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A VIBRATION-DAMPING PLATFORM FOR INTERFEROMETRIC APPLICATIONS

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Abstract

Keywords:

Vibration;
Damping;
Michelson Interferometry;
Accelerometer application;

Michelson Interferometry setups such as those used for holography require a very stable vibration free platform. The maximum permitted vibration amplitude for holography, for instance, is $\lambda/10$ where λ is the wavelength of the light used. This requirement is quite stringent. Michelson interferometer experiments also require vibrationally stable platforms where it is required to count fringes. We have attempted to set up an indigenous vibration damping platform and characterize its stability with help of a Michelson interferometric technique. The stability of the platform was determined in terms of attenuation of a shock applied near the base of the platform. Using a pair of accelerometer sensors, we have attempted to measure the magnitude of damping. The vibration damping platform was observed to dampen stray vibrations transmitted from the floor adequately to permit interferometric measurements. In the present paper, the construction details of this indigenous damping platform and the measurements related to shock attenuation by this table are presented.

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1. Introduction:

Interferometry of Light has been used for many sensitive measurement applications. It has been especially useful in the measurement of distances of the order of nanometers [1]. Optical measurements based on interferometry are extremely sensitive to vibration. Interferometric set ups such as those used for holography require a stable and vibration free platform. As thumb rule, the maximum permitted shock or vibration amplitude is λ /2 for fringe shift measurements and λ /10 for holography, where λ is the wavelength of light used for the measurement, and is typically, of the order of 500 nm. This requirement is quite is stringent. This is why Interferometer based experiments are carried out with help of Damping Platforms that reduce the effect of external vibration. A damping platform reduces the amplitude of external shocks and vibrations by dissipating their energy through frictional and other resistive forces. Rivin [2] has discussed several issues related to vibration isolation. Hundal [3] has theoretically computed responses of linear as well as quadratic shock isolators for shock pulses of different shapes. We have developed a low cost damping platform for setting up a Michelson Interferometer for sensitive measurements of changes in refractive index. We tested the stability of this platform with help of an experimental set up consisting of two accelerometer sensors and a Michelson interferometer as shown in the figure.

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2. Theory:

Vibration damping mechanism (Shock Dissipation of Energy)

Vibration Isolation is an important requirement for sensitive optical instruments. So the instruments which are sensitive to vibration and shock need to be vibrationally isolated. Vibration isolation is the process of mechanically isolating an object, such as a piece of equipment, from the source of vibrations so that mechanical impulses produced by the source are sufficiently attenuated for measurement to take place undisturbed.

Vibration isolation can be active or passive. Passive vibration isolation makes use of materials and mechanical linkages that absorb and damp the mechanical impulses and waves [4]. Active vibration isolation involves sensors and actuators that sense the vibrations and produce destructive interference that cancels-out incoming vibration [5,6]. Rakheja and Sankar [7] have proposed an 'ON-OFF' type active vibration damper based on feedback from sensors attached to the system. Ruzicka and Derby [8] have discussed several damping mechanisms including viscous damping, coulomb damping, quadratic damping, Hysteretic damping, and their combinations. Although active vibration isolation is far better, it requires a degree of sophistication that is generally not available. Also, the cost of such equipment can be quite high. So we have attempted vibration isolation of our Michelson interferometer apparatus using passive dampers.

Passive vibration isolation uses passive techniques such as rubber pads or mechanical springs and Pads or sheets of flexible materials such as elastomers, rubber, cork, dense foam as well as laminate materials for vibration isolation or mitigation of vibrations. These materials absorb shock and attenuate some vibration [9]. Chung [10] has also suggested various materials. But most of them are not suitable for Low budget applications such as that which we have attempted.

Effect of different factors on damping

Thickness of padding: Attenuation of shock or Damping of vibration depends, among other factors, on the thickness of the padding, Let us assume that the initial shock has power P_o and the thickness of damping pad is *t*. Also assume that the damping per unit length (λ) is constant. Then the transmitted power follows the equation $\frac{dP}{dx} = -\lambda x$ which has the solution $P = P_o \exp(-\lambda x) = P_o \exp(-x / x_0)$ .Thus the Power carried by the shock decreases exponentially with increasing distance. Here, x_o is the distance travelled in the medium for intensity to become 1/e of the initial value.

