MEASUREMENTS OF GROUND VIBRATION AT TLS

C. K. Kuan, D. J. Wang, H.C.Ho, S.Y.Perng, J. R. Chen
National Synchrotron Radiation Research Center
101 Hsin-Ann Road,Hsinchu Science Park, Hsinchu 30077, Taiwan.
E-mail: ckkuan@nsrrc.org.tw

Abstract

Ground vibration is one of many factors that contribute to the stability of a beam. Suppressing ground vibration from vibration source is more economical than increasing the anti-vibration ability of all of the components of the accelerator at TLS. A real-time vibration-measuring system is installed. Ground vibrations have been measured and the sources of vibration were identified. The air-handling unit (AHU) and water-chiller are the main sources of ground vibration. Some of the vibrations are suppressed, and measurements presented.

1. Introduction

Beam stability is a major concern for the third-generation synchrotron light source. Many factors influence the stability of the beam, one of which is ground vibration. At the Taiwan Light Source (TLS), the main sources of ground vibrations are mechanical vibrations, including those associated with the AHU, the water-chiller and the mechanical vacuum pump. The range of frequencies of the mechanical vibration sources most critical is 2 to 50Hz at TLS.

Many investigations have been conducted to examine the mechanical effects on beam stability at the synchrotron light source [1-3]. Damping methods have been applied to suppress the vibration of the magnet girder [4-5]. Many measurements of mechanical vibrations have been made to identify the sources of beam instability [6-7].

The ground vibration of TLS exceeds that of some other light sources [8]. The vibration sources on the site must be identified and suppressed. A series of vibration measurements were made to identify the vibration sources, and correlate the measurements with beam stability.

2. Method

A portable four-channel spectrum analyzer with piezo accelerators (PCB-393B12) was used to measure the vibrations. A real-time sixteen-channel spectrum analyzer with piezo accelerators (PCB-393B31, PCB-393B12, PCB-393A31) was used to monitor the vibrations. All the vibration data are transformed into power spectrum density (PSD) data. The displacements of the vibrations are defined as the root mean square (rms) displacements calculated from the PSD data in the range 2-50 Hz. The peak frequencies of the vibration spectrum were initially measured at hundreds of points to determine the main vibration frequencies. The vibration frequencies of all the vibrating machines were measured to identify possible sources of vibration of the e-beam. The amplitude of vibration caused by turning on and off the air-water-handling unit (AWHU), comprising the AHU and the water-chiller, was recorded. When the vibration amplitude of the mechanical components exceeded the tolerance, the structure was regarded as unstable, and the vibration source and amplification factor of the ground vibration is identified. When the maximum peak frequency of vibration

differed from the maximum peak frequency of vibration source, the frequency response of the structure was determined.

The purpose of investigating the vibration of the existing system is to stabilize the beam. If a correlation exists between the beam and the vibration source, whether the vibration of the source should be suppressed or the stiffness of the structure increased, must be determined. The spectra of the e-beam motion were measured using electric beam position monitors (EBPM) to evaluate the influence of the vibration source.

3. Vibration

The aim of measuring ground vibration is to identify the source of vibration that affects e-beam motion. The main vibration frequency of the storage ring floor was 25.5 Hz, and was associated with the AHU, on the second floor of the storage ring building [9]. This 25.5 Hz also was the maximum peak frequency of the e-beam vibration. Isolating the accelerator machines from all vibrations is difficult, so a choice was made to suppress the vibration source of the ground. After the worn-out bearings, damping spring units and some AHU with stronger vibration were replaced, the amplitude of the ground vibration was reduced and the maximum peak frequency was no longer 25.5 Hz.

