The Ground Vibrations Measurement at SSRF Site and Their Effect Evaluation

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Abstract

Shanghai Synchrotron Radiation Facility (SSRF) is a 3rd generation light source which is now under construction. In order to give full scope of its ability, it has to be operated in very stable conditions. Even slight movements of magnetic elements of the accelerator may lead to problems with beam stability.

It is a very challenging task to build an advanced 3rd generation light source on soft soil at urban Shanghai area where over 300 meters deep alluvion has an amplified effect on microseism, and the activities caused by the dense population give rise to high level cultural noises.

Vibration measurements have been carried out at SSRF site as a collaboration between SSRF and DESY. Both sides used their own measurement systems and data processing programs, and the results match well by comparison.

The predicted effect of the vibration on the SSRF lattice is also calculated.

1. Introduction

Shanghai Synchrotron Radiation Facility (SSRF) is a 3rd generation light source which locates in urban Shanghai area. The metropolis is one of the most bustling cities in the world with a population over 17 millions, busy traffic day and night, countless factories, harbours, and construction sites. All these lead to a high level of cultural noisy.

To make thing more complicated, Shanghai is at the exit of Yangtze River which flows west-eastern to the East Sea, and the area is in an alluvial delta with soft silt over 300 meters deep. This kind of soil has an amplified effect on microseism.

It is a very challenging task to build the light source on these cultural and geological conditions. In order to understand the ground vibration at the site, evaluate its effect on the beam stability, and to consider the possible measures to damp it, several measurement campaigns have been performed, among them, one is at SSRF site carried out as a collaboration between SSRF and DESY, and the other is on storage ring girder-magnet assembly. This paper presents these 2 measurement results. The predicted effect of the vibration on the SSRF lattice is also calculated.

2. Measurement Devices and Data Analysis

Vibration measurements have been performed at SSRF site at the same time by SSRF and DESY. The DESY part used 4 sensors: 2 CMG-6T and 2 CMG-3T, the former has a frequency range 60s-80Hz, and the latter 120s-80Hz. Every sensor has its own data acquisition system integrated in it, and the signal can be recorded in hard disk of a notebook by software SCREAM!. The SSRF part used 2 sensors: CMG-3ESP, which has a frequency range 60s-80Hz, and has a separate data acquisition system Ref Tek 130-01/6. The Guralp CMG series sensors are state-of-the-art high-resolution seismometers which measure velocity versus time along three axes. The GPS clocks were used to synchronization between sensors.

The data analysis is briefly reviewed here. The vibration velocity $v(t_n)$ is measured at the discrete times $t_n = n\Delta t$,with $n = 1,2,\cdots,N$ .The sampling rate is 200 sps, so $\Delta t = 0.005$ s. The power spectral density of $v(t_n)$ is defined as:

$$S_v(f_k) = \frac{2\Delta t}{N}\left|\sum_{n=1}^{N} v(n)e^{-i2\pi kn/N}\right|^2 \tag{1}$$

And the displacement power spectral density(PSD) $S_x(f_k)$ is related to $S_v(f_k)$ by:

$$S_x(f_k) = \frac{1}{4\pi f^2} S_v(f_k) = \frac{N\Delta t^3}{2\pi^2 k^2}\left|\sum_{n=1}^{N} v(n)e^{-i2\pi kn/N}\right|^2 \tag{2}$$

The integrated RMS displacement $\bar{x}(f)$ is given by:

$$\bar{x}(f) = \sqrt{\frac{1}{N\Delta t}\sum_{f_k}^{f_{\max}} S_x(f_k)} \tag{3}$$

where $f_{\max}$ corresponds to the largest measurable frequency.

The coherence function is defined as:

$$C_{xy}(f) = \frac{\left|S_{xy}(f)\right|^2}{S_x(f)S_y(f)}\,. \tag{4}$$

where S_x and S_y are auto power spectral densities for signals of two different measurement points respectively, and S_{xy} is their cross power spectral density.

3. Measurement results

3.1. *Measurement results of SSRF site*

Two measurement points were located at the concrete slab of experimental hall area. The distance between them is about 30 meters. The total data taking time at SSRF site is approximately 48 hours during ongoing construction work. In order to eliminate the noises caused by the construction work, it was stopped for 24 hours from 8:00 pm 17 to 8:00 pm 18 November.

The example results of vertical component power spectral densities and integrated RMS displacements ($f \geq 1Hz$) for quiet and noisy time are shown in Figure.1 and Figure. 2.

The RMS displacement versus time is shown in Figure.3, and the coherence function for vertical components of the two points is shown in Figure. 4.

Figure 1-2 show that the site features (1) clear microseismic peak at 0.23Hz and clear second microseismic peak at 0.64Hz, (2) typical sharp peaks around 1.3Hz (one or two), the frequency is not constant, and it is hard to explain their origin, (3) strong cultural noise above 1.5 Hz, the amplitude of the noise at daytime(noisy time) is much larger than that at night(quiet time), the 2.5Hz peak is the main peak of the cultural noise which caused by heavy traffics, see table 1.

Table 1 Frequencies and Integrated displacement at quiet and noisy time

	Frequencies(Hz)	Integrated displacement(μ m)
Quiet time	0.23,0.64,1.3,2.5	0.122
Noisy time	0.23,0.64,1.3,2.5	0.481

Figure 3 shows the RMS displacement is “quiet” during the night, maximum in the morning and has large fluctuations during noisy times. Figure 4 shows good “correlation” for 30m distance up to about 2Hz.

