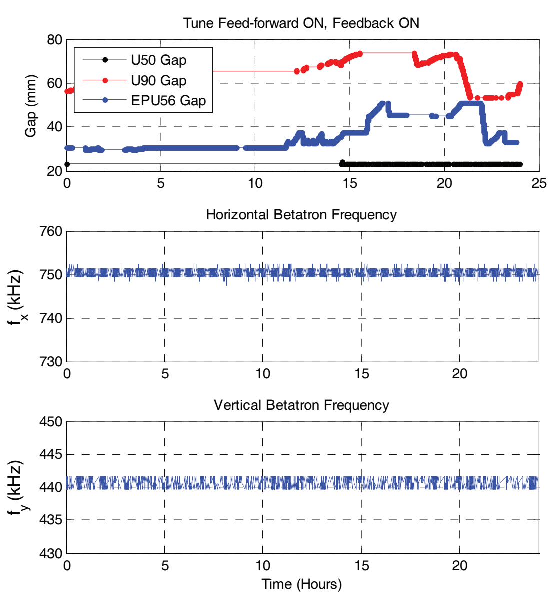

Figure 7: Tune keeps constant when feedback loop is closed.

CONCLUSION

This reports summary the efforts for the transverse tune measurement based upon transverse bunch-by-bunch feedback system, and performed preliminary tune feedback experiments. The tune is corrected by the quadrupole trim coils. Test results shown that the tune feedback can control tune to the about 2 x 10^{-4} level. Work out a faster tune measurement scheme and operation version of tune feedback is in the proceeding.

REFERENCES

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