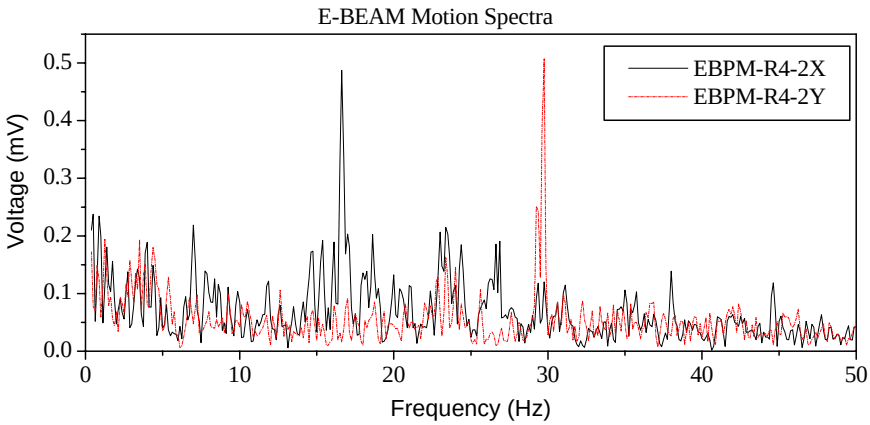

Figure 1. Spectra of the E-Beam Motion

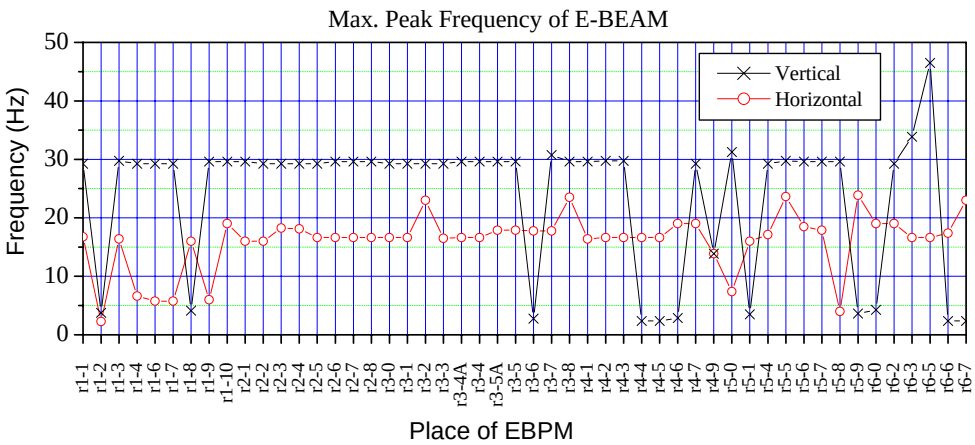

Figure 2. Maximum Peak Frequency of the E-BEAM

The cooling capacity of chilled water was added about 80% of the original one in the construction of a super-conducting RF cavity and a liquid-He plant. Now, a new utility system, a new RF cooling system and a liquid-He plant, are available. Therefore, more heavy machines vibrate more. Figure 1 plots the e-beam motion spectra. The frequencies of vibration of the e-beam motion at every EBPM are measured. If a frequency of vibration is observed only at a specific EBPM, then this vibration frequency is that only of the EBPM support or noise, and not of the real e-beam motion. Besides the peak amplitude of e-beam vibration varies with position. The maximum peak frequencies at all the EBPMs (Fig. 2) reveal that the dominant horizontal peak frequencies of the e-beam motion are 16.6 and 19.5 Hz, and the dominant vertical peak frequencies of the e-beam motion are 29.3 and 29.6 Hz.

3.1. Ground Vibration

The most interesting frequency range at the synchrotron radiation facility is 2-50 Hz, in which range the accelerator machine is sensitive to ground vibration. Below this frequency range, the global feedback system controls the orbit of the e-beam. Above this frequency range, the energy of vibration is always too low to cause vibrations of significant amplitude. Table 1 lists main frequencies of vibration of the vibration sources.

Table 1. Vibration Source

Source	*Frequecncy (Hz)*
Water-chiller	*19.5, 29.6, 37.4, 44.1, 45.7*
AHU	*19, 22.5, 24.5, 34.5(Noisy vibration with many small peak)*
Water Flow	*Noisy vibration with many small peak*
Mechanical Vacuum Pump	*29.1, 29.3, 29.5, 29.6*

