ISBN: 978-3-95450-201-1 doi:10.18429/JACoW-IBIC2018-TUPC12

BEAM TRANSVERSE QUADRUPOLE OSCILLATION MEASUREMENT IN THE INJECTION STAGE FOR THE HLS-II STORAGE RING*

F.F. Wu, B.G. Sun†, T.Y. Zhou‡, F.L. Gao, J.G. Wang, P. Lu, L.T. Huang, X. Y. Liu, J. H. Wei
National Synchrotron Radiation Laboratory
University of Science and Technology of China, Hefei, 230029, China

Abstract

Beam transverse quadrupole oscillation can be excited in the injection stage if injected beam parameters(twiss parameters or dispersion) are not matched with the parameters in the injection point of the storage ring. In order to measure the beam transverse quadrupole oscillation in the injection stage for the HLS-II storage ring, some axially symmetric stripline BPMs were designed. Transverse quadrupole component for these BPMs was simulated and off-line calibrated. Beam transverse quadrupole oscillation has been measured when beam was injected into the HLS-II electron storage ring. The spectrum of the transverse quadrupole component showed that beam transverse quadrupole oscillation is very obvious in the injection stage and this oscillation isn't the second harmonic of beam betatron oscillation. The relationship between transverse quadrupole oscillation and beam current was also analyzed and the result shows that the relationship is not linear.

INTRODUCTION

When twiss parameters and dispersion of injected beam are not matched with injected point of storage ring, some oscillaitons can be excited[1, 2]. The most obvious oscillation is beam betatron(transverse dipole) oscillation, which can be used to measure betatron tune. In some machines, beam transverse quadrupole oscillation can also be excited in the injected stage. In the HLS-II electron storage ring, beam transverse quadrupole oscillation can be measured based stripline BPM in the injected stage.

TRANSVERSE QUADRUPOLE OSCILLAITON MEASUREMENT SYSTEM INTRODUCTION

Axially symmetric stripline BPM was used to measure beam transverse quadrupole oscillation in the HLS-II electron storage ring The cross-section of this stripline BPM is shown in Fig. 1.

The stripline BPM should be offline calibrated before experiment. Simulation of beam positon and transverse quadrupole component can be as shown in reference 3. Offline calibration of beam positon and transverse quadrupole component can be as shown in reference 4. Beam transverse quadrupole component can be obtained and is shown as follows:

$$\sigma_x^2\text{-}\sigma_y^2=\frac{1}{0.0011}\begin{pmatrix} Q_{\Delta/\Sigma}+0.7870-0.0011x_0^2 \\ +0.0011y_0^2-0.0006x_0-0.0004y_0 \end{pmatrix} \quad (1)$$

$Q_{\Delta/\Sigma}$ is the beam transverse quadrupole signal acquired by the difference/sum method and can be espressed as:

$$Q_{\Delta/\Sigma}=\frac{V_R+V_L\text{-}V_T\text{-}V_B}{V_R+V_L+V_T+V_B} \quad (2)$$

V_R, V_T, V_L, V_B are induced voltages on the right, top, left, bottom electrode. $Q_{\Delta/\Sigma}$ can be obtained by BPM processor(Libera Brillianceplus). Beam position(x, y) can be obtained based the eqution(4) of the reference 4. So Beam transverse quadrupole component(σ_x^2-σ_y^2) can be finally obtained.

The measurement system block diagram is shown in Fig. 2. In the injected stage, The stripline BPM electrode signals are processed by Libera Brillianceplus and the turn-by-turn data is obtained by Labview code(or Matlab code) of PC, then, the relationship between beam transverse quadrupole component(σ_x^2-σ_y^2) and injected turn number n can be obtained.

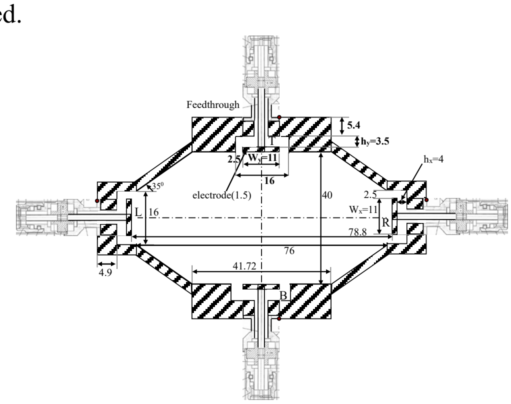


Figure 1: The cross-section of the stripline BPM.

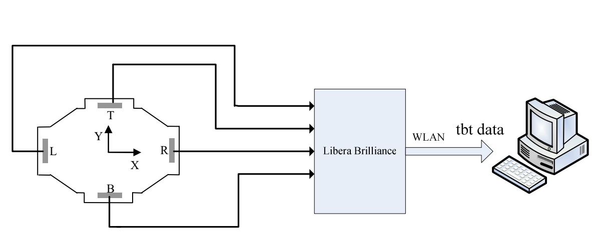


Figure 2: Measurement system block diagram for beam transverse quadrupole oscillation in the the injected stage.

