VIBRATIONAL STABILITY OF GLC/NLC LINEAR COLLIDER: STATUS AND R&D PLANS*

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Abstract

Multiple feedback systems are foreseen to ensure stable luminosity for the X-band linear collider. Beam-based train-by-train steering feedbacks will be used in the linac and at the IP. Active stabilization of the final doublet is being developed to counteract the possibility of excessive vibration from the detector. Another option is fast intra-train feedback that could recover a major part of the luminosity while other systems are being commissioned. An important part of the strategy is to limit vibration of collider components and their contribution to beam jitter.

STABILITY OF GLC/NLC

Several conditions contribute to luminosity stability of the GLC/NLC X-band linear collider. First, the site should be sufficiently stable. Fig.1 shows an example of the integrated spectrum measured at one of the California sites studied. The vibration tolerance of the GLC/NLC linac quadrupoles is approximately 12 nm above several Hz. The measured motion shown in Fig.1 for this site or even the intermediate noise model are several times better than the stability requirements.

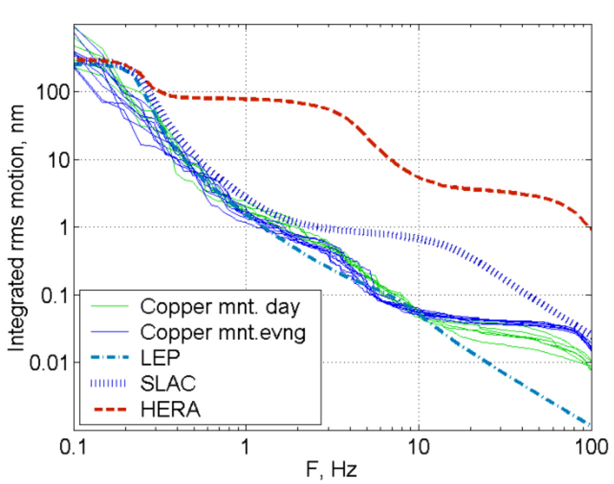

Figure 1: Integrated spectrum measured at one of the representative sites in California compared with low noise (LEP), intermediate noise (SLAC) and high noise (HERA) models.

Given a site that meets the stability requirements, one must then ensure a) that noise sources on the linac girder are minimized and decoupled from the quadrupoles, and b) noise produced in the utility tunnel is mitigated. The first issue was addressed in ref. [1] which showed that vibration of the accelerating structure induced by cooling water is decoupled from the linac quadrupoles. This paper will concentrate on describing the approach to minimizing utility tunnel noise.

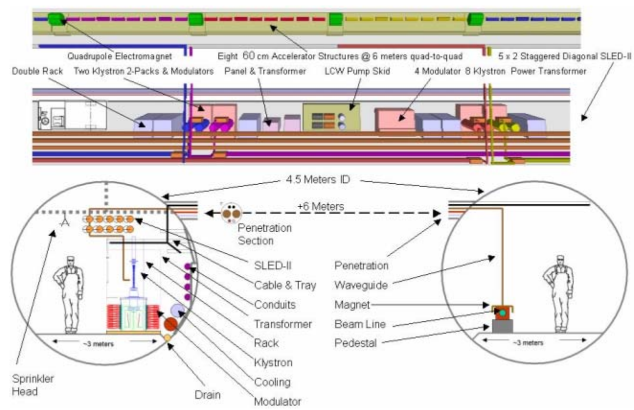

Figure 2: Layout of GLC/NLC beam and utility tunnels and schematic of equipment located in the utility tunnel.

A possible layout and cross-section of the GLC/NLC tunnels is shown in Fig.2. Most of the equipment that could produce vibration is located in the utility tunnel. Among the possible vibration sources in the utility tunnel are the klystron modulators and the equipment which provides cooling water.

