INTEGRATING THE MEASURING SYSTEM OF VIBRATION AND BEAM POSITION MONITOR TO STUDY THE BEAM STABILITY

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Abstract

For a low emittance, third-generation light source such as Taiwan Photon Source (TPS), beam orbit motion needs to be controlled within submicron for obtaining a high quality light source. Magnets vibration especially quadruples will be one of the main sources to destroy the beam stability. In order to study the relationship between vibration and beam motion, a synchronous data acquisition system which integrates the measurement of vibration and beam position monitoring system is highly desirable. For a larger vibration such as earthquakes are also deleterious to beam stability or even make the beam trip due to the quench of superconducting RF cavity. A data acquisition system integrated with an earthquake P-wave detector is also quite necessary to show and archive the data on the control system. First, the data acquisition systems of vibration and earthquake measurement system are summarized in this report. The preliminary study of the relationship between the beam motion and magnets vibration will also be presented here.

INTRODUCTION

For a low emittance, third-generation light source such as TPS, it 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. There are many sources [1] which may destroy the beam stability such as vibration, ill function of power supply, septum/kicker field leakage, etc. The ground vibration and the technical noise such as vacuum pumps and cooling water flow will cause the magnet and vacuum chamber vibration. It leads to the distortion of the close orbit [2]. The dominant effect for the beam motion caused by magnet vibration is produced by the quadrupole and it introduces a kick angle to the beam as the quadrupole has an offset to the beam due to the vibration.

To achieve submicron stability, various efforts and studies should be continuously performed such as power supply performance, RF system performance, cooling water, mechanical vibration, orbit feedback system and bunch-by-bunch feedbacks. Besides, it is also important to identify various sources and to minimize their effects to the beam instability. In this paper, the data acquisition system for measuring the vibration and beam position is introduced first. The setup of beam position monitoring and earthquake monitoring system are described in the third and fourth parts. In the fifth and sixth sections, the preliminary results to identify the vibration caused by turbo molecular pump (TMP) system and to study the beam stability are shown. Finally is the short summary.

VIBRATION DETECTOR AND DATA ACQUISITION SYSTEM

Low noise three-component seismometers, LE-3Dlite Mark II, 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 for long rang or by LXI WTB cable for short range application. A Matlab script can be running in the server for the long-term measurement or in the laptop for the short-term measurement, shown in Fig. 1. The synchronous data acquisition between vibration measurement and beam position monitoring system can also be through the timing system.

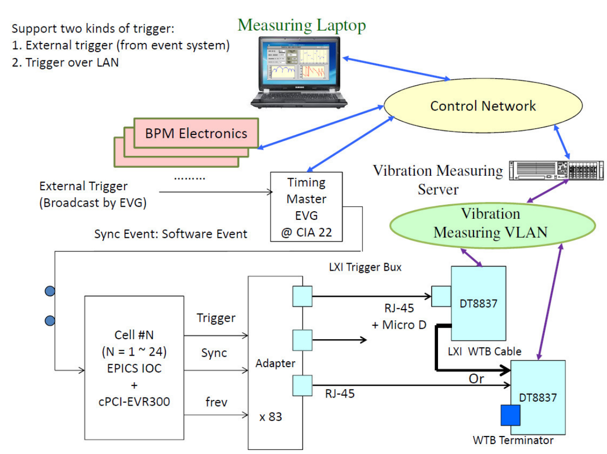

Figure 1: Configuration of vibration measuring system integrated with beam position monitoring system.

BEAM POSITION MONITORING SYSTEM

The TPS storage ring is divided into 24 cells and 7 beam position monitors (BPMs) are installed in each cell.

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Another six BPMs are installed at three long straight lines with inserting devices for the local measurement. Two kinds of BPM are installed in the storage ring: one is standard button BPM shape at arc section; the other is primary BPM shape with racetrack at the insertion device straight.

The BPM electronics provide several data types for various application. Analog-to-digital converter (ADC) and turn-by-turn (TBT) data are acquired for first turn and betatron tune analysis; 10 Hz slow acquisition data (SA) is for DC average orbit and 10 kHz fast acquisition data (FA) could be applied for fast orbit feedback application and beam stability analysis. An experimental physics and industrial control system (EPICS) input/output controller (IOC) is embedded in the electronics platform to control, monitor and configure the BPM system in the control network [3]. Here, FA is used to be integrated with vibration measurement system and to study beam stability.

