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GROUND MOTION MEASUREMENT AND ANALYSIS FOR HEPS *

Fang Yan[1†], Gang Xu[1], Zhizhuo Wang[1], Zhe Duan[1], Yuanyuan Wei[1], Daheng Ji[1], Yi Jiao[1]
Hanwen Zuo[2]
[1]Key Laboratory of Particle Acceleration Physics and Technology,
Institute of High Energy Physics (IHEP), Chinese Academy of Sciences 100049, Beijing, China
[2.]China Electronic Enginerring Design Institute (CEEDI), Beijing 100142, China

Abstract

HEPS have very challenging beam stability requirements. Special cares are mandatory in developing site vibration specifications, stable building design concepts, and passive and active ways to minimize effects on the stability of the photon beam and critical accelerator and beamline components caused by ambient ground motion sources. However, among all these work, reasonable assessment of the vibration induced beam instability has to be the first step. This paper will focuses on the measurement results of the ground motion on HEPS site, the establishment of reasonable beam dynamic models, the influences of ground motion to the beam of main ring.

INTRODUCTION

Currently, the low emittance storage ring has considered being the future development direction of the photo sources. However, with the decreasing of the designed emittance of the ring, the problems caused by the ambient ground motion have been increasingly highlighted. Delicate research has to be done during the design stage for the inducing beam instabilities caused by those sources. HEPS has a very challenging beam stability requirements with the transverse beam emittance specification of 0.1 nm.rad and designed natural emittance of ~0.03nm.rad while the effective vertical emittance of ~5pm.rad [1-2]. To ensure the stability of the beam on the experimental station, the vibration caused beam size increment has to be controlled being smaller than 10% of the RMS beam size. Thus, according to the current designed 34pm.rad lattice, the RMS beam position and angular motion has to be smaller than 1μm & 0.2μrad, 0.3μm & 0.1μrad, transverse and longitudinal respectively. [2] Special cares are mandatory in developing site vibration specifications, stable building design concepts, and passive and active ways to minimize effects on the stability of the photon beam and critical accelerator and beamline components caused by ambient ground motion sources.

Among all these work, investigating the vibration influence to the beam has to be the first step, reasonable model has to be set up to do the analyzation. According to the different sources, we divide the vibration into two categories. One is the ground motion of the HEPS site, it could be treated as a plane wave, as the ground motion is caused by the vibration source far away from the HEPS site. Other ambient motions could be treated as point sources. The vibration amplitude attenuate with distance as it propagates along the ground from the source to each element of the main ring with certain speed. The ambient ground motions caused by all sources transmit through the slab and girder-magnet assembling inducing orbit instability of beam.

GROUND MOTION OF THE HEPS SITE

The ambient ground motion include ground motion of the HEPS site and other ambient motions caused by critical vibration sources around the HEPS ring including utilities (such as pump, compressor, air conditioner et. al), machine related vibrations sources (such as pulsed booster magnet, water flow et. al) and cultural noises which has day-night cycle (such as traffic and other human activities). This paper will only focus on the former one.

PSD Spectrum

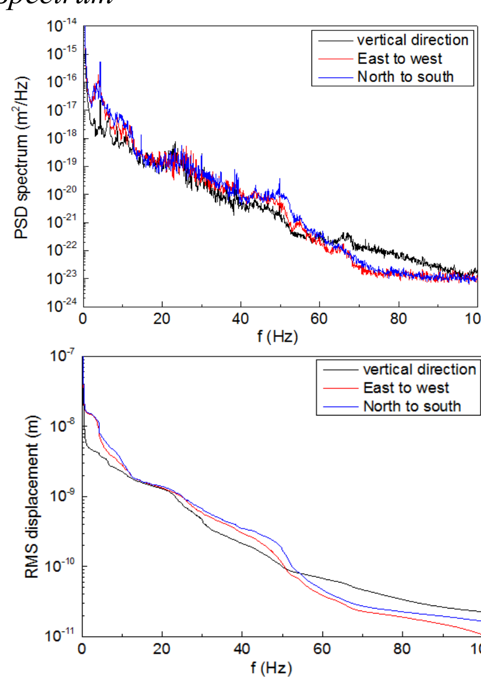

Figure 1: The ground motion measurement results of HEPS site: PSD spectrum in three directions (upper graph) and the RMS integral over 1Hz up to100Hz in three directions (below graph).

The HEPS site is located in Huairou of Beijing, it is relatively quiet, no major traffic and industrial activities around. The ground is covered by agriculture soil currently. Fig. 1 shows the spectral displacement in vertical (z), North-South (n), East-West (e) directions. The vibrations in the three directions are quite similar. The RMS displacement integral (1Hz-100Hz) are 6, 16 and 17nm on z, e and n direction respectively. CMG type seismometers as shown in Fig. 2 are used for the measurement.