Weight of the table top: There are many applications in which a heavy top is of benefit. It can lower the centre of gravity for systems in which gravitational stability is an issue. The increased mass of the table reduces the reaction motions of the table top. Suppose a lateral impulse **I** is transmitted by the table legs to the table top. Then the effect will be a change of velocity of the table top by Δ**v** where I = m Δ**v.** Clearly, a large table mass causes a smaller amplitude impulse.

Use of Air Pillow: To further dampening, we placed a set of five air pillows consisting of scooter wheel tubes, just below the table top. Using air pillow helps in further vibration isolation (passive) as it absorbs these mechanical shocks and vibrations and thus attenuates them.

3. Design of the Platform:

The Platform was indigenously erected in a normal dark room with its dimensions: Length 121cm, breadth 78cm, Height 68cm. The experimental arrangement is shown in Figure 1. The figure depicts the two sensors with respect to the platform. A photograph of the platform is shown in Figure 2. The legs of this platform were made using seven layers of Bricks. Thick cotton cloth was inserted between consecutive layers of bricks for absorbing vibration. A heavy stone sheet (Roughly 220 kg weight) was placed over the legs, and a rubber sheet (6 cm thick) was placed over it. Inflatable scooter wheel tubes, tightly filled with air, were placed over it. There were six of them for distributing the weight of the heavy table top. Above it a cotton mattress was placed and an iron tub completely filled with sand was placed over the mattress. This tub had depth 21cm and weighted approximately 150kg. The sand filling the tub further dissipated any shock coming from below. A heavy glass slab was placed over it for setting up the instrument.

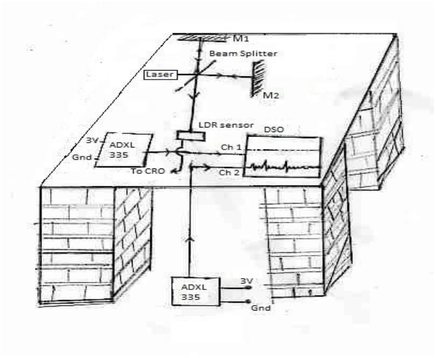

Figure 1

Figure 2

4. Measurement of Damping of the Platform:

The vibrations or random shocks that disturb the interference fringes obtained in an interferometer, are generally transmitted through the ground. The platform was constructed in order that it may vibrationally isolate the apparatus placed on it from the sources of vibration through mechanical damping. We attempted to measure the extent of this damping. For this purpose two accelerometers were employed. One of these was rigidly attached to the ground near one leg of the platform, while the other was placed on the table top. Mechanical shocks were produced on the ground by dropping a heavy object (~ 1 Kg) from different heights. This produced a shock that was sensed by the accelerometer (Figure 9) and appeared as a peak in the bluish white trace. The yellow trace shows the corresponding output of the accelerometer placed on the table top.

The dynamic accelerometer

For the purpose of measuring the transmission of shock produced by random events, we used a pair of ADXL335 accelerometer sensors (Figure 3). The ADXL335 is a complete 3 axis accelerometer measurement system with a measurement range of ± 3g. It contains a acceleration sensor and signal conditioning circuitry to implement an open-loop accelerometer measurement architecture. Figure 4 gives its pin diagram and Figure 5 depicts its block diagram. The output signals are analog voltages that are proportional to acceleration. The sensor measures acceleration with a full scale range of ± 3g. It can measure the static acceleration due to gravity, as well as dynamic accelerations resulting from motion, shock impulse or vibration.