EARTHQUAKE MONITORING SYSTEM

In order to monitor the earthquake information which is happened in NSRRC campus and to study the beam stability as an earthquake is happened, an earthquake P-wave detector which equips with MEMS accelerometers and an ADC with 16-bit output resolution is installed in the TPS building. A complied Matlab program is used to communicate with the earthquake detector through Modus TCP protocol, and transfer the useful information into the created IOC through the soft process variables (PVs), shown in Fig. 2. The EPICS IOC publish PVs into the TPS control network and earthquake information detected by the detector can be shown on the console on line.

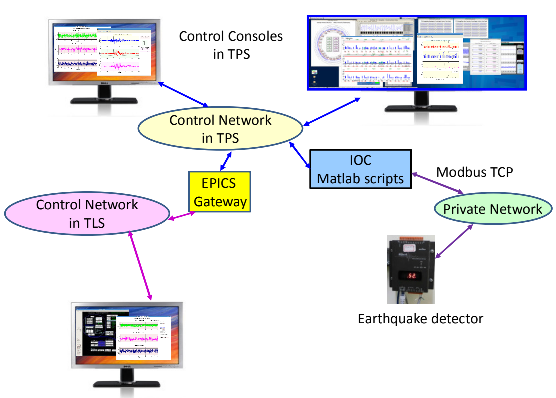

Figure 2: The configuration of the earthquake monitoring system.

As detecting an earthquake, the number of event flag in the data stream will be changed. When the Matlab program detects this flag, the earthquake information with 30 seconds before trigger and 90 seconds after trigger is recorded in the archived file for further analysis. A graphical user interface is used to show the events in the control console, shown in Fig. 3. To show the earthquake information in the Taiwan Light Source (TLS) control system, an EPICS gateway is used to transfer the earthquake related PVs from TPS control network into the TLS control network. Therefore, the earthquake monitoring system can also be launched in the TLS control system.

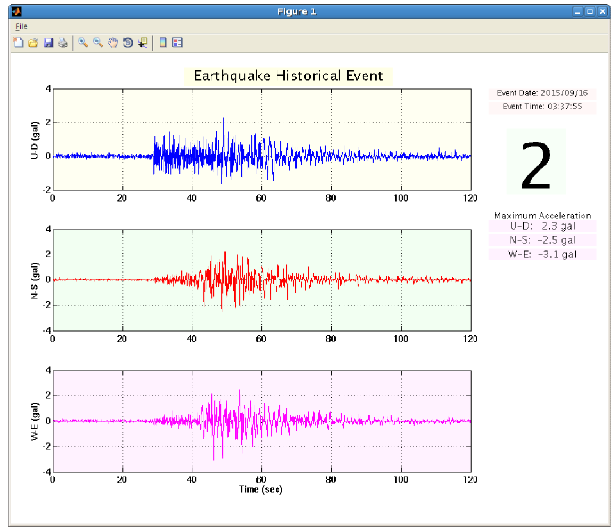

Figure 3: The earthquake historical event loaded from the archived files.

VIBRATION CAUSED BY TURBO MOLECULAR PUMP SYSTEM

In the first phase commissioning during December 2014 to March 2015 [4], an obvious beam motion around 29 Hz is observed. A sharp peak around 29 Hz can also be found in the magnet vibration [5]. As the TMP system, which contains a TMP, a dry pump and a mechanical pump, is turn off, the beam motion and magnets vibration around 29 Hz is highly eliminated. In order to investigate the vibration propagation path, a serious study is performed during the long shutdown from April to August. It was identified that the vibration source is from the mechanical pump, shown in Fig. 4. As a seismometer is put near the mechanical pump, a sharp peak in Fig. 5 can be found in the displacement spectrum.

The electric mains frequency in Taiwan is 60 Hz. All of these mechanical pumps are driven by induction motor. There are four poles in this motor so the synchronous speed should be 30 Hz [6]. The slip of rotor and stator makes the revolution frequency less than 30 Hz and the revolution frequency depends on the load of the motor. Therefore, the measured vibration frequencies of magnets in each girder are slightly different. The TMP system is the most pumping efficient for high gas load and was planned to operate during the early commissioning and the first year operation. In order eliminate the destroying of beam stability, all the TMP systems are turned off in the later period of beam commissioning.

