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SYNCHRONOUS DATA ACQUISITION SYSTEM FOR TPS AND ITS APPLICATIONS

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Abstract

Orbit stability in 100 nm range is essential for a very small emittance synchrotron light source. However, all kinds of vibration sources such as cultural noise and technical noise might deleterious the orbit stability. A synchronous data acquisition system is necessary to study the connection between orbit motions and various related vibration sources. In this report, we present a synchronous data acquisition system, which integrates the vibration and the measurement of beam position, and then will be deployed in the Taiwan Photon Source (TPS). To test its applicability, systematic study of vibration using this system was performed at TPS before the beam commissioning, which is scheduled in the third quarter of 2014. Results will be summarized in this report.

INTRODUCTION

Taiwan Photon Source (TPS) is a low emittance, third-generation light source in NSRRC. The vertical beam size at centre of insertion devices is less than 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 within 0.5 μm. To analyze the relationship between the mechanical vibration and beam motion, a data acquisition system which synchronizes the measurement of the vibration and beam position monitoring (BPM) systems is highly desirable. Both systems need to be locked with the machine clock to acquire data coherently. Because installation of the machine is in progress, beam is still unavailable at this moment. Before beam commissioning, ground vibration within the TPS building is explored systematically.

SYNCHRONOUS DATA ACQUISITION SYSTEM

The data acquisition unit (Data Translation DT8837), which is complied with LXI class C standard with an internal clock of 48.000 MHz, provides Ethernet accesses via SCPI command. It also supports an external trigger and clock with a wide range frequency (f_{ext}) from 20 MHz to 60 MHz. When the external clock deviates from the internal clock, the sampling frequency needs to be scaled by f_{ext}/48.000 MHz. The measurement can be synchronized with the BPM system when the clocks of both data acquisition system are derived from the common machine clock. Multiple DT8837s can be synchronized by wired trigger bus (WTB) interface. To extend length limit of WTB cable, a 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 as shown in Fig. 1. The system can be operated well when the connecting wire between adapter and DT8837 is within 100 m. Several kinds of accelerometers and seismometers are available to meet different applications. A high sensitive seismometer, CMG-6T, was used to study the ground motion of TPS during installation period due to its good low frequency response.

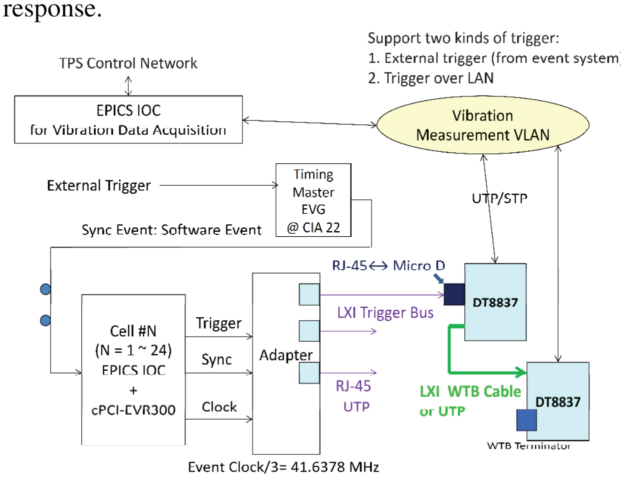

Figure 1: Configuration of synchronous data acquisition system.

APPLIED OF SYNCHRONOUS DATA ACQUISITION SYTSTEM FOR GROUND MOTION STUDY AT TPS BUILDING

The TPS with 24 lattice cells is close to three heavy traffic roads. The cultural noise caused by the traffic should be a main vibration source. Several selective locations for measurement are shown in Fig. 2.

To obtain the displacement of the vibration, the trapezoidal numerical integration method in time domain or $D(f) = V(f)/(j2\pi f)$ in frequency domain are used to integrate the velocity measured by the seismometer or geophone, where D, V, f are the displacement, velocity and frequency of vibration. The cross spectral density (CSD) or mutual spectral density is defined as $CSD_{12}(f) = D_1(f)D_2^*(f)/T$ for $f \neq 0$ and the Welch's averaged periodogram method is used to reduce the influence of the noise. T is the measuring time. When $D_1(f)=D_2(f)=D(f)$ the power spectral density (PSD) should be $PSD(f) = 2D(f)D^*(f)/T$. The factor 2 is added in this equation because the one-sided PSD is considered

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here. The integrated root-mean-square (IRMS) displacement can be obtained by

$$IRMS(f_1 - f_2) = \sqrt{\int_{f_1}^{f_2} PSD(f)\,df}\,. \quad (2)$$

When the normalized CSD defines as $CSP_{12} / \sqrt{CSD_{11} CSD_{22}}$, the real part is correlation and its module is coherence [1].

Figure 2: The layout of NSRRC campus and the measurement locations of vibration at TPS.

