

VIBRATION MEASUREMENT OF THE MAGNETS IN THE STORAGE RING OF TPS

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Abstract

Taiwan photon source is a 3rd generation synchrotron light source which is in beam commissioning at NSRRC. Orbit stability within 100 nm range is essential for such a small emittance light source. Technical noise from the vacuum pumps, water flow, etc. will cause the vibration of quadrupoles and deleterious orbit stability. In order to investigate the magnitude of vibration in the magnets of the storage ring, the vibration spectra of the lattice quadrupoles; the coherence between the magnets, girders and ground will be systematic investigated in this report.

INTRODUCTION

Taiwan photon source (TPS) is a low emittance, third-generation light source in NSRRC. Its circumference is 518.4 m with 24 double-bend achromat (DBA) cells [1]. There are 6 long-straight sections and 18 standard-straight sections to accommodate insertion device. The vertical beam size at the centre of the standard cell of insertion devices straight is around 5 μm . This imposes a stringent requirement for the orbit stability. To obtain a high quality light source, the beam orbit motion needs to be controlled at least within 0.5 μm .

Ground vibration and the technical noise such as vacuum pumps and water flow will cause the magnet vibration and then leads to the distortion of the close orbit. The frequency of such vibration is much smaller than the revolution frequency of the electron beam so the vibration of the magnet can be treated as a constant displacement or beam offset [2]. The dominant effect is produced by the quadrupole and it introduces a kick angle (θ) to the beam: $\theta = eckyL/E$. k is the quadrupole strength; y is the beam offset to quadrupole center; L is the quadrupole length; E is the beam energy [3]. The closed orbit distortion (Δy_j) at j -th position caused by i -th quadrupole would be $\Delta y_j = \theta_i \sqrt{\beta_i \beta_j} \cos(\pi\nu - |\psi_j - \psi_i|) / (2 \sin \pi\nu)$. Here β , ψ and ν are the beta function, phase and tune.

In this paper, we focus on vibration in the 240 quadrupoles of the storage ring. The vibration of devices and mechanical supports which may cause the magnets vibration will also be summary here. At last, the correlation between quadrupoles, girder and ground will also be studied.

PROBES AND DATA ACQUISITION SYSTEM

Low noise three-components seismometers, LE-3Dlite Mark II [4], with frequency range 1- 100 Hz is used in this study. The data acquisition unit (Data Translation

DT8837), which is complied with LXI class C standard, provides Ethernet accesses via SCPI command to acquire data. Multiple DT8837s are synchronized by wired trigger bus (WTB) interface. To extend length limit of WTB cable, an in-house made small interface adapter from RJ-45 to Micro D is installed at the WTB connector of the DT8837 side. It allows unshielded twisted pair (UTP) cables to replace WTB cables and to send the trigger, sync and clock single from the timing system adapter to DT8837 more than 100 m. Coherent data acquisition can also be achieved by the aid of global timing system. A Matlab script can be running in the sever for the long-term measurement or in the laptop for the short-term measurement, shown in Fig. 1.

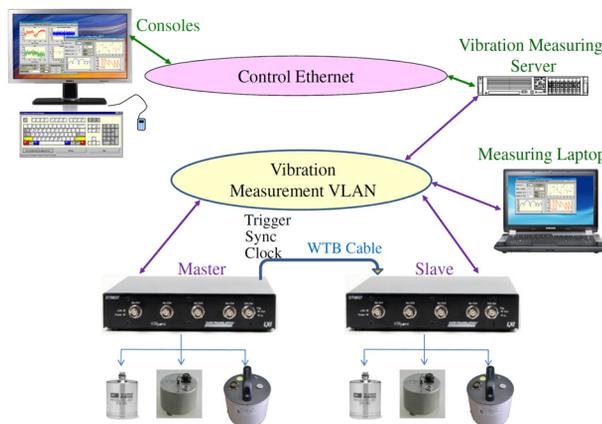


Figure 1: Configuration of vibration measuring system.

