# VIBRATION ISSUES REGARDING LINAC BEAM CHARACTERISTICS

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## Abstract

Although vibration issues have been realized to be among the most crucial problems regarding future large-scale accelerator design, there have only been a few experimental studies carried out concerning the effect of vibration on linac beam characteristics. A new project was started at the KEK electron linac division in collaboration with the University of Tokyo in April, 1992, involving a detailed investigation of vibration issues regarding linac beam characteristics: vibration measurements and a statistical analysis at linac sites as well as correlation measurements between vibration and linac beam characteristics. We have carried out the research and development of laser interferometers for the precise alignment of accelerators and beam lines required for future linear colliders. Using this interferometer technique vibration data was obtained at the 2.5-GeV linac as well as in a tunnel of Mt. Tsukuba 10 km distant from KEK. A new technique involving transverse alignment using a Fabry-Perot cavity is also proposed.

## Introduction

A detailed investigation of vibration issues regarding linac beam characteristics is indispensable for future large-scale accelerator design [1], since environmental vibrations may cause emittance growth or a reduction of the luminosity at collision points. In order to avoid these effects, a feedback system should, in principle, play an important role in beam diagnostics; detect the beam position or size, and then feed it back to a beam steering system or magnet supports. The performance of a feedback system, however, generally strongly depends not only on the frequency response of the system, but also on external noise (in this case, vibration noise). A survey of vibration noise in an accelerator site or its candidates as well as systematic investigations of their influence on the beam characteristics is thus urgently necessary for a well-designed feedback system. Since the time response of the feedback system in beam diagnostics may be relatively slow, vibration information over a frequency range of 0.1-100 Hz is especially important.

We started in April, 1992, at the KEK electron linac division in collaboration with the University of Tokyo a new project involving detailed investigations of vibration issues regarding linac beam characteristics. The main subjects have been divided into two categories: (1) vibration measurements and a statistical analysis at linac sites; (2) correlation measurements between vibration and linac beam characteristics.

We report here on some results concerning vibration measurements at the 2.5-GeV linac and (as a standard quiet place) in a tunnel located at the Tsukuba Seismological Observatory of the Earthquake Research Institute of the University of Tokyo at Mt. Tsukuba about 10 km from KEK.

A new technique for transverse alignment using a Fabry-Perot cavity is proposed here regarding the use of laser interferometers for gravitational radiation[3].

## Seismic Vibration Measurements

Three types of accelerometers (a homemade seismometer utilizing a laser interferometer developed for gravitational wave experiments at the University of Tokyo [2], and commercial servo accelerometers, RION LA-50 and RION LS-20C) were used in order to increase the confidential level of measurements. The data was Fourier-analyzed over the 0.1 - 100 Hz frequency range and then transformed into displacement per a unit bandwidth ($m/(Hz)^{1/2}$). Laboratory tests have indicated that the homemade seismometer and RION LA-50 have almost the same sensitivity in the above-mentioned frequency region, while RION LS-20C is less sensitive, especially below 1 Hz. Since accelerometers have sensitivity not only to vibrations, but also to environmental sounds, measurements were performed at the time of a linac shutdown, although the sound effects turned out to be dominant over 100 Hz.

The observation points are indicated in Fig. 1. At the KEK linac three points were chosen: on the floor of the linac tunnel, on an accelerator support and on the floor of the klystron gallery. The foundation of the KEK linac tunnel sits on a slab which is supported by many 33 m long pillars reaching hard rock at 44 m depth. The tunnel of Mt. Tsukuba is situated at an altitude of about 200 m and is surrounded by the hard rock of Mt. Tsukuba.

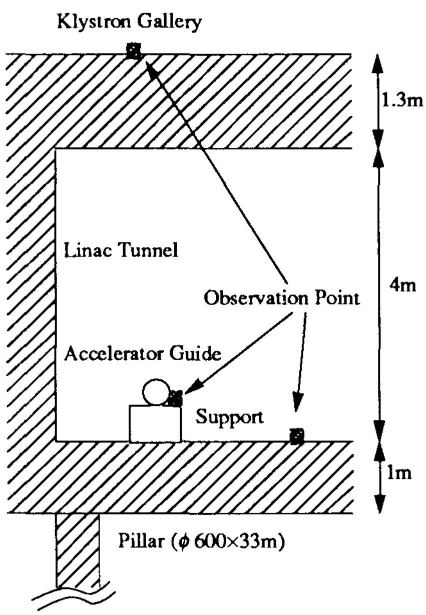


Fig. 1 Observation points at the KEK linac.

