DYNAMIC RESPONSE AND FILTERING EFFECTS OF A LIGHT SOURCE ACCELERATOR RING STRUCTURE *

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Abstract

Vibration stability in third generation light sources such as the 3 GeV NSLS II under construction at BNL sets out to achieving high brightness and extremely small photon beam sizes is paramount. Movement of the magnetic elements of the accelerator lattice, and in particular when uncorrelated, will induce jitter in the beam and degrade machine performance. The accelerator lattice response is coupled with the ring structure which in turn interacts with the site and the ground vibration field that characterizes it. Understanding the dynamic coupling between the accelerator ring and the site, and both for amplitude and spectral characteristics, is key in establishing lattice response. In this study, the site-ring dynamic interaction is evaluated based on the NSLS II design and site conditions using a 3-D wave propagation and scattering model. The study is augmented with an extensive array of measurements at the selected site as well as field studies at similar operating light sources.

INTRODUCTION

Third generation light source facilities are characterized by photon beam high brightness and small beam sizes. With smaller emittances in the storage ring the impact of the vibration environment that ultimately affects the magnetic elements in the lattice and induces beam jitter is more pronounced. Understanding the correlation between storage ring floor vibration and eventual electron beam oscillation is of primary importance towards achieving the design beam parameters of a 3rd generation light source. The spectral characteristics of the vibration arriving at the storage ring floor level, in addition to its amplitude, and its relation with the dynamic properties of the ring lattice represent the most important element of this complex relation between lattice movement and beam jitter.

To best describe the relationship between the vibration field at the NSLS II site and the accelerator while enabling the quantification of the storage ring oscillation due to the interaction of the future facility with the undisturbed site, field studies associated with detailed vibration measurements and data analysis have been conducted at a number of light source facilities currently in operation.

Free-field Ground Motion and Site Conditions

Extensive ground motion measurements have been performed at the selected NSLS II site to identify sources of vibration, types of waves that “corrupt” the free-field and estimate amplitudes of ground movement. The latter is used as a basis for lattice stability.

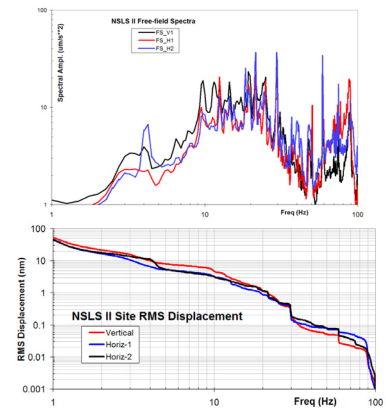

Figure 1: Free-field ground motion at NSLS II.

Figure 1 depicts ground motion spectra (vertical and two horizontal components) as well as rms ground displacement. Important to note is the presence of a unique peak (~5 Hz) in the vertical and one of the horizontal direction (normal to near by shore line and highway) indicating the Rayleigh wave mode. The NSLS II site is characterized by well settled, uniform layer of sand (~1000 ft to bedrock) exhibiting Rayleigh wave velocities of ~740 ft/s (Fig. 2). An acoustic interface exists at ~30 ft below the surface as a result of the water table horizon. Based on the dynamic characteristics of the top layer a wave-guide effect for ***f*** > 5 Hz is anticipated confirming the observations in Fig. 1. Even though the ground vibration is the result of all modes of wave propagation (surface as well as body shear and direct waves) the geophysical conditions and structure of the subsurface points to the fact the surface waves dominate. Of lesser contribution will be vertically propagating shear waves and with minimal contribution towards the total ground motion direct P-waves. Cultural noise expected from accelerator operations is considered separately.

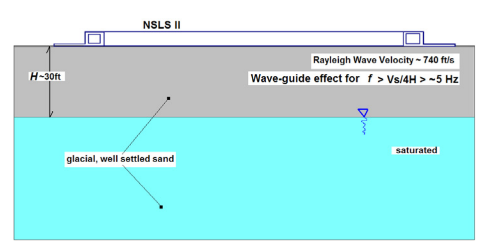

Figure 2: NSLS II site characteristics.

NSLS II Structure

To eliminate the interaction of the NSLS II ring and experimental floor with the superstructure which could be

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the source of additional cultural vibration (wind and thermal effects as well as operation of support systems) and to take advantage of the enhanced filtering of free-field ground vibration expected from a massive, large-scale structure, a “monolithic” structure comprised by the ring and experimental floor was adopted. This de-coupling allows for the sensitive part of the accelerator to be considered a ring structure resting on an elastic foundation. Fig. 3 depicts the separation from the superstructure.

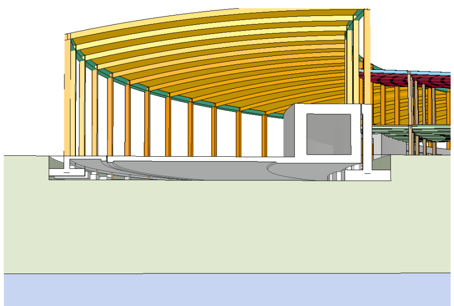

Figure 3: Picture of the NSLS II with superstructure.