MESASURMENT RESULTS

Vibration of Quadrupoles and Dipoles

In the beginning of the commissioning of the storage ring, the vibration of quadrupoles and dipoles in all storage are measured to realize the relationship between vibration and beam motion. From the displacement spectra of magnets of the 21th cell as shown in Fig. 2 for example, there is a sharp resonance around 29 Hz. The maximum displacement amplitude is larger than 200 nm in vertical direction and 600 nm in horizontal direction within all the quadrupoles of the storage ring, shown in Fig. 3. This vibration frequency is caused by the turbo pumps. Although the turbo pumps do not directly contact to the magnets, the vacuum chambers which connect to turbo pumps are supported by the girders. Unfortunately, the vertical resonance frequency of the girder is around 30 Hz in which vibration would be magnified and translated into the magnets above the girder.

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From the spectra of all quadruples in the storage ring (Fig. 4), there are several peak around 10 Hz and 20 Hz which can be observed in some particular quadruples besides the vibration below 4 Hz and 29 Hz. The amplitude is smaller than 10 nm, its contribution to the beam motion is limited.

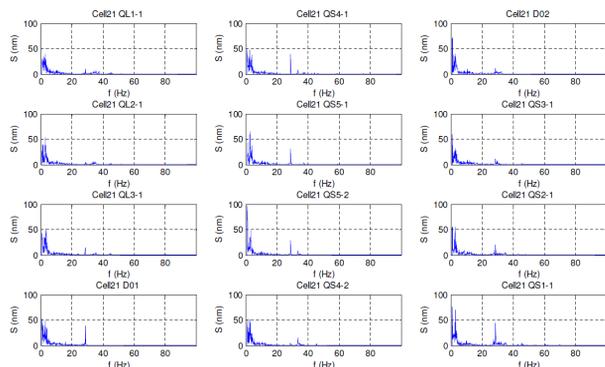


Figure 2: The vertical displacement spectra of quadrupoles and dipoles in the 21th cell of the storage ring.

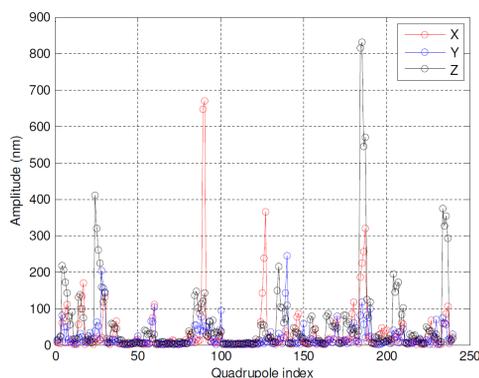


Figure 3: The amplitude of vibration in horizontal (X), vertical (Y) and longitudinal (Z) direction around 29 Hz of all quadrupoles in the storage ring.

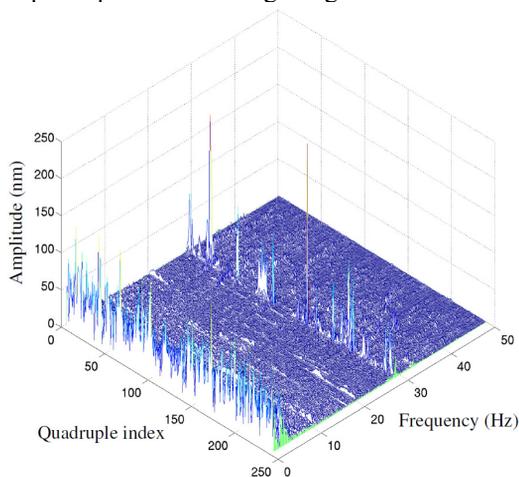


Figure 4: The spectra in vertical direction of 240 quadrupoles in the storage ring.

Long-term Variations

In order to minimize the contribution of vibration caused by turbo pumps which would be turned off in normal operation, we choose QS5-2 in the 22th cell for

long time measurement in which the contribution around 29 Hz is less than 5 nm. From the results in Fig 5. the integrated amplitude from 4 Hz to 100 Hz is usually smaller than 40 nm and 120 nm from 1 Hz to 100 Hz around noon. The minimum integrated displacement at midnight from 4 Hz to 100 Hz is all around 20 nm every day but the integrated displacement from 1 Hz to 100 Hz at midnight varies and is lower on the weekend. The daily and weekly variation might caused by culture noise which indicate activity of human and traffic of the traffic of the surrounding roads of the TPS site. The peaks on February 29th and March 14th are caused by earthquakes. Other large peaks may be due to the installation of the beam line and cryogenic system.