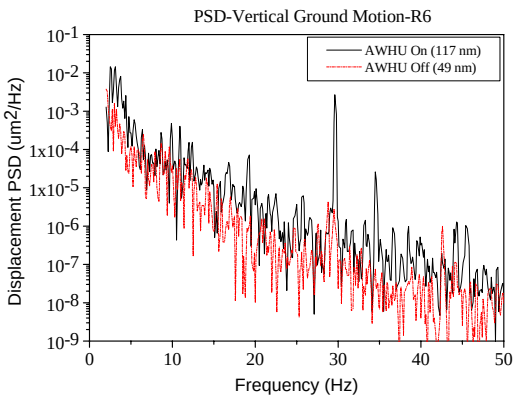

Figure 3. Vertical Ground Motion with AWHU On and Off on Floor R6

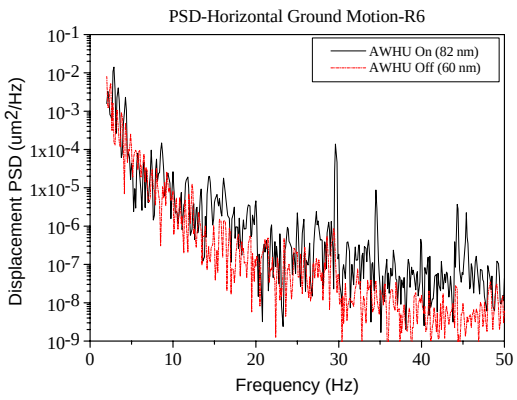

Figure 4. Horizontal Ground Motion with AWHU On and Of on Floor R6

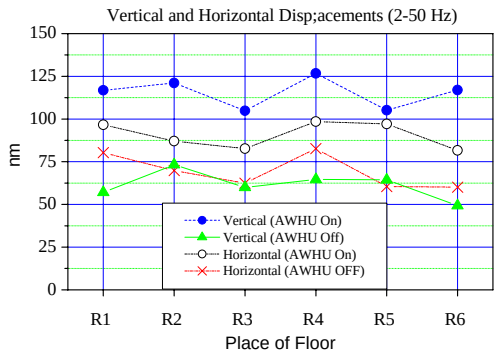

Figure 5. Ground Motion with AWHU On and Off on the Storage Ring Floor

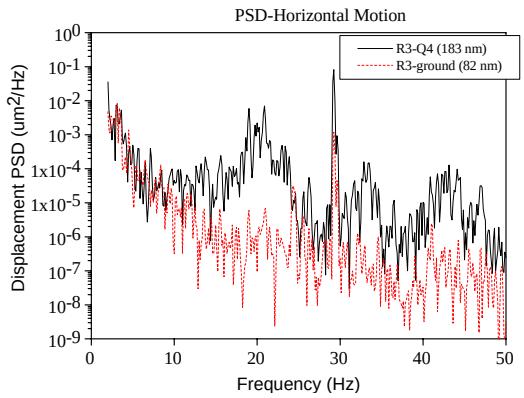

Figure 6. R3 Floor and R3Q4 Magnet Moving Horizontally

Figures 3 and 4 plot the PSDs of the floor in the storage ring. The main peak frequency is 29.6 Hz, and is induced by the heavy water-chiller, located in the utility building. When the AWHU was on, the rms displacements were increased by an average factor of around 1.9 vertically and around 1.3 horizontally (Fig. 5). The 29.6 Hz frequency of the ground vibration is that of the e-beam motion.

The storage ring everywhere exhibits a 29.6 Hz ground vibration, but only the R3 floor exhibits the 29.3 Hz vibration, because a mechanical vacuum pump is being temporarily used under the R3Q4 magnet. Figure 6 reveals that the amplitude of the 29.3 Hz vibration exceeds that of the 29.6 Hz vibration, both for the R3 floor and for the R3Q4 magnet. The ground vibration source induces the 29.3 Hz e-beam motion.

3.2. Vibration of Magnet

The horizontal ground vibration exhibits no clear peak amplitude at 16.6 or 19.5 Hz. The vibrations of the components of the magnet are thus investigated. The vibrations of the ID, the dipole, the quadrupole, the sextupole and the correcting magnet were measured, but only that of the quadrupole magnet is critical. The dipole magnet and the ID are very heavy, and their amplitudes of vibration are almost the same as that of the ground. Figure 7 plots the rms displacements of the quadrupole magnet, and indicates that some quadrupole magnets have larger amplitude of vibration, such as R2Q4, R3Q6, R3Q7 and R3Q8.