Typical examples of the Fourier spectrum density of various vibration data taken at the KEK linac are given in Fig. 2. The vibration level on the tunnel floor is considerably low at the observation frequency range compared with that on the underground floor of the University of Tokyo [2]; vibration noise on the gallery floor and on the accelerator support are larger within a frequency range above 1 Hz. This signifies that even if the foundation of the floor is made to be very hard and a low level of vibration is established, the vibration environment around the accelerators would not necessarily be quiet, probably due to a mechanical resonance of the concrete structures of the gallery floor and the accelerator support structure.

On the other hand, the vibration level in the tunnel of Mt. Tsukuba is even ten times lower than that in the KEK linac tunnel (see Fig. 3).

A comparison between the data taken on the tunnel floor of the KEK linac and in the tunnel of Mt. Tsukuba (Fig. 3) may indicate some interesting characteristics of the same origin. A broad peak at 0.35 Hz is explained by the effect of ocean wave, as reported in ref. [4]; that at 2.5 Hz is understood to be as rock vibration; a narrow peak at 1.27 Hz has not been identified. The two broad peaks are relatively small in the tunnel of Mt. Tsukuba.

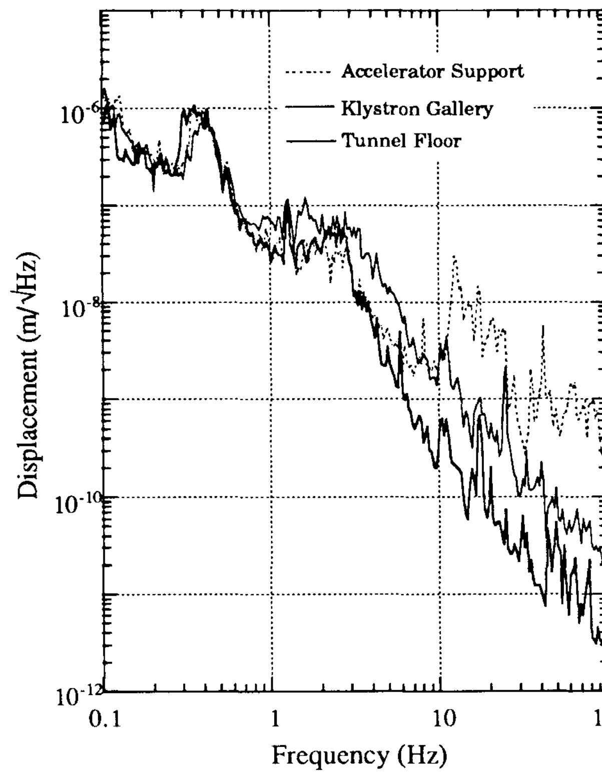


Fig. 2 Fourier spectrum density of vibration at the KEK linac.

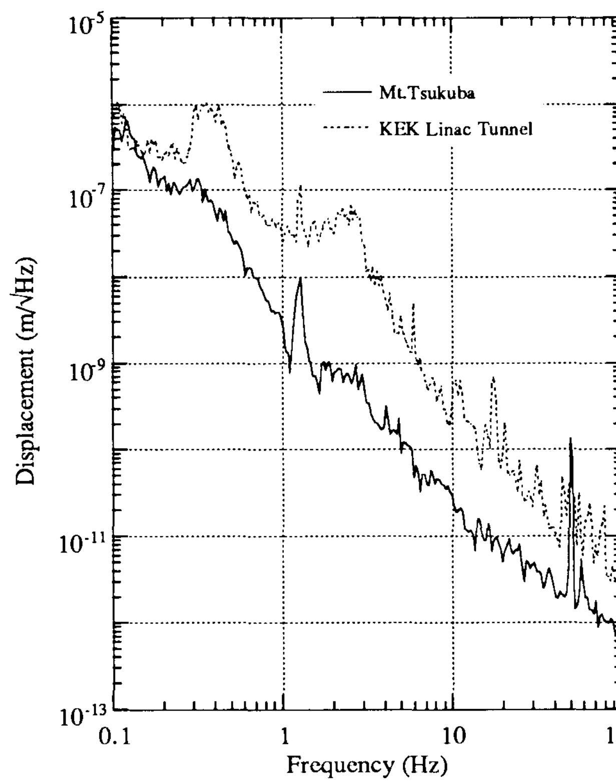


Fig. 3 Fourier spectrum density of vibration at Mt. Tsukuba and the KEK linac.