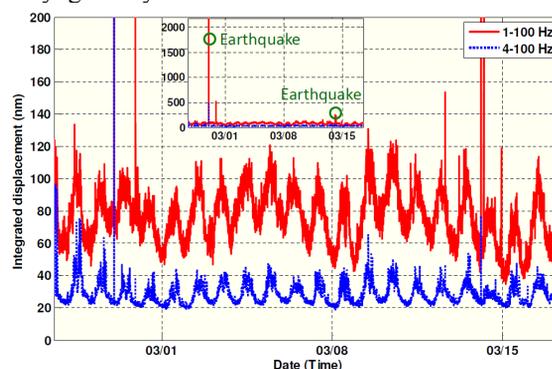


Figure 5: The integrated displacement of the vertical vibration in the QS5-2 of the 22th cell from February 24th to March 17th, 2015.

PSD or Vibration Spectra of Magnets, Girders and Ground after Turn-off Turbo Molecular Pump

To reduce the beam motion caused by quadrupoles vibration, the turbo pumps were all turn off on March 24th. From the spectrogram on March 24th as shown in Fig. 6, the peak around 29 Hz is almost disappeared at 15:00 when the turbo pumps were turned off. The spectra before and after the turbo turned off are similar expect the peak around 29 Hz. The low-frequency vibration, which is caused by the civil activities, is lower around the midnight. It is shown in Fig. 7, that the vertical spectra of quadrupoles in the 21th and 22th cell as turbo pump is turn off. The maximum amplitude around 29 Hz is smaller than 13 nm.

As we measure the vertical motion of girders, ground and quadrupole (QS5-2) in the 21th cell, the power spectra density (PSD), shown in Fig. 8, below 20 Hz is similar. The beam motion is larger than the quadrupole motion above 5 Hz. The PSD between three girders is quite different and much larger than the ground motion above 20 Hz. The PSD of QS5-2 which locates at the 2nd girder is only similar to the PSD of the 2nd girder between 20 and 65 Hz. Therefore, the magnitude of quadrupoles motion below 20 Hz is dominated by the ground motion and similar at latest within one cell. The magnitude of the quadrupole motion between 20 and 65 Hz is dominated

by the girder motion which is much higher than the ground motion.

between 20 Hz is mostly dominated the ground vibration here. They are partial correlated between 20 and 28 Hz; above 28 Hz, they seems to be uncorrelated. The correlation between the girder and quadruple (QS5-2) motions seems to be good up to 40 Hz. Therefore, the magnet motion within a girder would be almost in phase below 40 Hz. The correlation between the 1st and 2nd girder is similar with that in the 2nd and 3rd girder, but it becomes poor for the 1st and 3rd girder. That is due to the poor correlation of ground in high frequency as the separation is long [5].

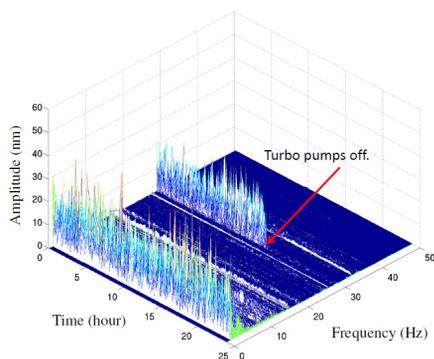


Figure 6: The spectrogram of vertical vibration at QS5-2 of the 21th cell on March 24th.

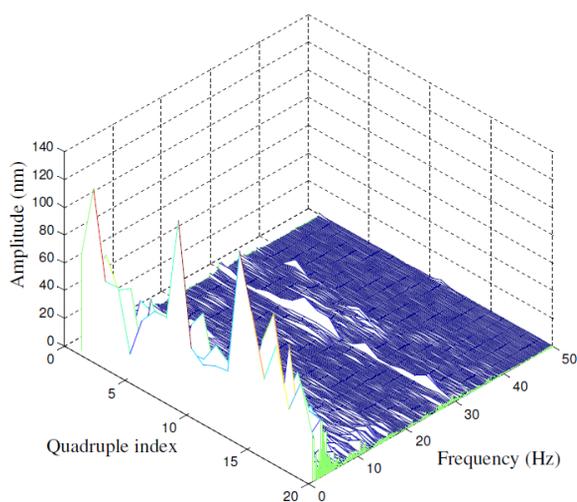


Figure 7: The spectra of vertical vibration in the quadruples of the 21th and 22th cell.