The R3Q6, R3Q7 and R3Q8 magnets are on the same girder and near the RF system. R3Q678 represents the three Quadrupole magnets. When the flow of the cooling water in the RF system is turned off, the amplitude of vibration of R3Q678 declines to the same level as that of the other quadrupole magnet (Figs. 8-9). However, Fig. 9 reveals that two peak frequencies 16.6 and 26.6 Hz in the horizontal direction remain¸ and these are not only related to RF water flow. The frequency response (Fig. 10) indicates that 16.6 Hz is the frequency of the first natural mode. Mode shape analysis demonstrates 26.6Hz is the frequency of the second natural mode [9]. The R2Q4 and R3Q4 magnets exhibit similar frequency responses (Fig. 11); the frequency of the first natural mode of each is 19.5 Hz. The peak frequency of magnet motion in the horizontal direction is the same as the frequency of natural mode of the magnet. If the frequency of the small ground vibration is close to the frequency of natural mode of the magnet, the vibration of the magnet will be increased.

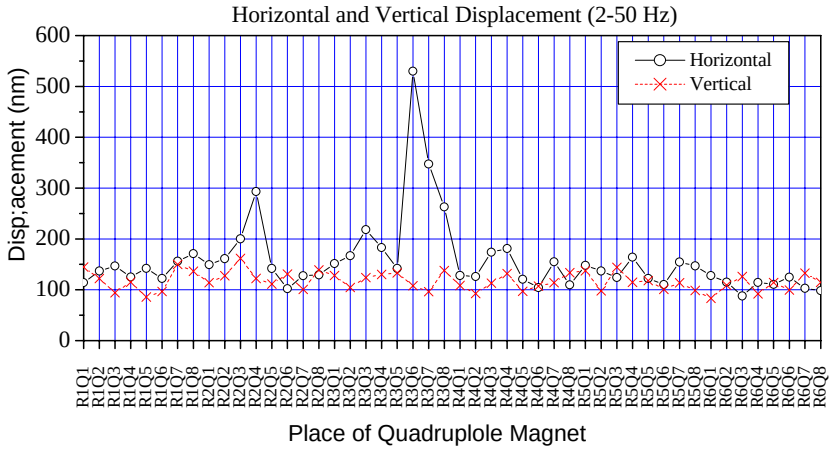

Figure 7. Displacement of the Magnet with AWHU On and Off

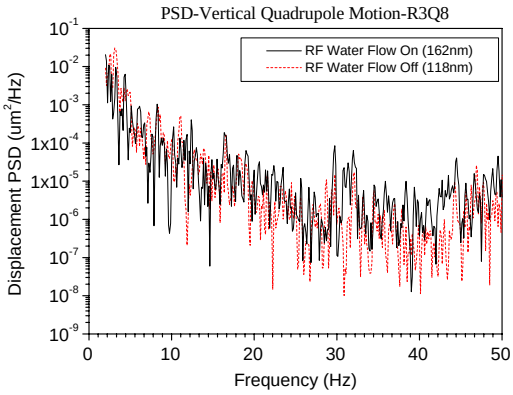

Figure 8. Vertical R3Q8 Magnet Motion with RF Cooling-Water-Flow On and Off

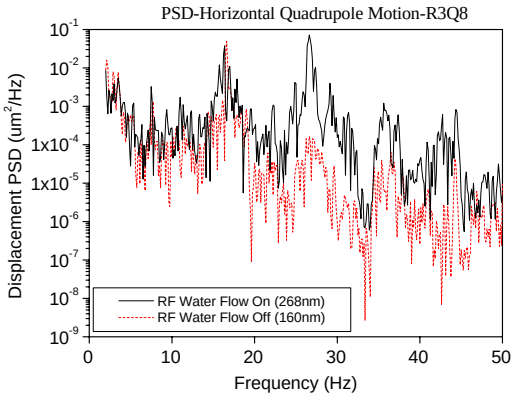

Figure 9. Horizontal R3Q8 Magnet Motion with RF Cooling-Water-Flow On and Off

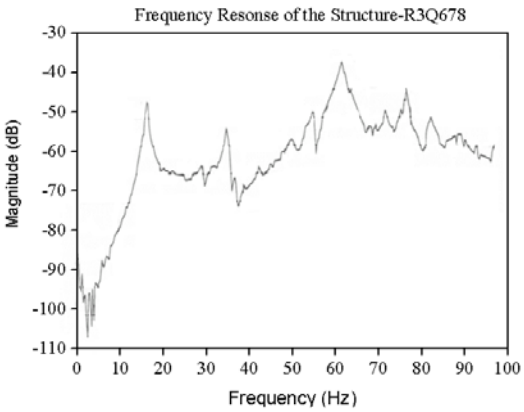

Figure 10. Frequency Response of the R3Q678

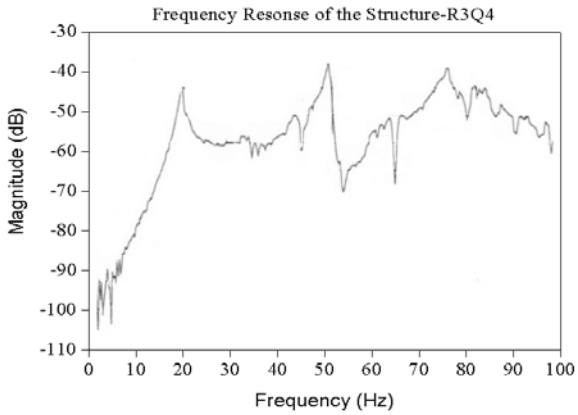

Figure 11. Frequency Response of the R3Q4

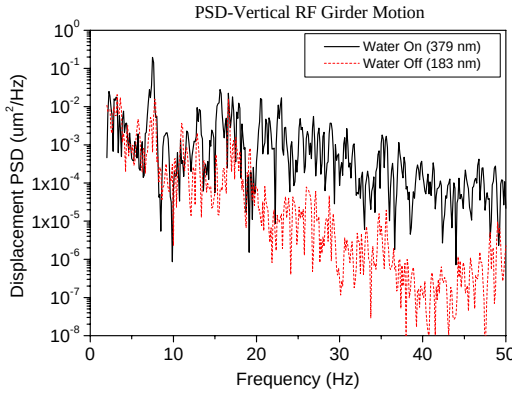

Figure 12. Vertical RF-girder Motion with RF Cooling-Water-Flow On and Off

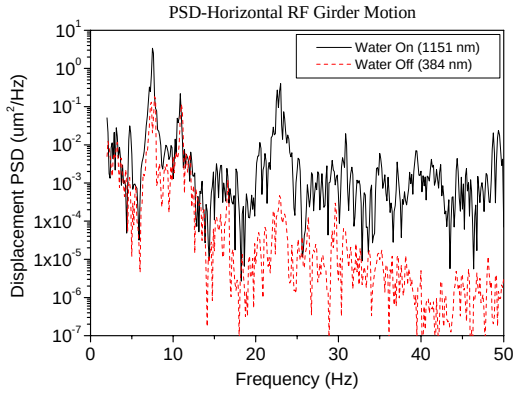