Figure 3

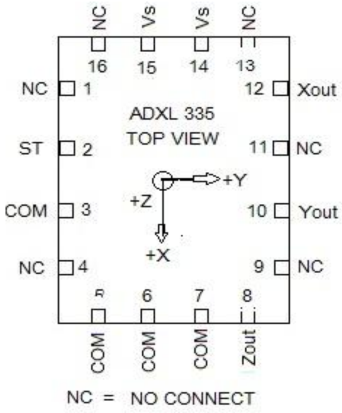

Figure 4

The bandwidth of the accelerometer can be selected using the Cx, Cy and Cz capacitors at the X_{out}, Y_{out} and Z_{out} pins. Since we were interested in transmission of shock along a vertical direction, we used only Y_{out} output pin of the sensors for the measurement of damping. For a supply voltage of 3 V, the sensitivity of this sensor is 300mv/g ± 30 mv/g, where g is the acceleration due to gravity (9.8m/s^2). The ADXL335 output is ratiometric. The output sensitivity at supply voltage used, V_s=5 V is about 500mv/g [11].

Functional Block Diagram of ADXL335

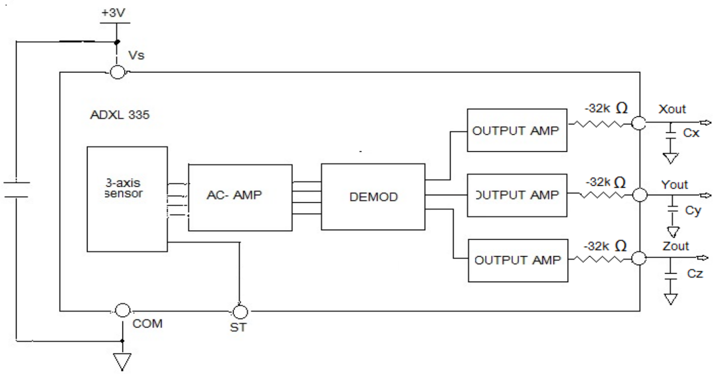

Fig.5

The zero g bias output is equal to $V_s/2$ at all supply voltage. The output noise is not ratiometric but is absolute in volts, therefore, the noise density decreases as the supply voltage increases. This is because the scale factor increases while the noise voltage remains constant. At V_2=5V the Y-axis noise density is typically 270 µg/Hz

Attaching sensor to surface: An ADXL 335 sensor was attached rigidly to a PCB and its wires were connected to the external circuit. Then the sensor mounted on a PCB card for extra rigidity so that the sensor would closely follow the acceleration of the base. Two sensors were prepared in this way. One of these sensors was rigidly attached to the table top with quick drying epoxy and the other was placed on the ground close to the leg of the table and was stuck with quick drying glue. The output wires from the accelerometer sensor were input to the Digital Storage Osciloscope so that the outputs could be viewed on its channels.

The accelerometer attached rigidly to the table top measured the received shock amplitude while the accelerometer rigidly attached to the floor near the base of the platform measured the transmitted shock amplitude. The two accelerometer outputs were displayed on two channels of a Digital Storage Oscilloscope as seen in Figure 6. To ensure that the vibration of the table top was sufficiently small, a Michelson interferometer was also set up on the table top (Figure 7) and fringe movements were observed during application of shock with help of a LDR sensor. The fringe shift was observed using LDR whose resistance changes whenever there is change in light intensity due to the crossing of a fringe across the sensor. Using an operation amplifier the variation was converted into voltage which was observed on one channel of Digital Storage Oscilloscope.

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Experimental Measurement:

A disturbance was created near the base of the platform by dropping a heavy object on the ground. The effect of this disturbance on the ground is seen in the accelerometer signal (Figure 8 upper blue trace). The effect on the table top is seen as the lower (yellow green) trace in the same figure A Michelson interferometer set up on the table. The disturbance in fringes of this Michelson interferometer was also observed.

Fig. 6

Fig. 7

The outputs were viewed on a Digital Storage Oscilloscope (Scientech 403 model, 100 MHz DSO). Figure 8 shows the snapshot for one of the readings. The bluish white trace (upper trace) shows output of sensor placed on ground near the leg of the table. Thus it shows the magnitude of the shock transferred to the base of the platform table. The yellow trace (lower trace) shows output of sensor placed on top of the platform table. One can see that there is an appreciable damping of the shock between the ground and the table top. For viewing simultaneous observations, the Digital Storage Oscilloscope was set for Chopping mode.

