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INVESTIGATIONS ON STABILITY PERFORMANCE OF BEAMLINE OPTICS SUPPORTS AT BSRF

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Abstract

The stability of beamline optics directly affects the beamline's performances, such as coherence, focal size, position stability of the beam and so on, it has become a serious issue for a low emittance 4th generation light source. The vibration transmitting function of supports plays a big role in the stability performance of the optics. In order to design better supporting structure, several types of support structures were tested, and the transfer ratio were studied. The result shows that wedge structures generally have a lower transfer ratio, and point contact support structures should be avoided.

INTRODUCTION

HEPS is a new generation light source which aims to reach emittance as low as 60 pm•rad with a circumference of about 1360 m. [1] It started construction in 2019 and will be finished in 2025. With the new light source there will be very small sized source, vibration will be a big challenge for HEPS. The beam position, intensity and focal size are often affected by stability of beamline optics such as monochromators, mirrors, sample stages, optical tables, etc. Those instruments are usually very sensitive to ground vibration, the vibration transfer ratio, or transfer function of their supporting structure, plays a big role in the performance of optics under ground motion and vibration. In order to build better optics for the HEPS project, also to get a better understanding of the issue of stability, investigations were carried out to find out what the common performances are, and provide some basic guidelines regarding design of stable supports.

The following sections will introduce the test conditions, and some results of different optics support.

TEST CONDITIONS AND METHODS

Most of the tests were carried out at BSRF, a first generation light source with about 3 months of dedicated synchrotron mode every year. The ground vibration level is about 18 nm RMS in the range of 1 Hz to 100Hz.

The vibration data was acquired by a DEWESOFT SIRIUSi 8xACC ADC [2], with DYTRAN 3192A and 3191A1 accelerometers [3]. The accelerometers were attached to different layers of optics support and on the ground. Sampling rate is usually set at 2000 Hz or 3000 Hz. The acceleration data then was integrated into RMS displacement. Then by comparing the RMS displacement of upper layer to lower layer, or to the ground, the transfer ratio, or transfer function of the RMS vibration displacement can be obtained. The eigenfrequencies are deducted by the peaks of amplification curve. Due to the noise of the accelerometers at low frequency (<5Hz), the analysis frequency range is defined between 5 Hz to 1000 Hz.

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TEST RESULTS

DCM Support

A DCM prototype shown in Fig. 1 was designed to verify technologies to be used for HEPS [4]. When it was designed, not much consideration in support stability was taken other than a granite table. The support of this DCM granite table are 6 wedges. A steel frame sits on those wedges, supporting a granite table with 6 screw levellers, which has ball bearings to make the adjustment easier. It is not good for high stability, because the ball bearings provide small area of contact, also screw levellers are not strong enough.

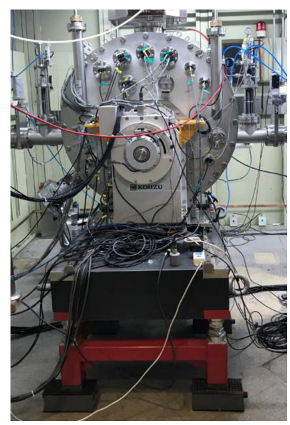

Figure 1: DCM under test.

The integrated RMS vibration of different layers are shown in Fig. 2. It shows that vibration level increase at 8 Hz and 31 Hz for the granite table (line 3, line 4 in the graph). With an eigenfrequency of 8 and 31 Hz, it has an overall transfer ratio of 3 from granite table to ground.

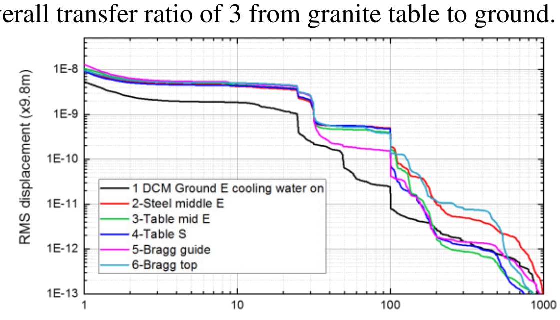

Figure 2: Integrated RMS vibration of DCM.

