# Investigation of the Efficiency of Vibro-Isolating Supports of Optical Tables

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## ABSTRACT

The main tasks of this work are to investigate experimentally the vibration behaviour of the optical tables and the floor structure and to establish the vibration transmission factor of vibro-isolating supports. It is established that the vibration frequency of the table is low, about 1 Hz. Therefore it is possible to mount the laser and optomechanical convergence system of multiple pump beams to the optical table, because the transmission factor of vibro-isolating supports varies from 0.879 to 0.968.

**Key words:** Optical Table, Vibro-Isolating Supports, Vibration Acceleration, Vibration Transmission Factor

## 1 INTRODUCTION

Lasers and their systems are sensible to vibrations and acoustic noise. Noise and vibrations can arise from sources inside or outside the building, for example, from passing cars, wind, heating, ventilation and air conditioning systems, etc [1]. Therefore precision balances, optical microscopes, lasers must be well isolated from vibrations to ensure their proper performance.

Ultrastable Fabry Perot cavities used to stabilize lasers also require vibration isolation [2]. Although these cavities are primarily sensitive to horizontal motion, vertical motion of the ground and optical table can distort the cavity and thus displace the reflecting surfaces [2]. Similarly, in precision atom interferometer measurements, a single optical element must be constrained to move such that it accelerates uniformly with respect to free falling atoms over a time scale as long as 1 s [2, 3]. In atom interferometer measurement of $g$, for instance, it is necessary to stabilize the position of a mirror to a small fraction of the wavelength of light for times approaching 1 s. The typical level of background vibrations in the frequency range between 0.1 and 10 Hz would completely wash out the interferometer fringes [2].

A mechanical spring can adequately isolate key elements from background vibrations, but only in a certain frequency range. Vibrations occurring at frequencies below the natural resonance frequency of the spring-mass system will pass through the spring virtually undiminished. Above the natural resonance frequency of a spring-mass system with negligible damping, vibrations are reduced by a factor proportional to $\omega^{-2}$ [2]. Standard optical tables floating on compressed air have resonance frequencies around 2 Hz and thus isolate the equipment from any ground motion faster than ≈2 Hz [2]. Isolating against background vibrations slower than 2 Hz requires a different approach. Custom designed optical tables are usually used in laser centres and laboratories to mount such equipment. The aim of this work is to evaluate the efficiency of vibro-isolating supports of optical tables.

## 2 OBJECT OF INVESTIGATION

Rigid tables assembled on vibro-isolating supports are shown in Figure 1 (2, 3). Vibration behaviour of two similar tables located at different technological premises was investigated. Arrangement of accelerometers is shown in Figure 2.

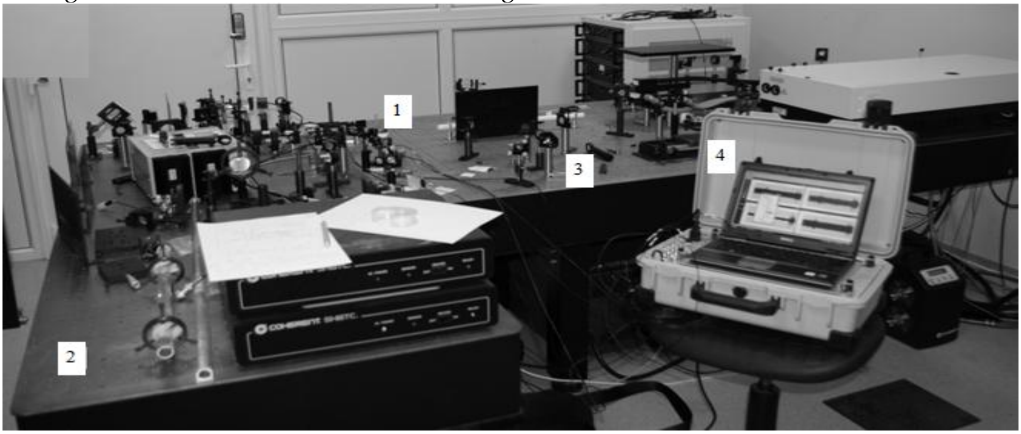


Figure 1: Experimental vibration isolating tables, which are rigidly connected to one another: 1 – accelerometer mounting place; 2, 3 – investigated table; 4 – Machine Diagnostics Toolbox (type 9727, Bruel&Kjaer)

