The Study of Seismic Vibration of SR Source "Zelenograd"

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Abstract

The measurement results of ground displacement in the frequency range from 0.1 to 100 Hz on the site of the SR source "Zelenograd" (Moscow) are presented. The data acquisition system and digital signal processing software are described. The computed amplitude spectra and correlation functions of vibrations are analyzed. Some models: uncorrelated ground motion and plane waves are investigated. The experimental results allow to estimate the effects of the ground motion on SR beam stability.

I. INTRODUCTION

The successful performance of experiments using high brilliant SR from a low-emittance light source calls for tough tolerancies to the orbit stability. Among many sources of time dependent closed orbit distortion (power supplies ripple, temperature gradient, etc.) the mechanical vibration of the magnetic elements has an essential effect on beam stability because of the strong optics and rather large amplification factor of the low-emittance lattice. Consequently, in the designing of high brilliant light rings, it becomes of great importance to analyze the effect of ground motion and find a way for effective elimination or control of the vibration to restrict orbit instabilities to an acceptable level. The dedicated SR source "Zelenograd" is a low-emittance 1.5-1.9 GeV storage ring intended for industrial application [1]. It has six-fold symmetry lattice with 115.7 m circumference. The horizontal emittance of the electron beam at 1.5 GeV is as small as 2.7×10^{-8}m-rad. Ten 3-m-long straight sections are optimized for insertion devices (including undulators and high field superconducting wigglers).

II. DISTORTION TOLERANCES

Due to the vibration of quadrupole lenses the error fields deflect the particle orbit. As the vibration frequencies (0.1-100 Hz) are much less than the revolution frequency, we can consider the orbit distortion caused by the constant displacement of magnetic elements. But the observer, who performs experiments using SR beam will see a time-dependent angular and positional displacement of the light source. If the duration of experiment is much more than the vibration period, the source displacement will lead to the growth of an "effective" emittance and to the reduction of the brightness [2]. If the vibration period is about the same as the experiment duration, there will be slow change in experiment conditions (radiation wavelength, flux, polarization, etc.) with time. In our case, the SR users requirement can be written as: $< z' > / \psi \leq 5$ %, where $< z' >$ is an effective angular deviation of the source point (rms) and ψ is the natural SR angular divergency. The above requirement corresponds to a 10 % emittance growth. For the case of the radiation from undulator (poles number $N = 24$) at 1.7 GeV energy $\psi = 1/\gamma\sqrt{N} = 60\mu$rad and $< z' >= 3\mu$rad. With the beta-function at the radiation point $\beta = 8$ m, the effective orbit disturbance can be estimated as $< z > \simeq 20\mu$m.

III. INSTRUMENTATION AND SOFTWARE

The industrial seismometer SM3-KV [3] is used to measure the ground vibration amplitudes. The ratio of the signal voltage to the displacement within the frequency range f = 0.1-100 Hz obeys the dependence $U/X = 5.2 \times 10^5 f$ [V/m]. CAMAC standard was chosen for the control electronics: a microcomputer, an ADC unit, a timer, etc. The measured data are treated by a set of codes running on IBM PC/AT under the MS-Windows. The features of the treatment are: Fourier analysis, signal correlation functions calculation, quadrupole displacement magnification factor calculation, etc.

IV. MEASUREMENTS

The vibration spectrum was measured in the 0.5-250 Hz range, with a frequency resolution equal to 0.5 Hz (the measurement frequency is 500 Hz, points number is 1024 and the total measurement time is 2 s). The ring foundation is a solid concrete mat which has no connection with the building walls. The seismometers were placed on the ring foundation. The data were averaged over 16 measurements. First, the correlation of vertical vibration was studied for two detectors at a distance of 0, 10 and 30 m between them. For adjacent detectors, the correlation function is close to unity within the 1-70 Hz range. As the distance increases, the frequency range where correlation is observed reduces. The vibration spectra were taken in different periods of the day. In particular, the effects of several local sources were under investigation. For example, Figure 1 demonstrates the growth of the amplitude of vertical vibration if a 10 t crane is in service in the storage ring building.

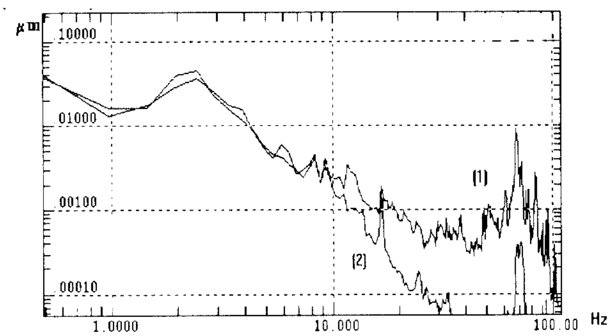

Figure 1: The vibration amplitude spectrum in the vertical plane, with the crane being run (1) and when it is idle (2).