### Transverse Alignment

In gravitational wave experiments using Fabry-Perot-type laser interferometers a laser light must be introduced into the Fabry-Perot cavity very carefully; the alignment of the laser light and the cavity is very important. Otherwise, higher modes are excited and the effective available power of the first longitudinal mode in the cavity decreases. We began to examine the feasibility of making a transverse alignment utilizing these characteristics.

In Fig. 4, a possible conceptual layout of the transverse alignment system is shown. A stabilized laser and the near mirror of the Fabry-Perot cavity are on the reference table, while the end mirror is located on an accelerator component. In this configuration, if one modulates, for instance, a transverse direction of the end mirror with some frequency, this frequency component of the light intensity is reflected by the cavity and represents a transverse misalignment. A demodulated signal can be fed back to the mover of the accelerator component. A sensitivity analysis is under investigation.

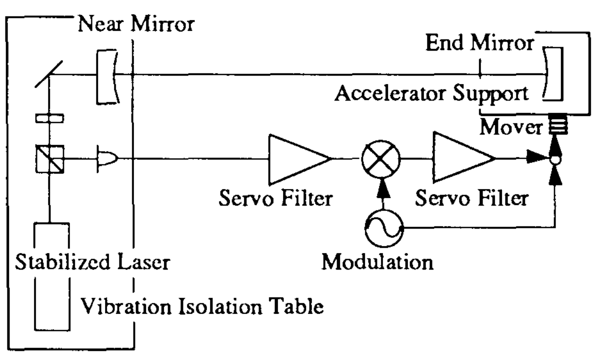


Fig. 4 Possible conceptual design of the transverse alignment.

### Conclusions and Discussions

The influence of vibration on a linac beam may take place through a route which originates from external disturbances, such as ground vibration motion, passing to an accelerator support and finally to a beam. In order to minimize such vibration influence on a beam it is first of all clear that one should select a quiet site. Besides the present measurement, we have been accumulating various vibration data at several sites in Japan; for instance, in a tunnel of the Kamioka mines[2]; we found that the noise level of vibration in a mountain tunnel is generally more than ten-times lower compared with that in other locations. It seems that the existence of a large amount of mass above the sites might be essential for low seismic noise. Secondly, within a frequency range from 1 to 100 Hz it is also important to prevent or damp in some way low-frequency mechanical resonance of the accelerator support. Fig. 5 shows a transfer function between the tunnel floor and the accelerator support. Several peaks at around 10-100 Hz may be due to a mechanical resonance of the support, which enhances the ground motion.

A direct observation of the correlation between vibration and the linac beam characteristics will be performed along with the development of sensitive beam position monitors in the near future.

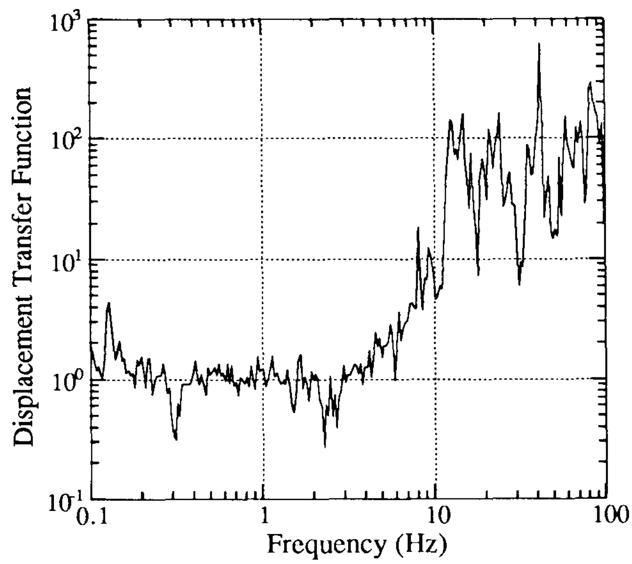


Fig. 5 Transfer function of the accelerator support to the ground.

### Acknowledgment

The authors would like to thank T. Watanabe at the Tsukuba Seismological Observatory of the Earthquake Research Institute of the University of Tokyo for permitting us seismic measurements in the tunnel.

### References

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