† yanfang@ihep.ac.cn

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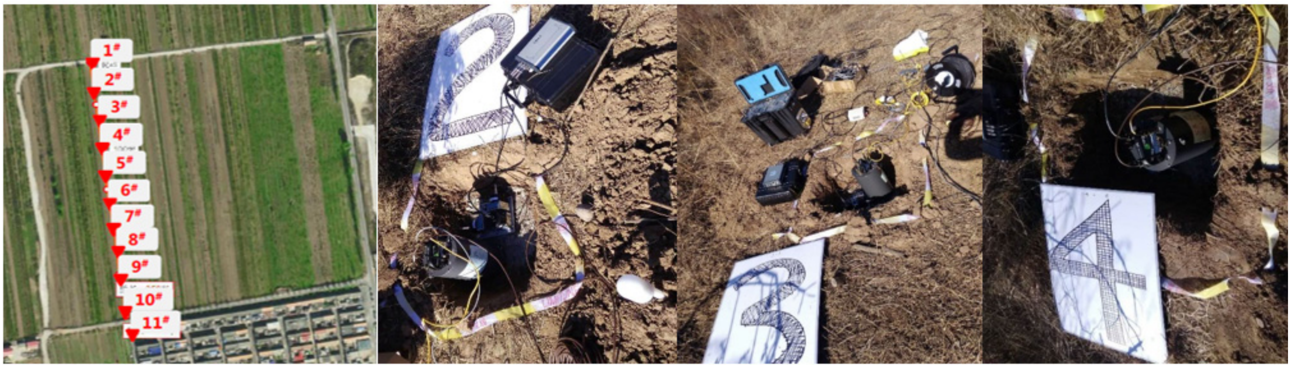

Figure 3: The positions of eleven pits distributed on HEPS site for ground motion measurement (left), the IHEP seismometers in the hole for the wave velocity measurement (middle and right graph).

Figure 2: The seismometers used for the ground motion measurement of HEPS.

Wave Velocity & Decay Factor

The beam orbit vibration is closely related to the wave velocity of the vibration as will be described in the next section. And the wave velocity is different for different geology conditions. We use three CMG seismometers equipped with GPS for the wave velocity measurement and five monitors for the decay factor measurement. The time accuracy of the seismometer with GPS is 10^{-9} s. The sampling rate could be 1000Hz, corresponding to 1000 collecting points within one second. Cooperating with CEEDI institute, we dug eleven holes to accommodate the monitors as shown in Fig 3 (left figure) and cover with plate on the top to avoid impacting of wind. The distance between the holes is 30 m. The five seismometers equipped with GPS are placed in the 2#, 3#, 4#, 6#, 8# holes. A truck loaded with ~30t construction waste were arranged to go through in the vertical direction of the measurement line. When the truck going through, the vibration caused by the truck at 1# position decay along the measurement line because of long distance.

The wave velocity of HEPS site is estimated to be smaller than 2500m/s (max. wave velocity in clay), so the at least time for the wave propagation from one seismometer to another is more than 12ms. The seismometer sampling rate in used was 500Hz during the measurement, corresponding to collecting one point in every 2ms. The time resolution in used is enough for the measurement.

After analyzation, the wave velocity on HEPS site is confirmed to be 268m/s for the vibration in vertical direction and this value is very close to the shear wave velocity (193m/s) according to the initial survey of HEPS ground [3]. Shifting the vibration wave measured by last four monitors according to the above mentioned wave velocity, the vibration PSD spectrum at five measurement points when truck crossing 1# position (averaged over time range of one second) is shown in Fig. 4. The RMS displacement integral measured by five detectors over 1Hz-100Hz are plotted in Fig. 5 (the black points), the decay factor (68.6) has been obtained by fitting curve of the five data points.

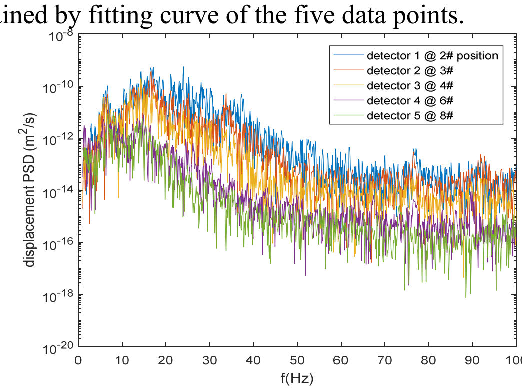

Figure 4: Vertical PSD spectrum of ground motion measured by five seismometers placed in 2#, 3#, 4#, 6#, 8# holes.

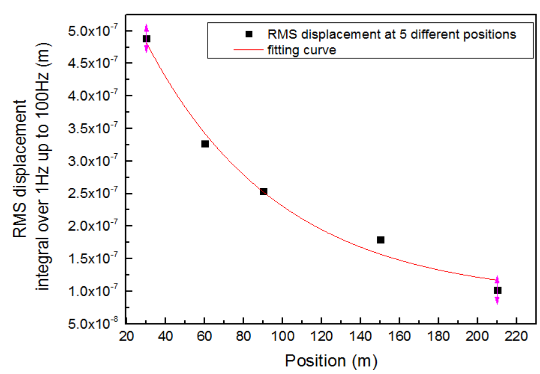

Figure 5: RMS displacement vertically at 5 measurement points on HEPS ground when truck crossing 1# position and the vibration wave decay factor.