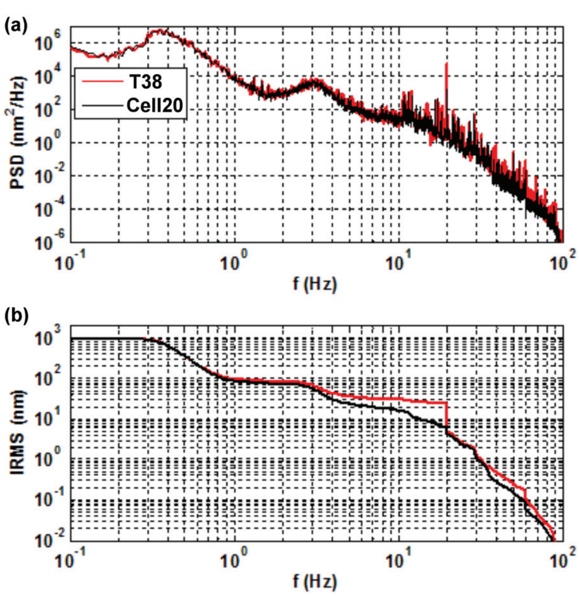

Figure 3: The vertical (a) power spectral density (PSD) and integrated root-mean-quare (IRMS) displacement of the ground vibration measured in the beam line area (T38) and tunnel (Cell20) of TPS.

MEATUREMENT RESULTS

Form the PSD of vibration shown in Fig. 3(a), the displacement of the low frequency region (<10 Hz) in the beam line area of TPS is similar to that in the tunnel. For the frequency above 10 Hz, the vertical vibration in the beam line area is larger than that in the tunnel especially for the frequency around 19.6 Hz which may be excited by the air-conditioning system. This vibration frequency also leads to the higher IRMS displacement in the beam line area as shown in Fig. 3(b). In the other hand, the PSD of vertical vibration at different sites of the tunnel shown in Fig. 4 is quite similar and is largest around 0.3 Hz.

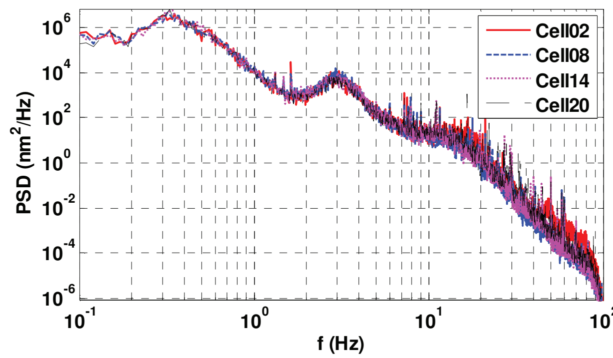

Figure 4: The vertical PSD of the ground vibration at Cell 2, 8, 14, 20 of the tunnel.

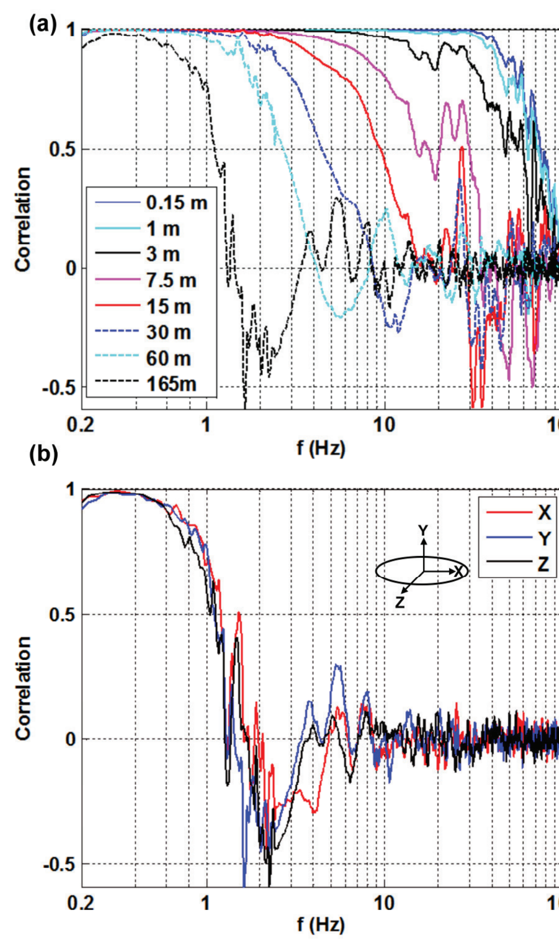

Figure 5: (a) Vertical correlation of ground motions with various separations. (b) Correlation of ground motions separated by 165 m in the X, Y and Z direction.

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Although the PSD is largest around 0.3 Hz in the tunnel, this vibration frequency does not necessarily influence the quality the radiation light seriously around this frequency because the correlation of the vibration must be taken into consideration. Figure 5 (a) presents the results of vertical correlation measurements with various separations. Note that a moving average is done at the high frequency region for good reading. As two sensors are set side by side, the correlation is good up to 80 Hz. The correlation decreases as the distance of two sensors increasing. The correlation at 1 Hz is only around 0.7 when two sensors are setup with the distance of 165 m, i.e. the diameter of the ring. It means that for the frequency below 1 Hz, the vibration is almost in phase in the all ring as shown in Fig. 6(a). For the vibration around 2 Hz in which the correlation is negative, the vertical displacements of two points separated by a distance of 165 m in the ring tends to be out of phase as shown in Fig. 6(b). The correlations in the horizontal direction (X & Z) in Fig. 5(b) have similar results with that in the vertical (Y) direction.