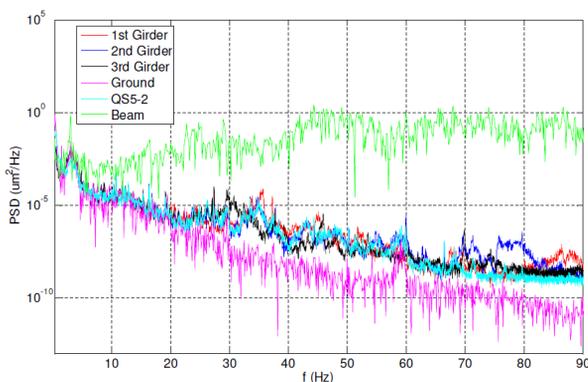


Figure 8: The vertical power spectra density (PSD) of the 1st girder, 2nd girder, 3rd girder, ground, QS5-2 and beam motion.

Correlation Measurement

From the correlation in vertical direction shown in Fig. 9(a), the ground and girder (or QS5-2) motions are correlated below 20 Hz. This means the magnets vibration

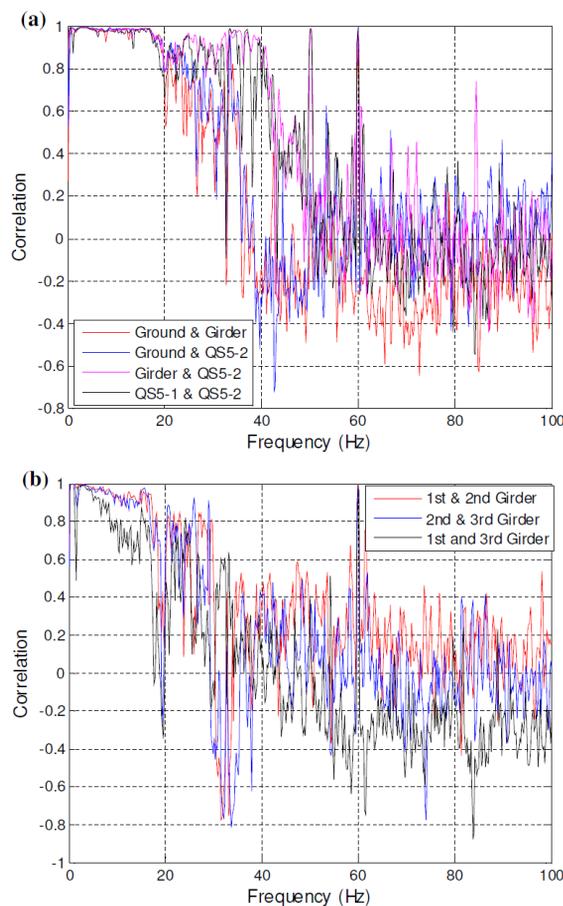


Figure 9: The correlation (a) between the ground, girder and quadruples at (around) the 2nd girder; (b) between girders in 2nd cell.

CONCLUSION

We systematically surveyed the vibration of quadruples and dipoles in the beginning of the storage ring commissioning and found out the beam motion is affected by the vibration of quadruples due to the operation of turbo pumps. To eliminate the influence, all the pumps were turned off, and then beam motion around 29 Hz becomes unobvious. From the long-time observation of quadrupole motion, the integrated displacement from 4 to 100 Hz at midnight is around 20 nm and 40 nm around the noon. The girders and quadruples below 20 Hz is correlated with the ground motion and amplification is near 1. For the frequency above 20 Hz, the quadruples

motion is larger than the ground motion. The quadrupoles and their supporting girder are correlated below 40 Hz with similar vibration amplitudes.

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