COMMISSIONING TUNE FEEDBACK IN THE TAIWAN LIGHT SOURCE

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Abstract

Tune plays a crucial role to the performance of a synchrotron light source. Tune change might caused many reasons include the 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 constant are also important to achieve high beam stability. User controllable insertion devices will disturb 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 insertion devices are operated independently with various conditions. The global orbit feedback can minimize the orbit change. The tune feed-forward control is the most common approach to compensate tune change during insertion devices operation. However, it still hard to keep tune unchanged. Tune feedback might the best method to prevent tune change during insertion devices operation. The tune measurement is parasitic in the operation of the transverse bunch-by-bunch feedback system and tune feedback loop test are summarized in this report.

INTRODUCTION

The storage ring of Taiwan Light Source is designed to tolerance the fluctuations in tune, coupling and chromaticity and many factor. However, 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. In the other way, if tune change is too large, is easy to create fast perturbation and peak lost of the transverse feedback system in the insertion device operation. That will be hard to keep orbit to stable. The document describes a measurement strategy, discusses new challenges requirement, dynamic stabilization systems and testing result.

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. These user adjustments are performed in standard operation, so these actions need to be transparent for the global ring optics as well as for other insertion devices and users. That will add difficult y of beam optic and orbit by feed-forward compensation.

The orbit can be controlled by orbit feedback, but the beam optic needs to keep constant, too. Keep the tune constant for a synchrotron light source is an important issue.

RELIABLE TUNE MEASUREMENT

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

Spectrum analyzer is the 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 rate 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.

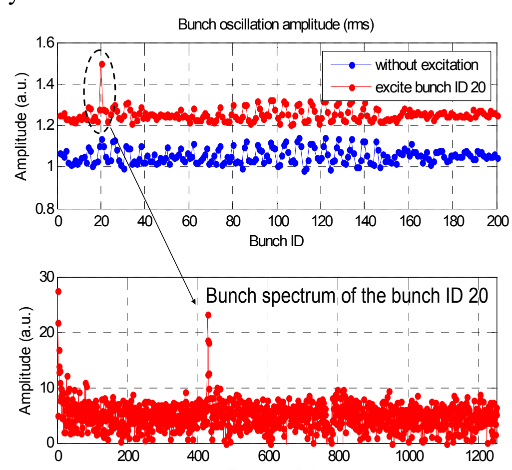


Figure 1: Tune measurement by single bunch excitation and Fourier analysis of its small bunch oscillation.

Parasitic tune measurement accompany with the bunch-by-bunch feedback is also promising [1]. 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 performed peak identification of the beam spectrum of a selected excited single bunch data without disturbing the positional stability of the beam. Figure 1 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. Only a single bunch is excited, beam blow-up effect can be negligible. It is also a user transparency.

Another method is used by the notches happened in the turn-by-turn averaged bunch spectrum as shown in Fig. 2, these notched are derivate from the noise suppression natural of the negative feedback loop. The explanation is shown in Fig. 3. Beam response is resonant at the tune frequency; Attenuation of detection noise by the feedback is proportional to the loop gain; Transfer gain from noise to the feedback input is 1/(1+L(w)), Maximum attenuation is at the resonance frequency, thus a notch [2,3].

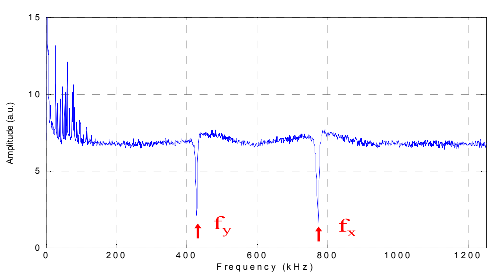


Figure 2: Tune measurement by the notches occurred in the bunch averaged spectrum due to negative feedback natural of the transverse feedback loop.

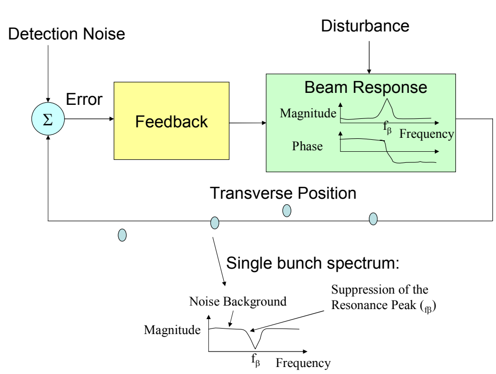


Figure 3: Functional block diagram of the tune feedback experiment.

PRELIMINARY TUNE FEEDBACK TEST

The functionality of the tune feedback experiment is shown in Fig. 4. 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 [4].