The propagating path from the mechanical pump to the TMP is by the vacuum pipe connected between TMP and dry pump. The TMP is combined with the vacuum chamber of the storage ring so vibration of mechanical

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pump would also propagate into the vacuum chamber. There are no direct contact between magnets and vacuum chambers so the vibration propagating from the vacuum chambers to the magnets should be through the girder.

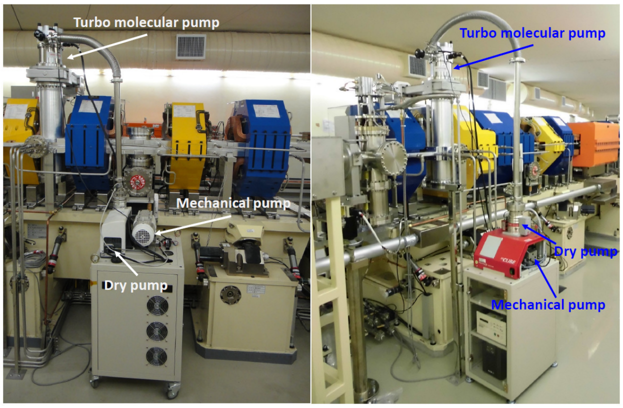

Figure 4: The setup of the turbo molecular pump systems.

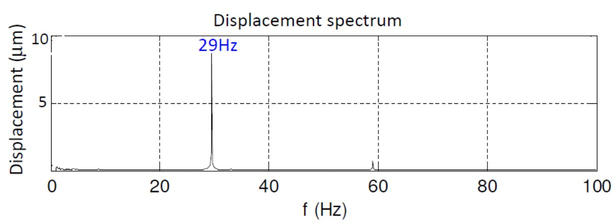

Figure 5: The displacement spectrum near the mechanical pump.

As comparing the vibration of quadruples in the third cell, it can be observed that the peak around 29 Hz is disappeared as the TMP system is turned off. When the cooling water of magnets and vacuum chamber is turned off, the vibration around 20 - 40 Hz is greatly reduced, shown in Fig. 6. Therefore, the source of vibration around this frequency should be the water flow. However, the measuring results in the magnets is not only corresponding to the amplitude of the vibration sources but also the transform function or resonance frequency of supporting mechanical structures such as the girder so advanced study is necessary to figure out a complete conclusion.

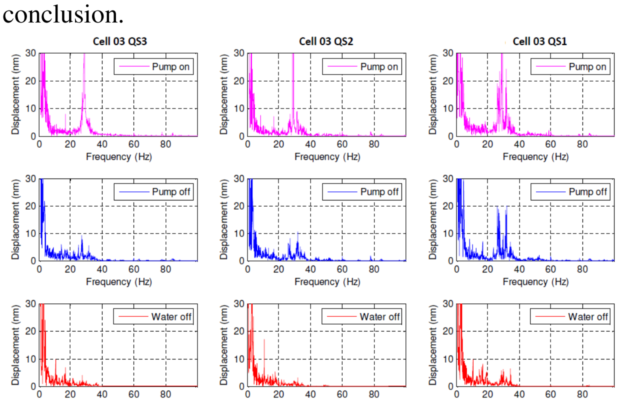

Figure 6: The vertical displacement spectra of the quadruples in the third girder of the cell #3 as TMP is turned on, TMP is turned off, and cooling water is turned off.