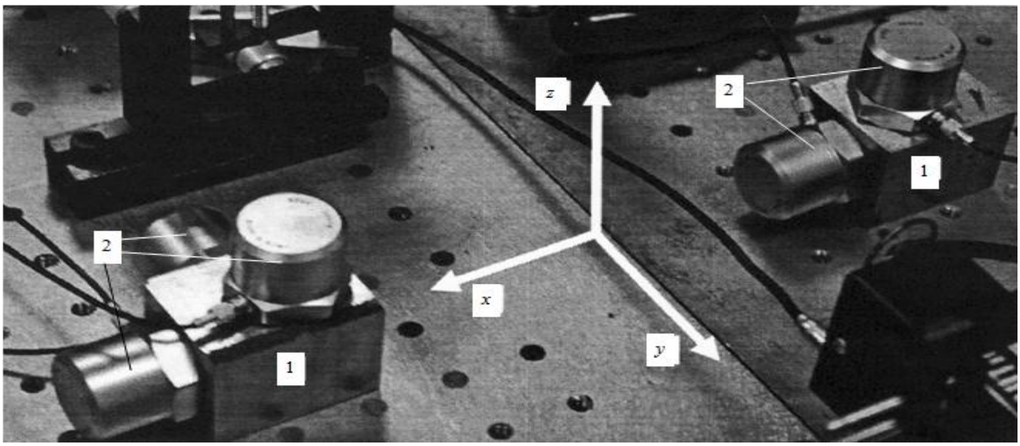


Figure 2: Arrangement of accelerometers on vibration isolating tables: 1 – block; 2 – accelerometer (type 8344, Bruel&Kjaer); $x$, $y$, $z$ – coordinates

A lightweight honeycomb table structure was used. Mechanical properties of the honeycombs depend on the size of the cells, thickness of the walls and material properties. Honeycomb tables are characterized by excellent vibration damping properties; they are much lighter than conventional granite tables. One of the most important properties of the vibro-isolating supports of such tables is vibration transmission from floor to the table top. In order to establish vibration transmission characteristics two points were chosen (Figure 2).

## 3 RESULTS OF INVESTIGATION

Results of measurements of vibrations of the floor and the 1st table are presented in Figure 3 and Figure 4.
Statistical parameters of the vibration acceleration signal are presented in the Table 1.

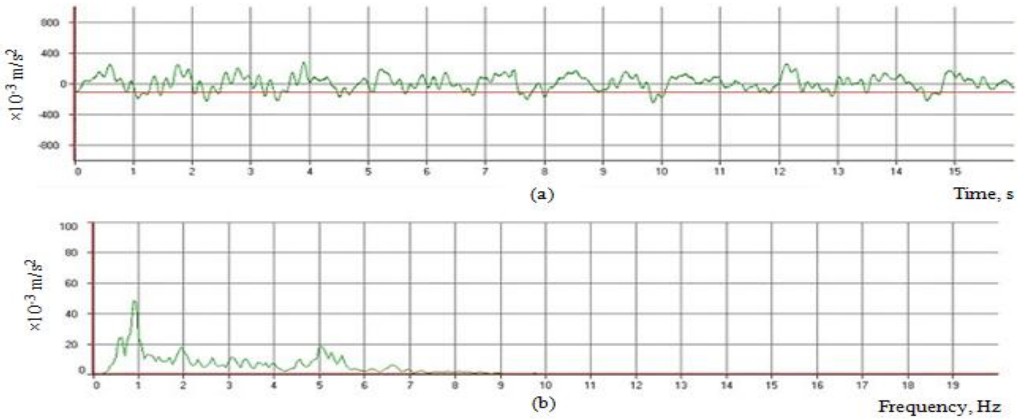


Figure 3: Vibration acceleration of the 1st table measured in vertical direction (a) and vibration acceleration spectrum (b) (results obtained from accelerometer 8344 data)

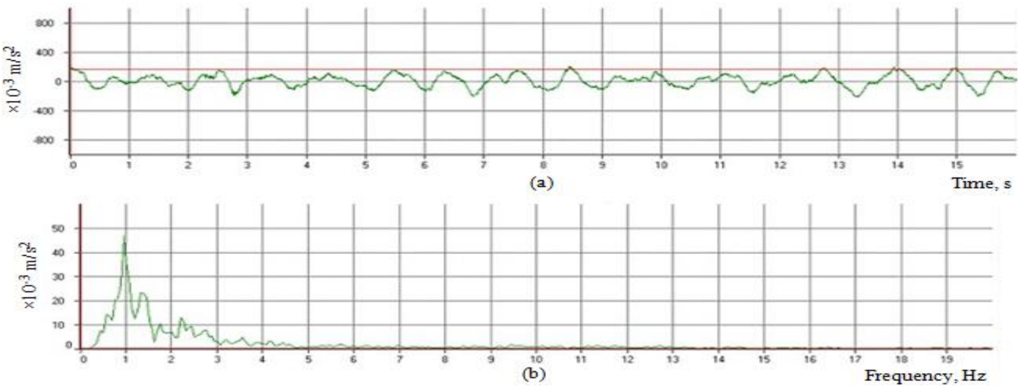


Figure 4: Vibration acceleration of the floor surface measured in vertical direction (a) and vibration acceleration spectrum (b) (results obtained from accelerometer 8344 data)