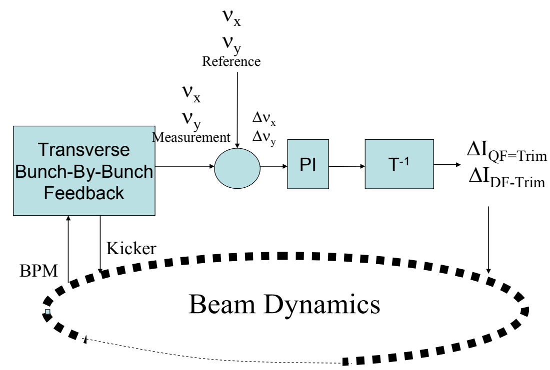


Figure 4: Functional block diagram of the tune feedback experiment.

Quadrupole trims are adopted for the test without disturbed the routine operation, which the global tune feed-forward setting was applied [5]. 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.

Tune feedback was tested with U90 gap change and feed-forward tune correction active. There are several deep peak in the Fig. 5 when tune feedback is operated in the off session. It defines tune measurement is fail and beam isn't stable when U90 gap is operated in the special location. Undulator gap can be changed during user service, 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. In the other undulators, U50 and EPU56 are not 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, as shown in Fig. 7. After tune feedback loop closed, the tune can keep constant.

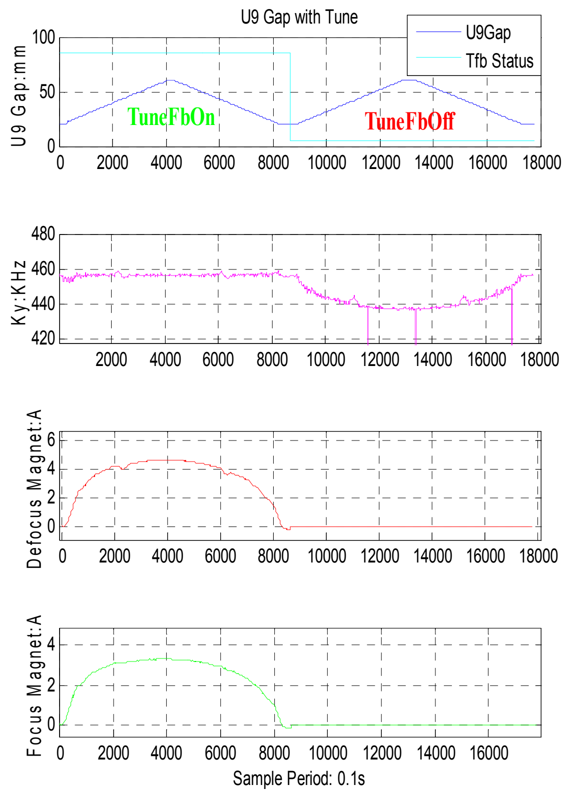
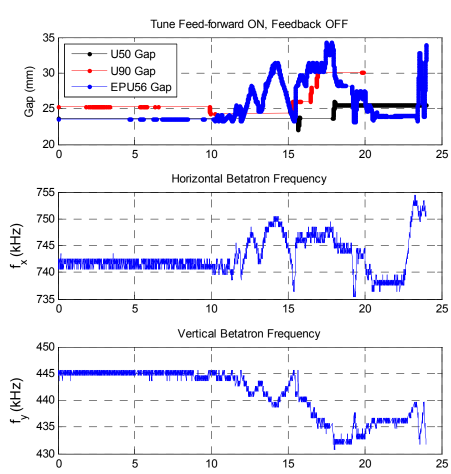


Figure 5: Vertical tune status corresponding to undulator U9 gap without and with tune feedback. Unstable beam and tune measurement fail when U9 gap is operated.



(b) Vertical tune variation.

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 applied.

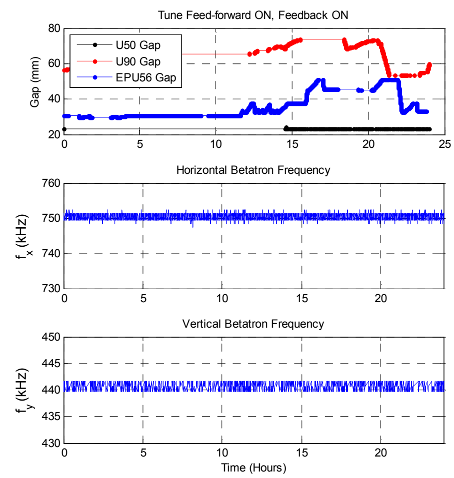


Figure 7: Tune keeps constant when feedback loop is closed.

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 feedback is in proceed.

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