PRELIMINARY ANALYSIS OF BEAM STABILITY

The phase II commissioning with SRF cavities and inserting devices starts at September, 2015. All the TMP systems are turned off. In the beginning of the commissioning, we found there is a 3 Hz oscillation in horizontal axis plane from the 10 Hz BPM data. As the ramping the booster power supply is turned off, the 3 Hz peak is disappear, shown in Fig. 7. From the power spectral density (PSD) of the 4th BPM in the cell #5, the variation contribution is mainly from 20 - 50 Hz in the horizontal axis plane

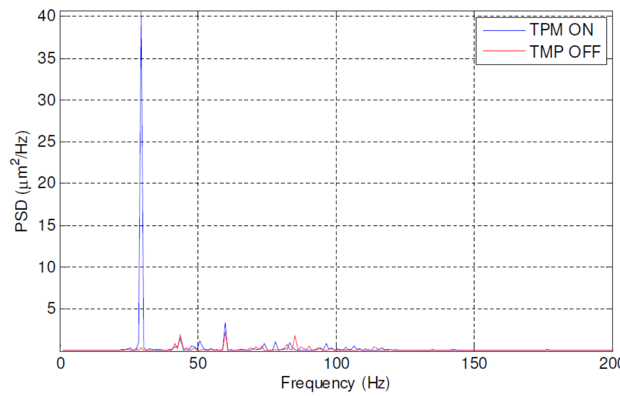

Figure 7: Power spectral density (PSD) in horizontal axis plane of the 4th BPM in the cell #5 as the ramping power supply (PS) in the boostering ring (BR) is turned on or turned off.

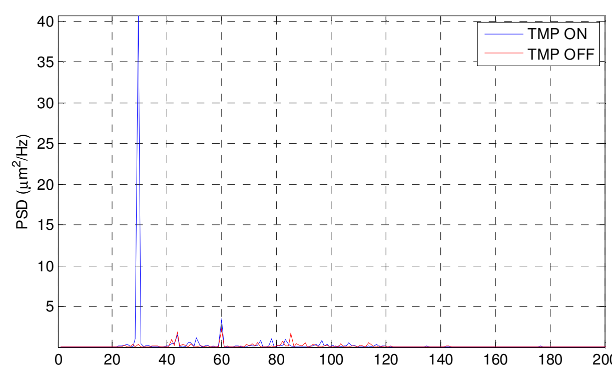

Figure 8: The comparison of vertical beam motion in the 5th BPM of cell #7 as the TMP in the 3rd girder of the cell #7 is turned on and turned off. The beam motion around 29 Hz disappears as TMP is turned off.

In order to test the data acquisition between vibration and BPM system, the TMP system in the 3rd girder of cell #7 is turned on. Comparing with the results as all TMP systems are turned off, a strong beam motion can be observed around 29 Hz in the vertical direction, shown in Fig. 8. Note that the beam motion around 29 Hz could be

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observed in all of the BPMs with various amplitudes due to the different beta function and phase advance. As measuring the coherence between the quadruple vibration and beam motion, the coherence around 29 Hz is almost 1 and the coherence in the other frequencies is lower, shown in Fig. 9.

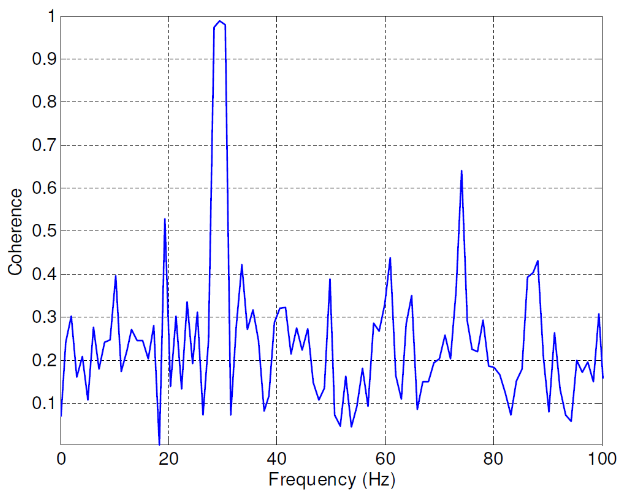

Figure 9: The vertical coherence between the 8th quadruple and 5th BPM in the cell #7.

SUMMARY

The phase II commissioning with SRF cavities and inserting devices is in process. Data acquisition which integrates with the beam position monitoring system and vibration measurement is setup for studying the relationship between beam stability and vibration. The earthquake monitoring system is also setup not only to monitor the earthquake but also try to investigate the relation between the earthquake and beam motion. By the vibration measurement and beam position monitoring system, the source and propagation path of the beam motion around the 29 Hz is identified and the strong coherence is found. However, the beam motion around 20 – 50 Hz is still not low enough. A lot of efforts should be done to increase the beam stability.

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