Table 1: Statistical parameters of the vibration acceleration signal (1st optical table)

| Measuring point | Statistical Parameter | | | | | | |
|---|---|---|---|---|---|---|---|
| | Arithmetic mean, $m/s^2$ | Standard deviation $S_x$, $m/s^2$ | Standard deviation of the mean, $m/s^2$ | Minimum value $x_{min}$, $m/s^2$ | Maximum value $x_{max}$, $m/s^2$ | Variation, $m/s^2$ | Sum |
| On the table surface | 0.00106 | 0.09716 | 0.00152 | -0.257 | 0.267 | 0.524 | 4.3594 |
| On the floor surface | 0.00142 | 0.08447 | 0.00132 | -0.216 | 0.195 | 0.411 | 5.810 |

Vibration transmission factor of vibration isolating supports was calculated as follows:

$$k_{tr} = \frac{S_{x_t}}{S_{x_f}} = \frac{0.09716}{0.08447} = 1.15 \qquad 1)$$

where $S_{x_t}$ is the standard deviation of the vibration acceleration of the table; $S_{x_f}$ is the standard deviation of the vibration acceleration of the floor structure.

Results of measurements of vibrations of the floor and the 2nd table are presented in Figures 5–7. Statistical parameters of the vibration acceleration signal are presented in the Table 2.

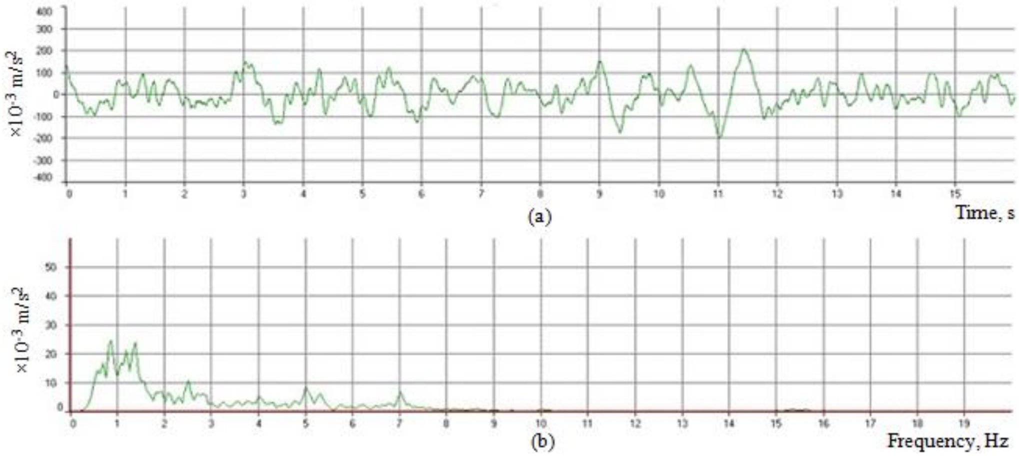


Figure 5: Vibration acceleration of the 2nd table (with additional mass) measured in vertical direction (a) and vibration acceleration spectrum (b) (results obtained from accelerometer 8344 data)