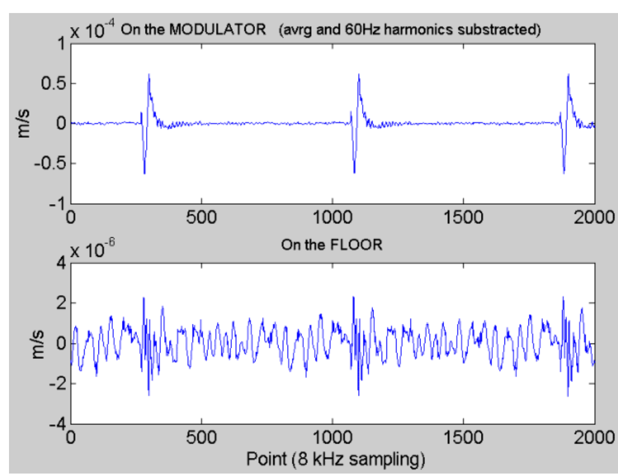

Figure 3: Vibration measured directly on the modulator (top plot), and on the floor near the modulator (bottom). The 60 Hz harmonics are removed for clarity.

Vibration produced by the modulator has been studied at NLCTA, with the IGBT modulator operating at a

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reduced rate of 10 Hz but with nominal power and nominal load. Fig.3 shows that vibration is clearly seen on the modulator, but transmission to the floor is very small (integrating the velocity one can estimate that vibration transmitted to the floor is about 2 nm). This indicates that vibration from the modulators should be negligible compared to that from the water equipment, which would need to be mitigated, as discussed below.

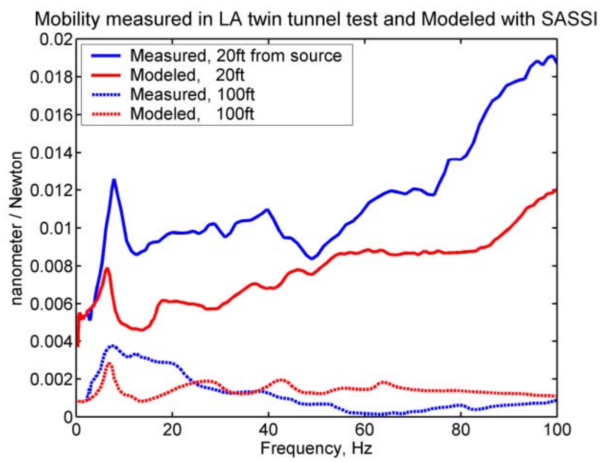

Figure 4: Mobility (response / driving force) measured in Los Angeles metro twin tunnel vibration transmission test in comparison with simulation results obtained with 3D code SASSI, for different longitudinal separation between the source (located in 1st tunnel) and receiver (2nd tunnel).

In order to evaluate the necessary mitigation strategy for the noise sources located in the utility tunnel, one must know the transmissibility of vibration between two tunnels. Transmissibility was studied experimentally in twin tunnels of the Los Angeles metro [2], which were chosen for these tests because their size and separation are very similar to those proposed for GLC/NLC, and the geology is very similar to the California site.

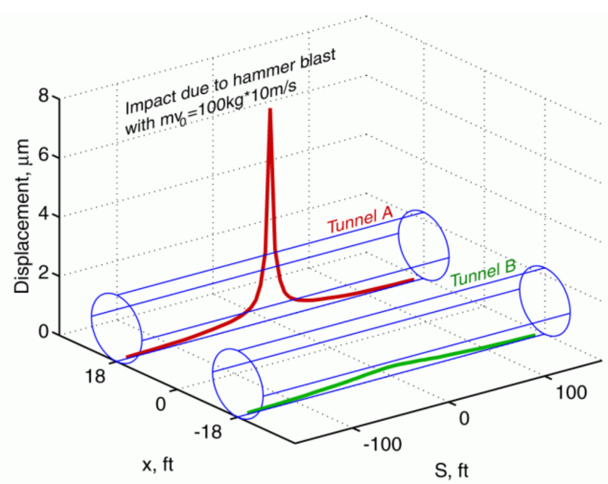

Figure 5: Impact due to a hammer blast with 100 kg*10m/s initial momentum in the 1st tunnel and response in the 2nd tunnel simulated with 3D code SASSI.