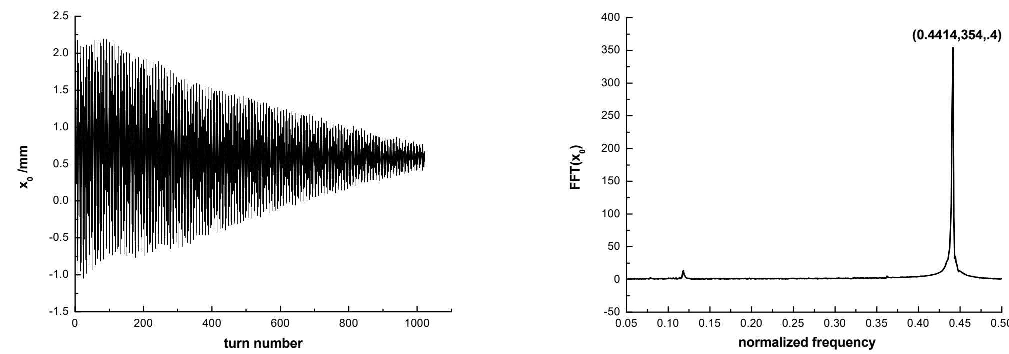
EXPERIMENT AND DATA ANALYSIS

The turn-by-turn data of beam position(x, y) can be used to measure fractional part of machine tune($\Delta\nu_x$, $\Delta\nu_y$). When

* Work supported by the Anhui Provincial Natural Science Foundation(Grant No. 1808085QA24), National Science Foundation of China (Grant No. 11705203, 11575181, 11605202), Chinese Universities Scientific Fund (Grant No. WK2310000057)
†Corresponding author (email: bgsun@ustc.edu.cn)
‡Corresponding author (email: tiany86@ustc.edu.cn)

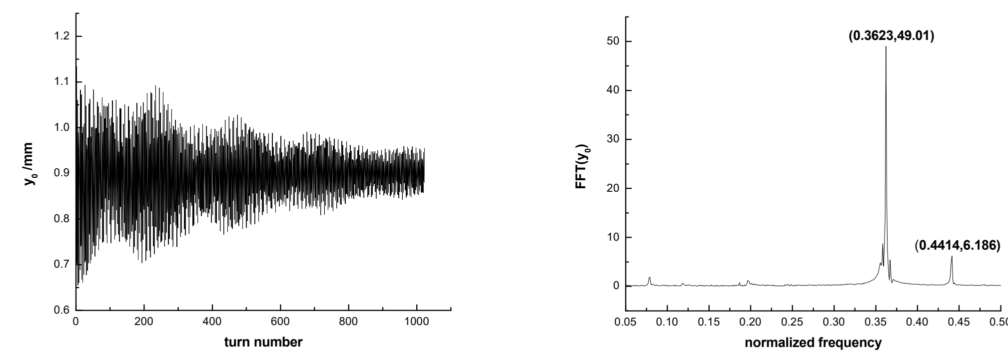
ISBN: 978-3-95450-201-1 doi:10.18429/JACoW-IBIC2018-TUPC12

multi-bunches were injected into the HLS-II electron storage ring and beam current was 174.8 mA, horizontal position and corresponding spectrum normalized to revolution frequency(4.534 MHz) were acquired and is shown in Fig. 3. Vertical position and corresponding spectrum normalized to revolution frequencywere acquired and is shown in Fig. 4. Beam transverse(horizontal) quadrupole signal and corresponding spectrum normalized to revolution frequency were acquired and is shown in Fig. 5.



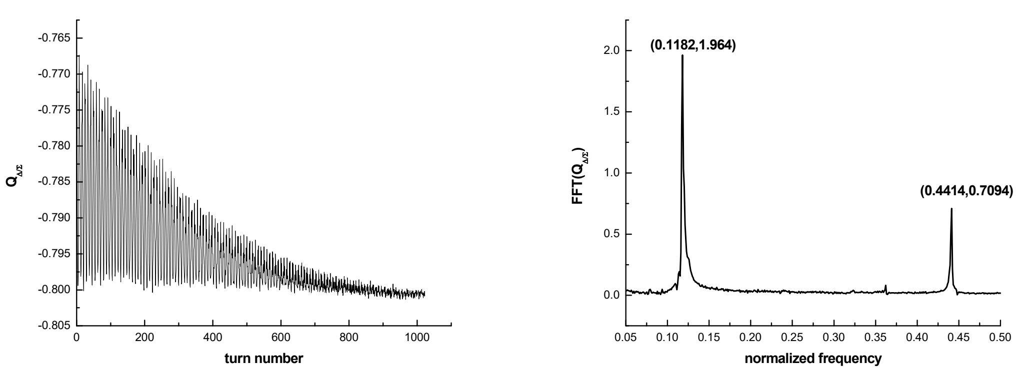
(a) Horizontal position x_0 (b) The spectrum of x_0

Figure 3: Horizontal position and corresponding spectrum in the injected stage.