In order to see the extent to which the fringe pattern is affected by vibration of the table top, a Michelson interferometer, LEOT-22 precision interferometer manufactured by Lambda Scientific [12] was set up on the platform. In an enclosure with a thin slit, a LDR Optical sensor was placed and was set up in front of the interferometer. The output, after due amplification, was displayed on a DSO. The output from the LDR sensor was displayed in Channel 1 (Blue white trace) and the output of the accelerometer sensor B was displayed in Channel 2 (Green trace). Figure 9 shows the CRO traces. Because of a slow response time of the LDR sensor compared to the fringe passage time, there is a certain amount of averaging of signal (over time) as seen in the Channel 1 trace. Although the LDR had a slow response time, we did observe a vibration in the fringe system when the top of the table was tapped (blue white upper trace in Figure 9). But when the ground was impacted, there was no appreciable vibration of the fringes.

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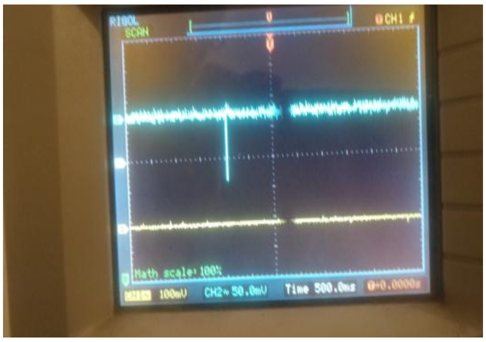

Fig.8

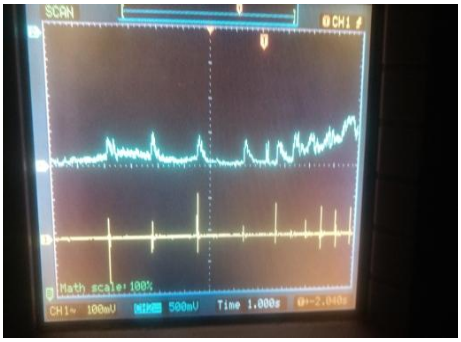

Fig. 9

5. Observations:

Several observations were made to check the transmission of the shock from ground to the platform top. In all cases the amplitude of the shock transmitted to the table top was less than the background noise. The peak to peak noise amplitude at the table top was nearly 10 mV.

Accelerometer o/p for different Shock pulses at Ground (mv)	Shock amplitude at the ground	Damping correlation With platform	Shock amplitude at the platform less than noise amplitude
140	0.46g	14times	Very small (<0.033g)
160	0.53g	16times	Very small
130	0.433g	13times	Very small
150	0.5g	15times	Very small
60	0.2g	6times	Very small
70	0.23g	7times	Very small
40	0.13g	4 times	Very small

Background noise:

There was random vibration signal in the oscilloscope traces. We could not reduce the noise as observed in the oscilloscope trace. The peak to peak amplitude of this noise as observed by sensor B placed at the table top was 10mV while the peak to peak noise amplitude as observed by sensor B placed near the table leg was 20mV. We could not trace its cause. Probably it was caused by ambient vibrations and transmitted through multiple channels. It was observed that Normal foot movement of persons around the table produces very small disturbance in fringe and the fringe pattern was quite stable.

6. Conclusion:

The present experiment deals with measurement of the shock absorbing capacity of a vibration damping table to be used for setting up a Michelson Interferometer. A shock was applied to the ground near the legs of the table. Its magnitude was observed using an accelerometer rigidly attached to the floor just near one of the legs of the table. The shock was transmitted via the legs of the table to the table top. The effect of the applied shock on the table top was observed by help of a second accelerometer attached to the Table top. The effect of the shock on the steadiness of the table top was further tested by observing disturbances in the fringes produced by a Michelson interferometer set up on the table. It was observed that even for significant mechanical disturbance created at the ground, the shock amplitude measured at the platform is less than the instrumental and ambient level of 0.033g. It is concluded that this indigenous damping platform is sufficiently stable for work on a LEOT-22 precision interferometer and is useful for Michelson's experiment as well as many other optical experiments.

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