To confirm the results of transmissibility measurements in the twin tunnel configuration, and also to create a tool that would allow extrapolating the measured results to a different layout or geology, 3D simulations of vibration transmission have also been performed [3]. A comparison of measured results with simulations is given in Fig.4, where the so called mobility is shown versus frequency. The mobility was measured for blasts of force applied in one tunnel, with simultaneous measurement of the applied force and of the response in the opposite tunnel. At 60 Hz the mobility is about 1 nm per 100 Newtons across the tunnels, and the simulated results are in good agreement with the measurements. Another illustration of the simulated results is given in Fig.5, where displacement due to a hammer strike and geometrical attenuation with distance is clearly seen. The peak at 7-8 Hz observed in both measurements and simulations (Fig.4) was attributed to the frequency of the soil column below the tunnel, which is bounded by much harder layers located at a depth of 200 ft below the tunnel. The difference between the measurements and simulations observed around 65Hz may be explained by the energy being radiated as Stonley waves (also called "tube waves" and often observed in vertical borehole measurements) that propagates in the interface between the tunnel and the medium [4].

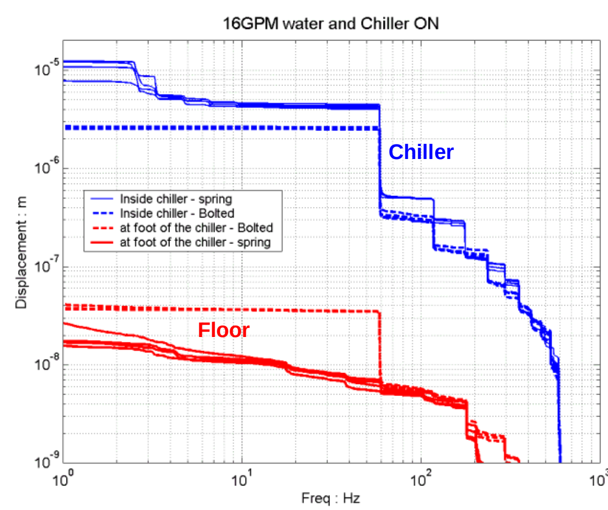

Figure 7: Vibration measured on an NLCTA water chiller and on the floor near the support with the chiller mounted rigidly, and with it placed on soft 3 Hz springs.

To evaluate possible vibration produced by water equipment located in the utility tunnel, we have measured vibrations on and near a water chiller (~700 lb total mass) that is used to provide water for NLCTA modulators. The chiller body vibrates with amplitude approximately 2-3 microns at 59 Hz, see Fig.7. If mounted rigidly, transmission to the floor just near the support is about 30 nm, and this amplitude decreases rapidly with distance from the chiller, see Fig.8. A standard engineering method to mitigate vibration transmission is to place the source on soft springs. One can see in Fig.7 and Fig.8 that the same chiller mounted on 3 Hz springs transmits negligibly small vibration to the floor (much less than a nanometer). Using the measured twin tunnel transmission one can estimate that such a chiller mounted on soft springs in the GLC/NLC utility tunnel would produce only a few picometers of vibration in the beam tunnel. This type of mitigation with soft springs is easy, inexpensive, and can be applied to all the rotating and water equipment in the utility tunnel.

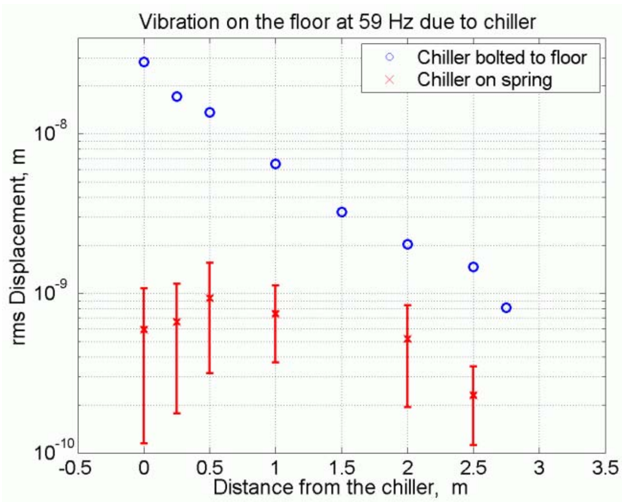

Figure 8: Vibration at 59Hz measured near the NLCTA water chiller when it is bolted to the floor and when placed on soft springs, averaged on several measurements.