SIMULATION OF NSLS II INTERACTION

The primary goal of the study is to allow for the best possible estimate of the vibration on the lattice and experimental floors contributed by the site natural ground vibration. In addition, and based on the assessment of this analysis, deduce information regarding minimal floor mat thicknesses for the ring and experimental floor while ensuring that stability goals set by the e-beam and experimental lines are met.

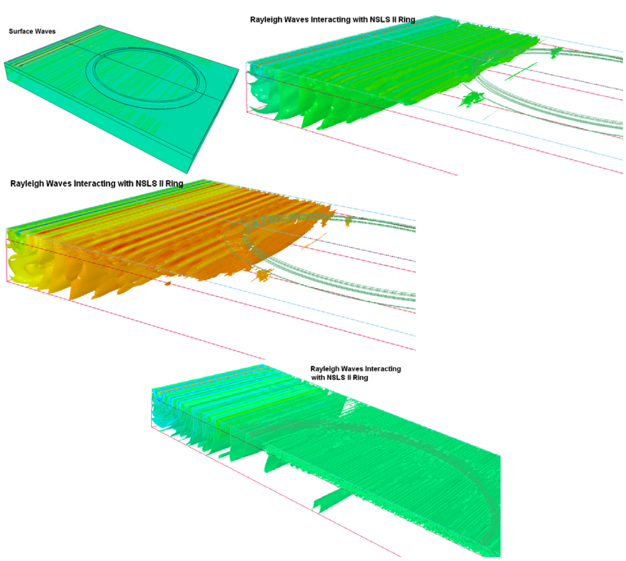

Figure 4: Surface waves interacting with NSLS II.

To study the effects of the different wave modes that affect the site, large-scale models capturing the propagation and scattering have been adopted using the LS-DYNA solver for their analysis. Wave types analyzed include surface (Rayleigh mode), vertically propagating body shear waves and vertically propagating direct waves.

In all cases the spectral composition of the input ground motion reflected the measured spectral characteristics at the site. Fig. 4 depicts the simulation of propagation and interaction of surface waves (dominant mode) with the NSLS II ring. Fig. 5 represents acceleration spectra of the free-field compared with the “filtered” spectra on the experimental and ring floors.

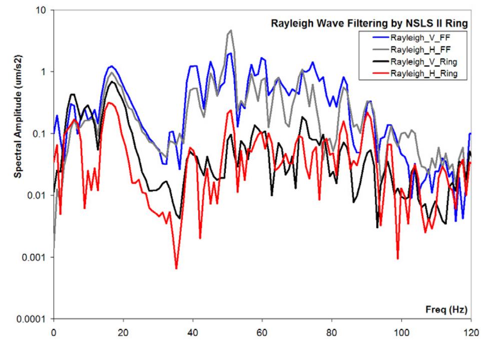

Figure 5: Rayleigh wave filtering by the structure.

The simulation of propagation of upward shear waves and the quantification of “filtering” due to the interaction with the structure are depicted in Figures 6 and 7 respectively. To properly solve the problem, recorded free-field ground motion (horizontal) was de-convoluted to depth from which it was convoluted to the surface with the presence of the accelerator ring. As seen in Fig. 7 “filtering” for this wave mode is effective at frequencies above 30 Hz. The propagation of P-waves are shown in Fig. 8.

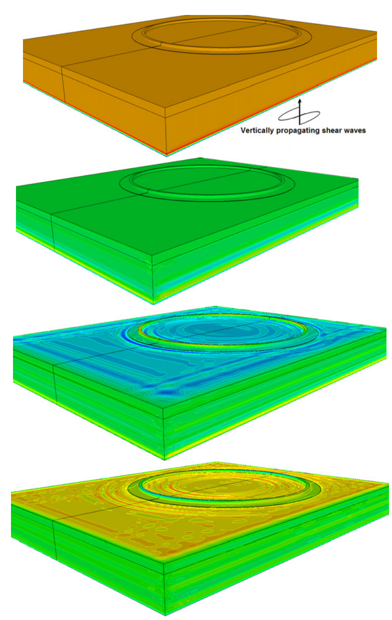

Figure 6: Vertically propagating shear waves (SH).

ESTIMATION OF NSLS II RING MOTION

To arrive at an estimate of the anticipated vibration once the ring/experimental floor structure is placed on the green-field, the results of the simulation studies of different wave modes were used that led to the generation of special transfer functions. Assuming that the free-field ground motions are stationary processes power spectra relations were used to transfer the measured free-field to the accelerator. Fig. 9 depicts both the process and the resulting ring floor rms displacement.

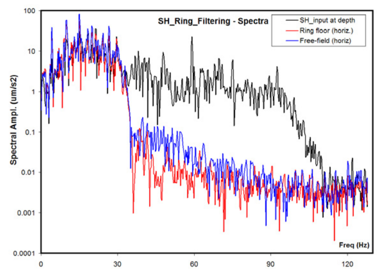

Figure 7: Filtering effects in SH wave propagation.