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Mirror Support

This mirror support provides 5 DOF adjustment capability of a bending mirror is shown in Fig. 3. The button level is directly put on the floor, the second layer provide horizontal adjustment, supported and guided by 2 ball linear guide ways. The third layer provide yaw adjustment, supported on 2 sliding bearings. The fourth layer provide roll adjustment, supported on 2 arc shaped ball guide ways in a cantilever way. The mirror installation base is the fifth layer, sitting on 2 roller bearings arm, with the capability of pitch and vertical adjustments.

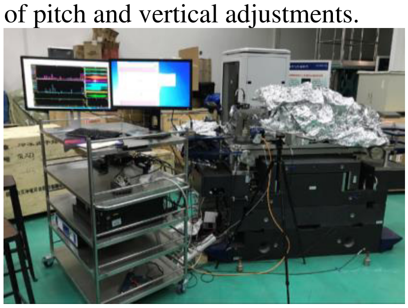

Figure 3: Test of a mirror support.

The integrated RMS displacement is shown in Fig. 4. It shows that vibration level increase at 8 Hz, which indicates it to be an eigenfrequency, it has a total transfer ratio of 1.76. With no increase at 8Hz on the third layer, it can be concluded that the fourth layer should claim this eigenfrequency. The contact of cantilever ball bearing support may be not perfect and resulted in this behaviour.

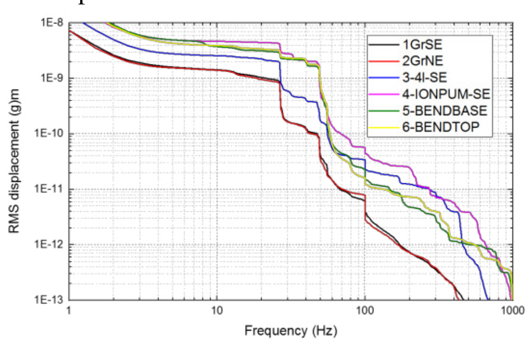

Figure 4: Integrated RMS displacement.

LAUE Monochromator Support

The double Laue crystal monochromator shown in Fig. 5 support provides 6 DOF adjustment capability of 2 crystal assemblies. The bottom layer sits on 4 screw levellers, providing height, roll and pitch of the whole monochromator. The second layer is supported by 2 sliding bearing and confined in horizontal movements in the middle, providing the yaw adjustment capability. The third layer also supported by 2 v-grooves, driven by a stepper motor, providing the horizontal adjustment capability. The fourth layer is supported by 2 levering arms with sliding bearings, which is driven by screw-nut mechanism. The vacuum chamber sits on the fourth layer, supported by 4 screw levers, with point contact at the bottom end of those drivers. And the crystal assembly is put on the bottom plate of the vacuum chamber.

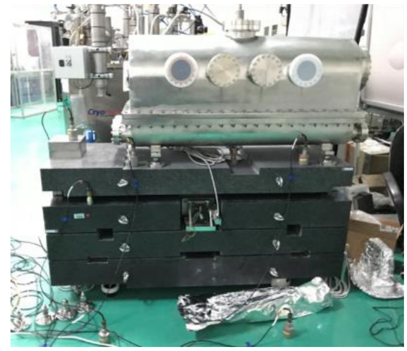

Figure 5: Test of a LAUE mono support.

The integrated RMS displacement is shown in Fig. 6. It shows a sudden increase at 8 Hz on the fourth layer, which could be the lowest eigenfrequency for this layer. The fourth layer has an overall transfer ratio of 6.5 to the ground. It also shows that on top of the chamber the vibration level is lower than that of the fourth layer, which shows vibration isolation behaviour on this layer. This means that the eigenfrequency of the vacuum chamber is so low that most of the vibration is above 1.41 times of its eigen frequency.

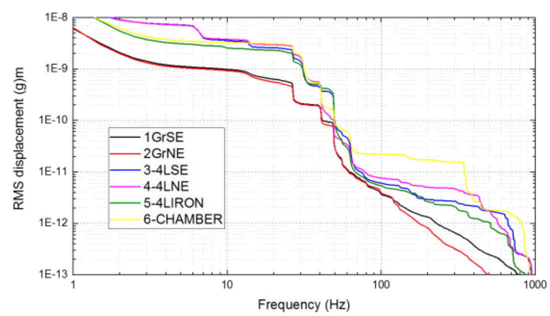

Figure 6: Integrated RMS displacement.