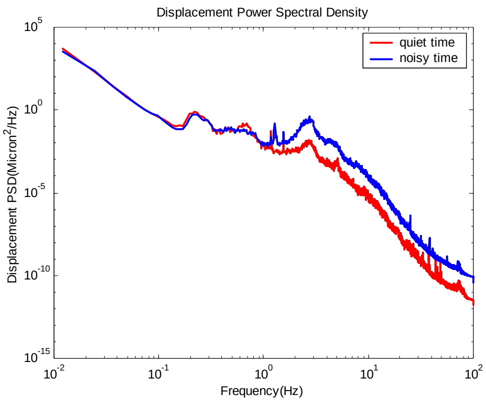

Figure. 1 Displacement Power Spectral Density for vertical component for quiet time and noisy time

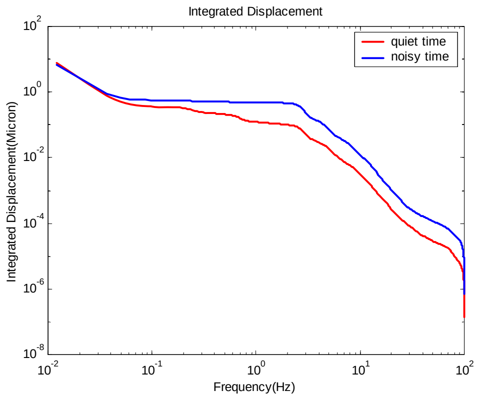

Figure. 2 Integrated Displacement at quiet time and noisy time

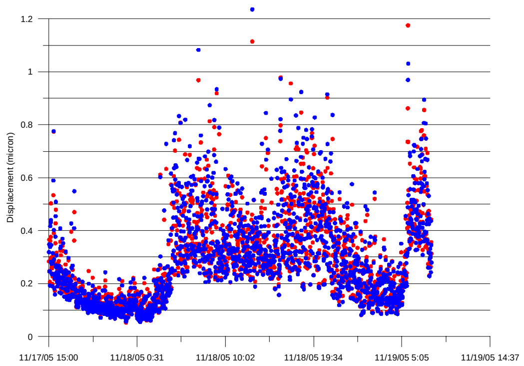

Figure. 3 RMS displacement versus time

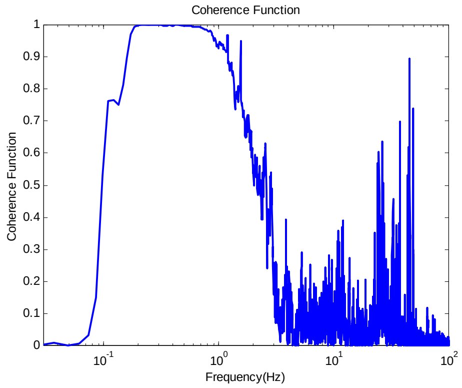

Figure. 4 The coherence function between two points

3.2. *Measurement results of girder-magnet assembly prototype*

A storage ring girder-magnet assembly prototype has been manufactured, and a vibration measurement has been performed for it. The sensors are 2 CMG-3ESP's, one is put on the ground near the girder support, the other on the one of the magnets.

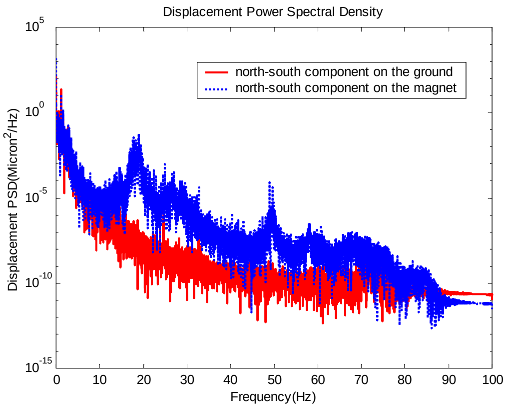

Figure. 5 Displacement PSD for north-south components on the ground and on the magnet

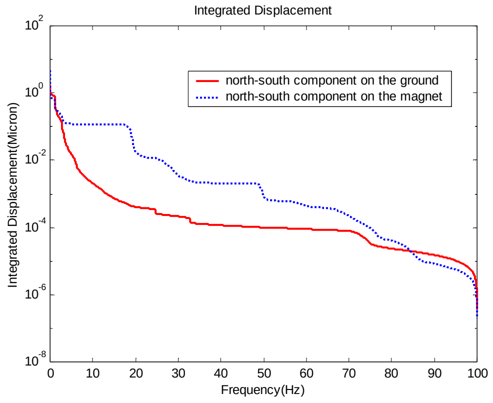

Figure. 6 Integrated Displacement for north-south components on the ground and on the magnet

Figure 5-6 show the girder-magnet system has an amplified effect on the ground vibration above 1.5Hz, especially for $f > 10Hz$. There is a very big peak around 18Hz which may be caused by wedge and ball bearing support system of the girder.

3.3. *The predicted effect of the vibration*

Ground vibration can propagate through girder which usually has an amplification effect for higher frequencies, then cause movement of quadrupoles, and in turn, closed orbit distortion (COD). Big COD will lead to problem of electron beam stability, and consequently the effective emittance growth and brightness degradation. The calculation shows the ratio of magnet transverse motion to the resultant electron beam motion, which is called amplification factor, can be far above 10 (see Table 2).

Table 2 COD tolerance and amplification factor

Straight Type	COD Tolerance (μm)		Amplification Factor	
	Horizontal	Vertical	Horizontal	Vertical
Standard	16	1	34	16
Long	23	2	56	25

Note: COD tolerance is 10% of the beam size

It can be seen from table 2 that COD due to ground vibration greatly exceeds the tolerance. So careful design, modelling and test of the girder are necessary. And when needed, use the measures of vibration isolation and damping.

References

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