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BEAM DYNAMICS OF GROUND MOTIONS WITH FREQUENCY OF 1HZ UP TO 100HZ

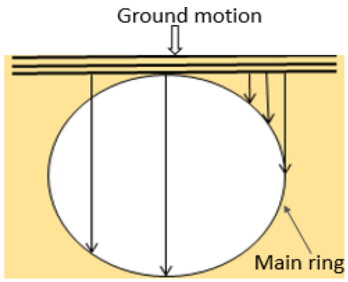

Figure 6: Schematic beam dynamics model ground motion.

Ground motion cause optic displacement and beam orbit deviation in the HEPS ring. The schematic beam dynamics model shows in figure 6. The ground motion propagate as a plane wave and the main ring is approximated as a circle. The displacement of each element is determined by the mo-ment vibration arrived and the frequency of the vibration. And the time vibration arrived is determined by the dis-tance between the vibration source to the element and the wave velocity of the motion on HEPS site as having been introduced in the above section.

The beam dynamic analysis for the orbit distortion have been carried out for the ground motion of HEPS from 1Hz-100Hz. Closed orbit are calculated by AT program after im-planting the time varied displacements for each single fre-quency with step of 0.1Hz. The beam orbit at all critical positions including insert device (ID) positions and dipole radiator positions of the HEPS ring are monitored. The maximum beam orbits along the main ring for each fre-quency are traced after scanning initial phase from 0 to 360 degree and plotted for different wave velocities of 268m/s, 700m/s, 1500m/s as shown in Fig. 7. The top graph show-ing that the lattice sensitive frequency range is 10-50 Hz with wave speed of 268m/s. The Eigen-frequency of the hardware designed and manufactured should at least been avoided being sitting in this range. For higher wave veloc-ity the sensitive frequency range goes up and the amplitude of the maximum orbit goes down in both horizontal and vertical directions as shown in the middle and below graph of Fig. 7. From Fig. 7, we can tell that beam is more sensi-tive to element displacements with lower wave velocity than higher. However, the wave velocity is mainly deter-mined by the geology conditions, could not be easily changed. The slab of main ring might have improvement as the wave velocity in the slab is usually 2000m/s or even higher, but the effect is needed to be further investigated.

The situation is the same for the amplification factors. Higher wave velocity gives smaller amplification factor both in horizontal & vertical direction. Figure 8 shows the maximum amplification factor (maximum beam orbit over optic displacement) with wave velocity of 286m/s without Fast Orbit FeedBack (FOFB).

CONCLUSION

The ground motion measurements of the HEPS site has been carried out. The beam dynamics for the actual meas-ured PSD spectrum of HEPS ground have been carried out to determine the sensitive frequency range. Later, the girder will be will be introduced in the simulations. The FOFB system will be introduced in and the beam orbit will be simulated and corrected by the FOFB system, the beam vibrations size will be compared with the 10% rms beam size. The maximum allowed ground motion specification will be determined accordingly.

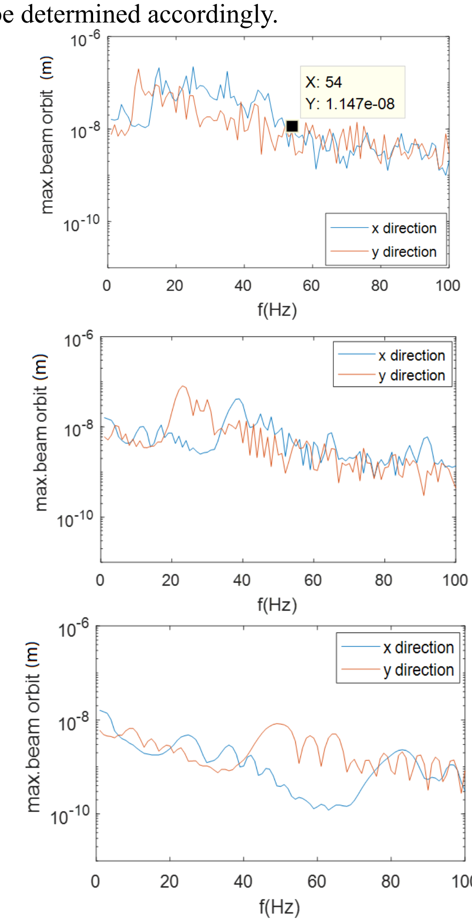

Figure 7: The maximum beam orbit over frequency for different wave velocities of 268m/s (top graph), 700m/s (middle graph), 1500m/s (below graph).

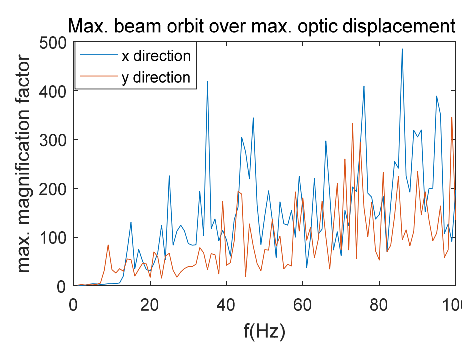

Figure 8: Maximum amplification factor with wave velocity of 286m/s.

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