V. MAGNETS DISPLACEMENT MODELS

For a strong focusing lattice of low emittance rings a major source of orbit distortion is the transverse shift of quadrupoles δz. The vertical closed orbit displacement (COD) at position s where $\beta(s)$ and $\phi(s)$ are the betatron function and the betatron phase respectively is given by:

$$z(s)=\sqrt{\beta}(s)/2sin(\pi\nu)\Sigma_i(\sqrt{\beta}_i k_i l_i \delta z_i \cos(|\phi(s)-\phi_i|-\pi\nu)) \ (1)$$

Here β_i and ϕ_i are the betatron amplitudes and phase for the i-th lens with the strength k_i and length l_i ; ν is the vertical betatron tune.

Two models were under studies:

i) the lenses are randomly displaced, with the rms deviation, $< \delta z >$. For this case, the rms COD $< z(s) >$ is determined by:

$< z(s) >= P < \delta z >$, (2)

where P is the COD magnification factor:

$P = \sqrt{\beta}(s)/(2\sqrt{2}\sin(\pi\nu))\sqrt{\Sigma_i\beta_i k_i^2 l_i^2}$.

For the middle of the straight intended for undulator $P = 35$.

ii) The displacement of quadrupole lenses is caused by the plane wave propagating in the ground. This is true for a vibration source being far apart from the object to be examined. Of significance is to analyse the dependence of the magnification factor on the vibration frequency and to calculate the COD for a particular spectrum of vibrations. In the case of plane waves, the i-th lens is displaced depending on the the direction of wave propagation, the wavelength and the position of the lens over the azimuth of the storage ring:

$\delta z_i = A\cos(\omega t + (1 - \cos\vartheta_i)2\pi R/\lambda))$, (3)

where A,ω , and λ are the amplitude, frequency and length of the wave, ϑ_i is the angle between the wave propagation direction and the azimuth of the i-th lens (the lenses are assumed to be positioned over a circle with radius R).

According to (1) and (3), the displacement and the angular deviation of the closed orbit at point s are:

$z(s) = AP(\omega, \vartheta))$ (4)

$z'(s) = AP(\omega, \vartheta)\sqrt{1 + \alpha^2(s)} \ /\beta(s)$ (5)

where $P(\omega, \vartheta)$ is the plane wave magnification factor. Figure 2 shows the results of calculation of the magnification factor P in the case of random displacements of quadrupole lenses and the plane wave magnification factor $P(\omega, \vartheta)$ as a function of the wave frequency at a wave velocity of 1000 m/s.

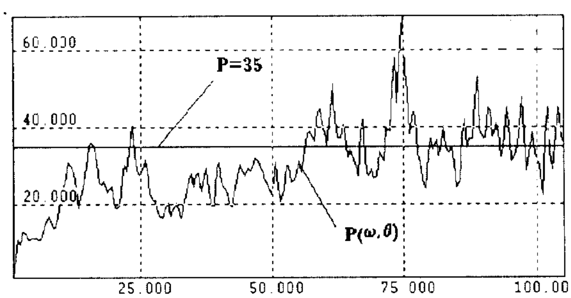

Figure 2: The error magnification factors.

Figure 3 gives the ϑ -averaged amplitude spectrum of ground vibration which was measured on the ring site and the vertical COD at the observation point in the middle of the undulator straight section.

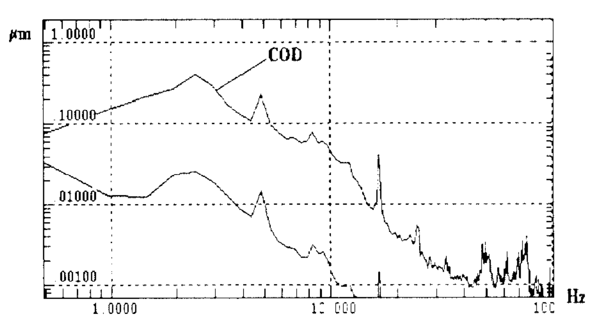

Figure 3: The spectrum of vibrations and COD.

The maximum displacement and angular deviations of the closed orbit in the vertical plane occurred at the frequency 2.5 Hz: $z = 0.6\mu$m and $z' = 0.3\mu$rad.

VI. Conclusions

The developed instrumentation and software make it possible to measure the spectrum of the microseismic vibrations and calculate COD due to the transverse shift of quadrupoles. In our case, the measured results are quite good and they meet the requirements for the beam stability. But when the machine equipment (vacuum pumps, ventillation, compressors, etc.) will be put into operation, it may effects drasticaly the magnet components displacement. The local noise sources and the influence of the magnets supports is planning to be investigated in the near future.

For more detailed information on the subject, please contact us by the address given under the headline or use e-mail: kuzn@ksrs.msk.su

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