Vertical Direct Drive Spindle

The direct drive spindle shown in Fig. 7 was built for future monochromator, the support of its granite table are 4 wedges. The integrated RMS displacement is shown in Fig. 8. Due to the simplicity of this support and good contact of those wedges, it shows some increase at 66Hz, which should be the eigenfrequency, it has an overall transfer ratio of 1.12 from granite table to ground. The air bearing support is very stable, with an transfer ratio of 1.04 without air flow is the lowest of all.

Figure 7: Vertical direct drive spindle.

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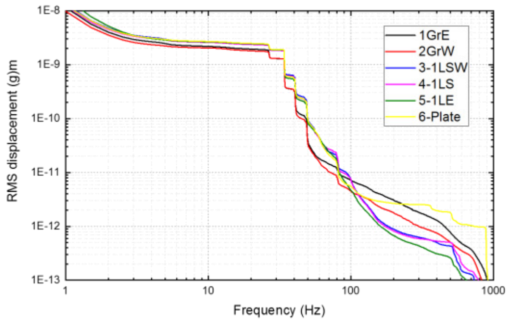

Figure 8: Integrated RMS displacement.

Horizontal Direct Drive Spindle

The horizontal direct drive spindle is shown in Fig. 9. The support of this massive granite table are 4 wedges. The integrated RMS displacement is shown in Fig. 10. The support and granite layout is the same as those of the vertical direct drive spindle, but it’s significantly heavier (5 tons vs 3 tones).With an eigenfrequency of 56 Hz, it has an overall transfer ratio of 1.21 from granite table to ground. This is due to the added mass to those wedges thus lowering the eigenfrequency.

Figure 9: Horizontal direct drive spindle.

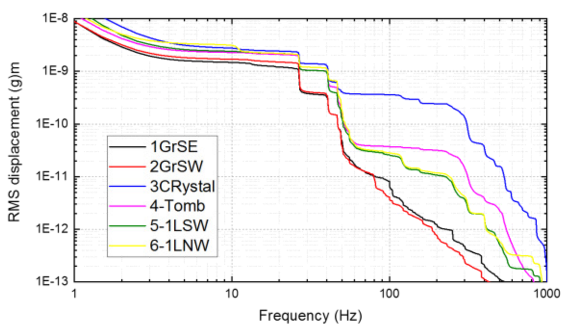

Figure 10: Integrated RMS displacement.

Summary of Relationship Between Amplification Ratio and Eigenfrequencies

Other than those results discussed above, a lot of other supports were also tested. With the eigenfrequency and transfer ratio calculated, plotted in Fig. 11. It shows that with an eigenfrequency above 50 Hz, a transfer ratio around or below 1.2 could be expected.

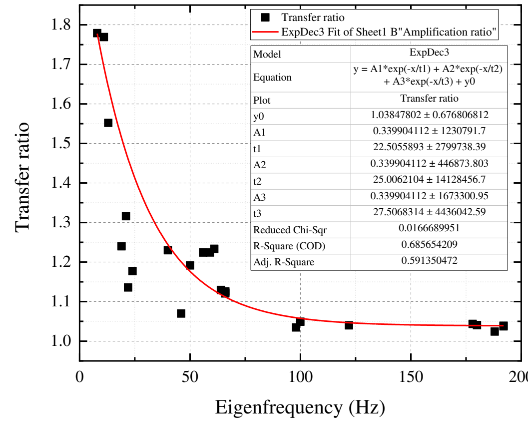

Figure 11: A summary of relationship between eigenfrequency and vibration transfer function.

CONCLUSION

A lot of optics support were tested and the relationships between eigenfrequency and transfer ratio were tested and studied. It can be concluded that wedges combined with granite tables could be a good combination, such as the supports of those two direct drive spindle. Also screw type levelers such as the DCM and the Laue monochromator support, does not perform well. Point support like those of the vacuum chamber of Laue mono is so low that they are isolating vibration, which is not recommended.

Another thing we noticed is that even on the same layer, the vibration level depends on where the sensors were put. Geometry plays a big role in the final vibration level. For a more thorough study, more sensors should be added and the modal shapes should be considered.

In general, a first eigenfrequency above 50Hz will provide a transfer ratio around or below 1.2 for the BSRF site. For future HEPS optics supports, those results will be taken into consideration.

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