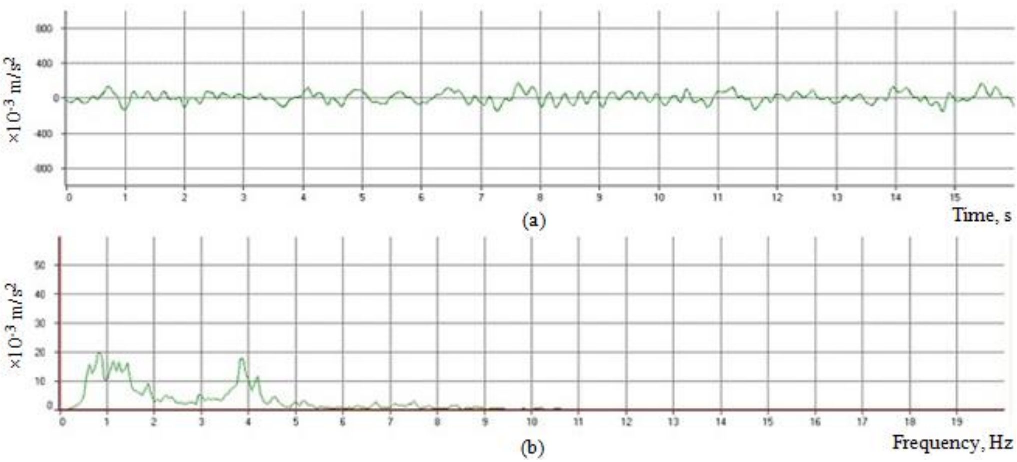


Figure 6: Vibration acceleration of the floor surface measured in vertical direction (a) and vibration acceleration spectrum (b) (results obtained from accelerometer 8344 data)

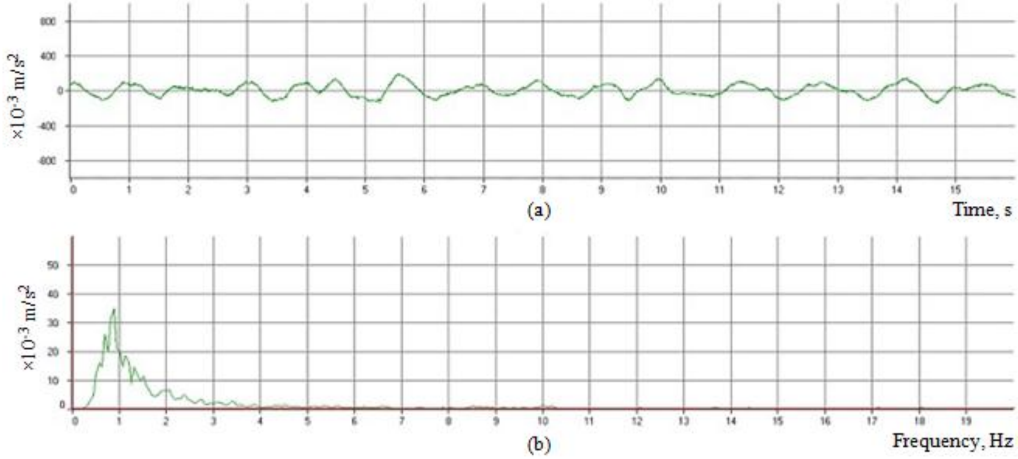


Figure 7: Vibration acceleration of the 2nd table (without additional mass) measured in vertical direction (a) and vibration acceleration spectrum (b) (results obtained from accelerometer 8344 data)

Table 2: Statistical parameters of the vibration acceleration signal (2nd optical table)

| Measuring point | | Statistical parameter | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Arithmetic mean, m/s² | Standard deviation $S_x$, m/s² | Standard deviation of the mean, m/s² | Minimum value $x_{min}$, m/s² | Maximum value $x_{max}$, m/s² | Variation, m/s² | Sum |
| Table with additional mass | On the table surface | -1.49198E-4 | 0.06362 | 9.94039E-4 | -0.198 | 0.206 | 0.404 | -0.611 |
| | On the floor surface | -1.34346E-4 | 0.06575 | 0.00103 | -0.145 | 0.186 | 0.331 | -0.55 |
| Table without additional mass | On the table surface | 5.30981E-4 | 0.05783 | 9.03581E-4 | -0.158 | 0.164 | 0.322 | 2.1749 |
| | On the floor surface | -1.34346E-4 | 0.06575 | 0.00103 | -0.145 | 0.186 | 0.331 | -0.55 |

Vibration transmission factors of vibro-isolating supports of the 2nd table were calculated by formula (1):

$$k_{tr(withmass)} = \frac{S_{x_t}}{S_{x_f}} = \frac{0.06362}{0.06575} = 0.9676,$$

$$k_{tr(withoutmass)} = \frac{S_{x_t}}{S_{x_f}} = \frac{0.05783}{0.06575} = 0.8795.$$

Obtained results show that transmission factor of the vibration isolating supports varies from 0.8795 to 1.15.

## 4 Conclusions

In accordance with the results of experiments, the following conclusions can be drawn:

- Vibration behaviour of vibro-isolating supports of optical tables was investigated, vibration transmission factors were established.
- Transmission factor of the vibro-isolating supports of the first table reached value of 1.15; therefore additional vibration isolation is required.

## References

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