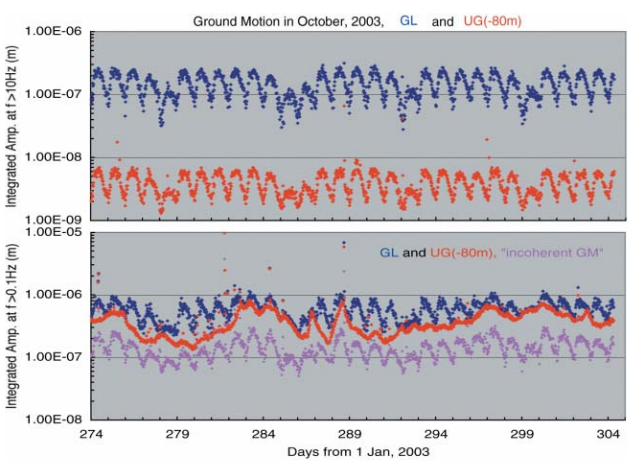

Figure 9: Integrated amplitude of ground motion measured at the KEK site on the surface (GL) and underground (UG) at 80 m depth.

As part of the continuing evaluation of potential sites for GLC/NLC, ground motion has been measured at the KEK site very close to the main access road (R408) since April of 2003. This site is located in soil (not bedrock) and the measurements were performed on the surface and 80 m deep underground. The sensors used in this study are CMG40T with a frequency band of 0.033 to 100 Hz, and the sampling rate of measurements is 200 Hz. One can see in Fig.9 and Fig.10 that the underground vibration is attenuated by about two orders of magnitude in the high frequency region compared with motion on surface. Daily and weekly variations have been observed at both points as expected from cultural noise. The underground motion also shows slower variations at low frequency (~0.3 Hz). Based on these measurements, a model of ground motion at the KEK site has been created and simulations of luminosity stability using MatLIAR have been performed [5]. These indicate that the high frequency ground motion at the KEK site is manageable. The slow motion (few minutes) is also expected to be larger at the KEK site and possible mitigation needs further investigation.

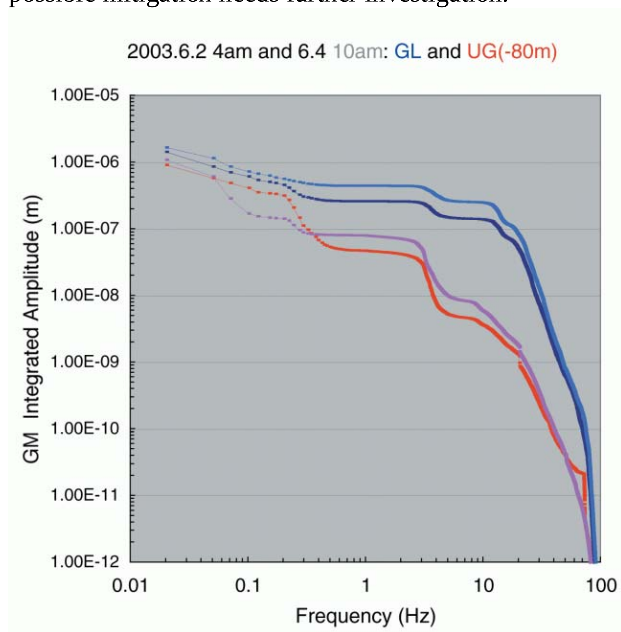

Figure 10: Integrated spectrum of ground motion measured at the KEK site on the surface and underground.

CONCLUSION

Luminosity stability of the GLC/NLC X-band linear collider can be provided by the combination of a suitably quiet site, minimization and decoupling of the noise created inside the beam tunnel, and mitigation of the noise sources located in the utility tunnel. For the latter, standard engineering solutions have been evaluated and found to be adequate. Further R&D will include more detailed prototyping of the utility tunnel noise sources and their mitigation, as well as further investigation of potential sites.

REFERENCES

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