(a) Vertical position y_0 (b) The spectrum of y_0

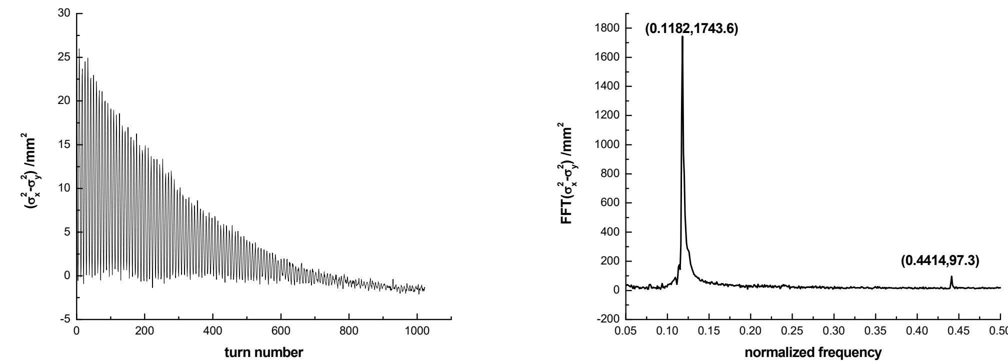
Figure 4: Vertical position and corresponding spectrum in the injected stage.



(a) Beam transverse quadrupole signal $Q_{\Delta/\Sigma}$ (b) The spectrum of $Q_{\Delta/\Sigma}$

Figure 5: Beam transverse quadrupole signal and corresponding spectrum in the injected stage.

ISBN: 978-3-95450-201-1 doi:10.18429/JACoW-IBIC2018-TUPC12



(a) Beam transverse quadrupole component (σ_x^2-σ_y^2) (b) The spectrum of (σ_x^2-σ_y^2)

Figure 6: Beam transverse quadrupole component and corresponding spectrum in the injected stage.

As is shown in Fig.3, Fig.4 and Fig.5, machine tune $\Delta\nu_x$=0.4414, $\Delta\nu_y$=0.3623. The fraction part tune $\Delta\nu_Q$ of beam transverse quadrupole oscillation can also be obtained and is equal to 0.1182. $\Delta\nu_Q$ is equal to (1-2*$\Delta\nu_x$). So beam transverse quadrupole oscillation can be measured based stripline BPM in the injected stage.

According to the equation(1), beam transverse quadrupole component (σ_x^2-σ_y^2) can be obtained. (σ_x^2-σ_y^2) and corresponding spectrum normalized to revolution frequency were acquired and is shown in Fig. 6. From the result of Fig.6, the spectrum peak of beam transverse quadrupole component is very obvious. Since contribution of beam position to (σ_x^2-σ_y^2) is eliminated, the effect of beam position for (σ_x^2-σ_y^2) is very small.

The relationship between beam transverse quadrupole component (σ_x^2-σ_y^2) and beam current in the injected stage was obtained and is shown in Fig.7. Since duration turn number of beam transverse quadrupole oscillation is not too long(about 1000 turns), interpolated FFT method was used to improve frequency domain measurement resolution. As is shown in the Fig.7, the relationship between beam transverse quadrupole oscillation and beam current is nonlinear.

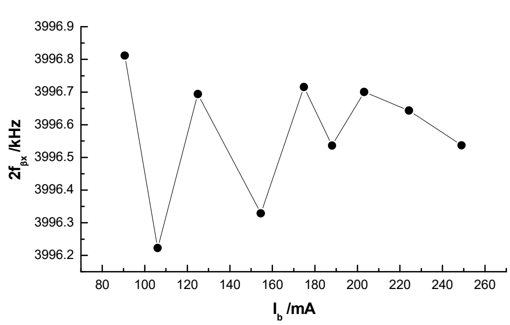


Figure 7: The relationship between beam transverse quadrupole component (σ_x^2-σ_y^2) and beam current in the injected stage.

CONCLUSION

Based on the stripline BPM, beam transverse quadrupole oscillation can be measured. The relationship between beam transverse quadrupole component (σ_x^2-σ_y^2) and beam current was also obtained. In the future, beam transverse quadrupole oscillation for different bunches will be excited by stripline transverse quadrupole kicker.

REFERENCES

[1] J. Dietrich, I. Mohos, "Broadband FFT Method for Betatron Tune Measurement in the Acceleration Ramp at COSY-Jülich". *AIP Conference Proceedings* 451, BIW'98, Stanford, CA, May 1998, pp. P454-458.

[2] A. Jansson, L. Søby. "A non-invasive single-bunch matching and emittance monitor for the CERN PS based on quadrupole pick-ups", in *Proceedings of PAC'01*, Chicago, 2001, pp. 528-530.

[3] F. F. Wu, Z.R. Zhou, B.G. Sun, *et al.*, "Design and Calculation of the Stripline Beam Position Monitor for HLS II Storage Ring", *Proceedings of IPAC'13*, Shanghai, China, pp. 562-564.

[4] Wu F. F., Zhou Z. R., Sun B. G., *et al.*, "Offline calibration of the stripline beam position monitor for HLS II. High Power Laser and Particle Beams", 2011, 23(12): pp. 2971-2975.