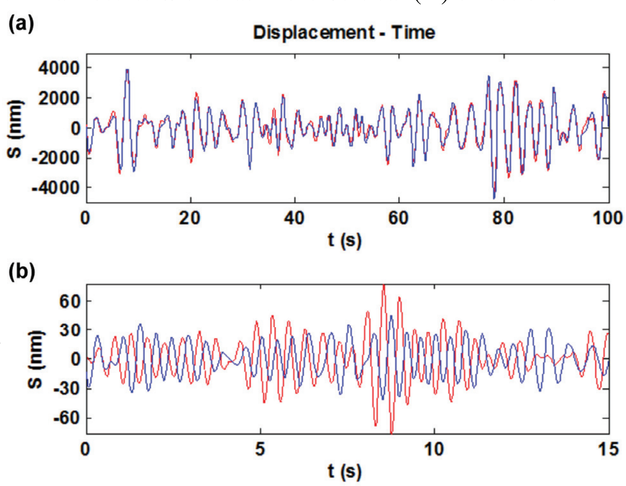

Figure 6: Vertical displacements of two points separated by a distance of 165m, and band-pass filtered between (a) 0.2-1 Hz and (b) 1.5-2.5 Hz.

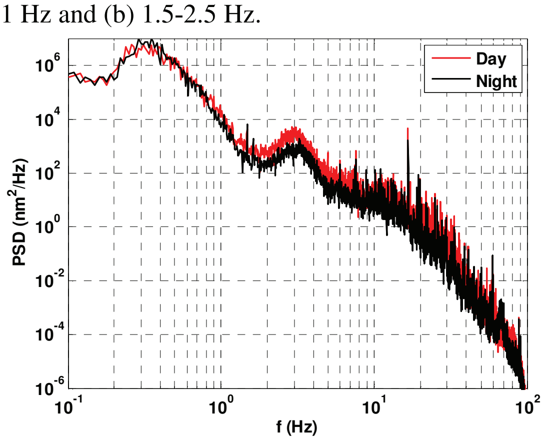

Figure 7: The comparison of spectrum of day and night.

General speaking, the vibration are usually caused by nature source and cultural noise [2]. The one-day period of the PSD variation of vibration caused by nature source is usually not obviously, but the vibration of cultural noise will be largest around the 11:00-12:00 & 13:00-14:00 and lowest at 02:00-04:00 due to the human activity. From the Fig. 7, the PSD difference between day and night below 1 Hz is not obviously but is apparently above 1 Hz [3]. Therefore, the human noise dominates the vibration of ground in the tunnel above 1 Hz very much. The IRMS displacement of ground vibration at various frequency bands in Cell20 shown in Fig. 8 can also lead to this conclusion. The largest IRMS displacement above 1 Hz to 100 Hz around the noon can be twice than the lowest one at midnight. Because the TPS is under installation at the measuring period, the heavy objects knock the ground is negligible. Therefore, several peaks can be observed in Fig. 8 unless the peak at March 30th, which is caused by an earthquake.

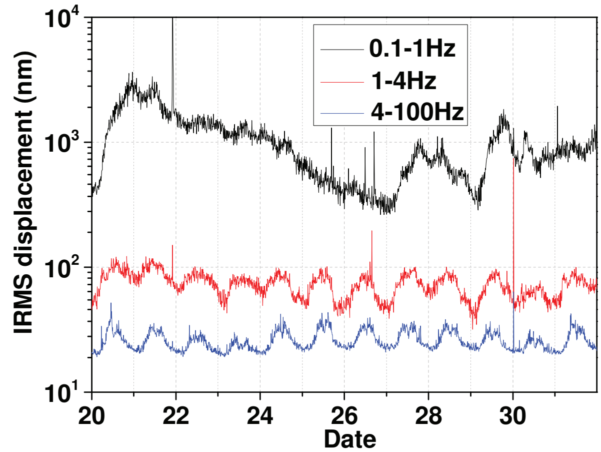

Figure 8: The IRMS displacement of ground vibration at various frequency bands in Cell20 of TPS from March 20th to 31th.

CONCLUSION

The synchronous data acquisition system of the vibration and beam position measurement is introduced and used to study the vibration of TPS before beam commission. From the measurement results, the PSD of the vertical vibration is similar between the tunnel and beam line area and is largest around 0.3 Hz. Fortunately, the vibration below 1 Hz is correlated which does not disturb the beam motion. The vertical vibration below 1 Hz is similar between day and night but is larger in the day above 1 Hz due to the culture noise. Although TPS is under installing period in which cooling water system and vacuum pump does not fully operate, this paper provides the vibration study caused by the nature source, traffic noise and human activity in the NSRRC campus. It also provides a composition material with the vibration during the fully operating period.

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