Figure 13. Horizontal RF-girder Motion with RF Cooling-Water-Flow On and Off

3.3. Water Flow Vibration

Turning off the flow of the cooling water at the dipole, the quadrupole and the sextupole magnets, has almost no effect on vibrations, except on that of the R3Q678, as stated in section 3.2. The ground vibration of the RF floor is similar to that of other floors in the storage ring. The RF girder vibrates strongly, regardless of whether the cooling water flow is on or off (Figs. 12-13), but this vibration does not detectably affect the motion of the e-beam, because the RF system is not sensitive to low frequencies.

4. Conclusion

The main source of ground vibration is the water-chiller, which has large vibration energy. The AHU is the second source of ground vibration. The third vibration sources are the mechanical vacuum pump and the water flow. The vibration of the AHU was reduced, but the vibration of the water-chiller requires further investigation.

The vibration sources of the mainly vertical motion of the e-beam are the heavy water-chiller and the mechanical vacuum pump. Preferably, no mechanical vacuum pump should be installed near the quadrupole magnet. The sources of the mainly horizontal vibration of the e-beam are the AHU and the water flow. The frequency of the first natural mode should be as high as possible.

The magnet girder is being newly designed, and the natural resonance frequency analyzed using a commercial finite element program, to increase the stiffness of the quadrupole magnet girder and reduce the vibration amplitude of the e-beam.

5. Acknowledge

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6. References

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