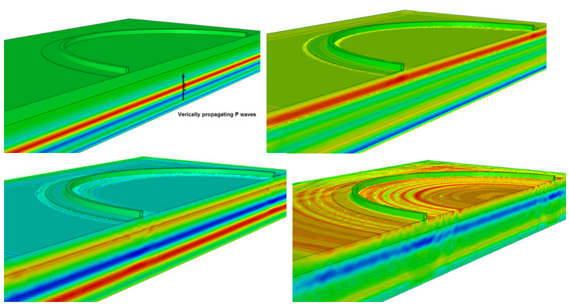

Figure 8: Simulation of upward P-waves and NSLS II.

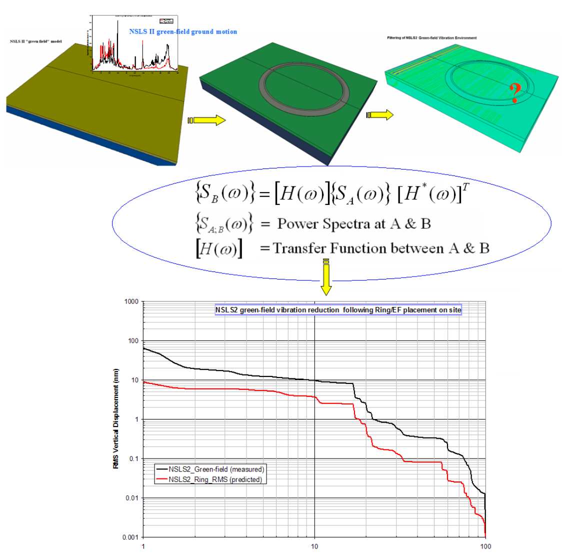

Figure 9: Power spectra relations enabling free-field ground motion transfer to the NSLS II structure (a), and (b) resulting rms displacement on ring floor.

Figure 10 shows the filtering effect measured by the author and observed at two operating light sources (Advanced Photon Source and Diamond Light Source). Important to note is the striking similarity in the way the free-field ground motion is filtered through similar structures (APS and NSLS II).

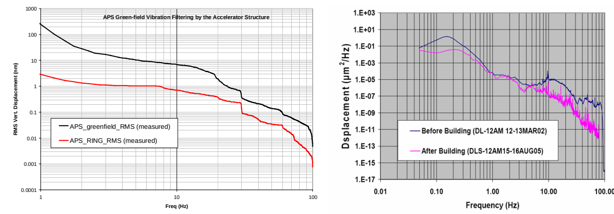

Figure 10: Filtering effects at APS and Diamond LS [2].

The effect of accelerator ring slab thickness on the resulting floor vibration levels has been studied to optimize the thickness without compromising performance. Fig. 11 depicts the theoretical aspect of the relationship between a massive body and the ground vibration. An extensive sensitivity study performed quantified the effect of foundation mat reduction. Fig. 12 shows NSLS II ring floor acceleration comparison for two slab thicknesses (39-inch and 27-inch).

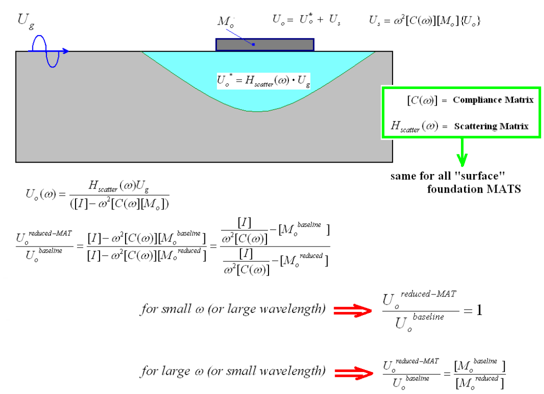

Figure 11: Relations of floor slab thickness effects.

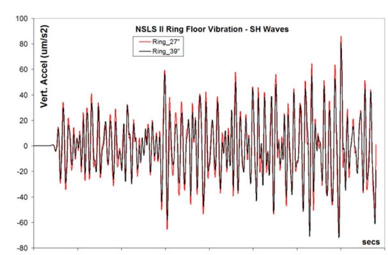

Figure 12: NSLS II ring floor thickness influence.

SUMMARY

Based on large scale wave propagation models the filtering effects of the NSLS II accelerator were addressed and quantified. Experience data and measurements confirmed the validity of the adopted process and showed the potential of simulation-base analysis towards the design of large, vibration-sensitive facilities.

REFERENCES

[1] N. Simos et al. “Ground Motion Studies at NSLS II” Proc. EPAC2008, Paper No. MOPC50, 2008.
[2] H. Huang and J. Kay, “Vibration measurement at Diamond and storage ring response,” EPAC 2006.
[3] LS-DYNA, LSTC Software, Livermore, CA.