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A simple method to stably float a coupled system of optics tables

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Abstract

We demonstrate that one may safely float a composite system of mechanically coupled heavy-duty optics tables with a stability of $\pm\lambda/10$ for several months without requiring the presence of an air compressor in the building. Furthermore, we demonstrate a simple and non-disruptive method to mechanically couple two floating tables such that the two-table system has sufficient stability for most optics experiments, and describe precautions that need to be taken in order to avoid mechanical damage to the tables. We checked the stability of the coupled system by use of a Michelson interferometer that spanned across the two tables.
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Floatable heavy-duty optics tables are used widely in experimental physics. The heavy table-top provides stability to the experiment, while the ability to float the table-top on an air cushion provides vibration isolation. However, some physics laboratories may lack access to a reliable in-house compressed air supply. Also, compressors often supply moisture-laden air. This moisture, unless filtered out, may eventually cause damage to the floatation system. Furthermore, researchers are often faced with the task of connecting together, in situ, two optics tables of different table-top thicknesses. The procedure required by commercial optical companies for connecting two optics tables is to insert two steel plates between the tables, weld each plate to a table, then bolt the two plates together [1]. However, this procedure is highly disruptive in the (common) situation where complicated optical setups have already been installed on each table.

In this brief technical note, we demonstrate that it is possible to conveniently float a composite system of two mechanically coupled optics tables for several months using a compact portable air tank of modest volume purchased from the local hardware store. We also show that a simple but careful mechanical connection between the two tables with steel bars imparts the two-table system sufficient stability for most optics experiments. We briefly discuss cautionary measures that need to be adopted to avoid mechanical damage when connecting together two optics tables of different table-top thicknesses. We checked the stability of the two-table system by monitoring the motion of the central fringe of a Michelson interferometer that spans across both tables, and found the stability to be better than $\pm\lambda/10$.

First, we connect the air-lines and valves supplied with the optics table (TMC $6' \times 4'$, tabletop thickness 11 in). The plane of floatation is defined by three points, therefore three legs had pressure sensitive valves ("masters") and the remaining leg was a "slave". Fittings were provided by the manufacturer to mate the air tubing to conventional air connections ($\frac{1}{4}''$ female NPT fitting). We employ a 7 gallon portable air tank (Campbell Hausfield Model KT0700 which is generally used for inflating car and bicycle tires, bought from the local hardware store for $17) supplied with a pressure gauge, and an airhose with a standard quick-connect fitting. The tank was charged to 90 PSI at the hardware store and was then brought into the lab and connected to the system. The tank comfortably floats the table (which, in addition to its own weight, has its top

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surface fully occupied with optical and vacuum equipment for various experiments) for 6 months before the pressure in the tank drops down to 30 psi owing to leaks, at which point the tank needs to be disconnected and re-charged. It is convenient to maintain a full back-up tank that is connected to the system while the first tank is being re-charged.

Next, we connect two optics tables together (the second table is another TMC table $6' \times 3'$, with a tabletop thickness of 7 in). Note that companies such as TMC, Melles Griot, etc. routinely sell tables that have been connected at the factory by first welding "joiner plates" to each table and then bolting these plates together (for table-tops of equal thickness the welding may be avoided) [1]. This process can be very disruptive in cases where these tables were initially installed separately in the laboratory, and complicated optical setups are already in place on each table. It would, indeed, be convenient if one could achieve the coupling without needing to insert any plates between the tables, and without welding. However, one must be careful because the tables are not one solid steel unit. Instead, the interior construction of these tables comprises a rather more complex system of steel honeycomb webbing located between top and bottom sheets of steel. Indiscriminately drilling holes and bolting braces into the table would likely damage the webbing on the inside. Therefore, one needs to be careful not to attach the two tables by simply bolting just the top sheets together with a strut, or just the bottom sheets. We joined the two tables by using three strips of Unistrut bolted to the tables and running perpendicular across the joint of the top of the two tables. To prevent damage to the top sheets as described above, we used four large C-clamps, located two per table, on the outside strips of Unistrut, clamping the angle strips on top and supporting the bottoms of both tables to prevent tearing the table away from the honeycomb.

Furthermore, when pressurizing the composite system, it is important to realize that if one of the tables were to rise faster than the other, the force could either peel off the top sheet of steel from the other table or risk damaging the bottom sheet of its own. For this reason, it is important to slowly and uniformly raise all 8 legs of the tables in such a way that one table would not rise faster than the others. We distributed the three available masters over the new, 8 legged system, resulting in five slave legs, as shown in Fig. 1. The two pairs of slave legs that are connected to the same master are chosen to lie on different tables. This distribution creates an interwoven system whereby fluctuations in one table would have corrective responses in the other table as well [2]. Because of this, when air is supplied to all of the master and slave table legs, the table rises slowly and uniformly, without causing stress to the struts. The Unistruts prevent the tables from starting to bow inward or outward with respect to the joint while attempting to float the system. Levelling of the two surfaces is accomplished with a spirit-level, and by fine adjustment of the pressure valves on the three master legs.

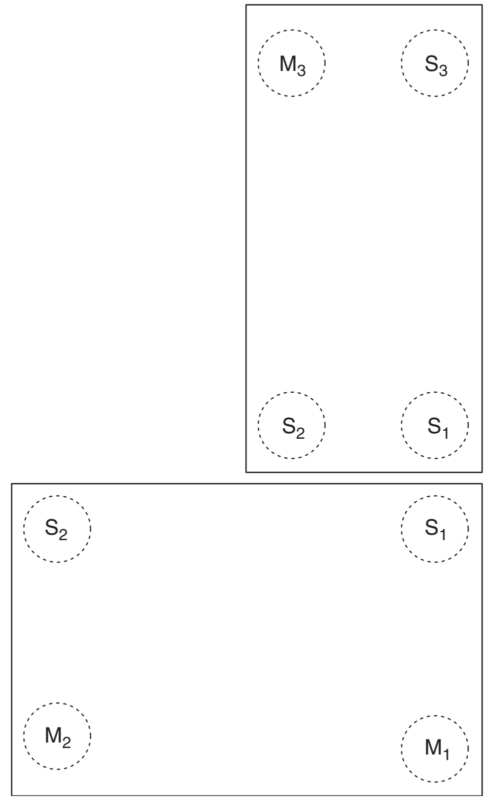

Fig. 1. Overhead view of the two table system highlighting the location of each "Master" (M) and its corresponding "Slaves" (S). M1 and M2 control slaves on both tables.

In order to test the stability of the floating composite system, a simple Michelson interferometer was employed. An iris was placed in the path of the interference pattern, selecting the center of the bullseye interference pattern, which was then imaged onto a photodetector. Fringe movement in the interferometer indicated relative motion of the two mirrors in the arms of the interferometer. The intensity of the central maximum as a function of time was recorded for a minute and a half, with fluctuations in the intensity corresponding to movement of the fringe pattern and hence to relative motion between the two mirrors.

We first run a control test with both arms of the interferometer located on the same optical table. The top plot in Fig. 2 shows a time-plot of the light intensity on the photodetector. The average value of the intensity was 0.106 units with a standard deviation of ± 0.014. This ascribes a drift of $\pm 13\%$ in the intensity, which approximately corresponds to a relative motion between the mirrors of less than $\pm \lambda/10$.

After this trial was run, one of the arms of the interferometer was extended such that it crossed the joint of the two tables. Again, the intensity as a function of time was measured as shown in the bottom plot in Fig. 2. The average intensity for this trial was the same as for the previous trial, but with a standard deviation of 0.016. This ascribes a drift of 15% in the intensity owing to relative

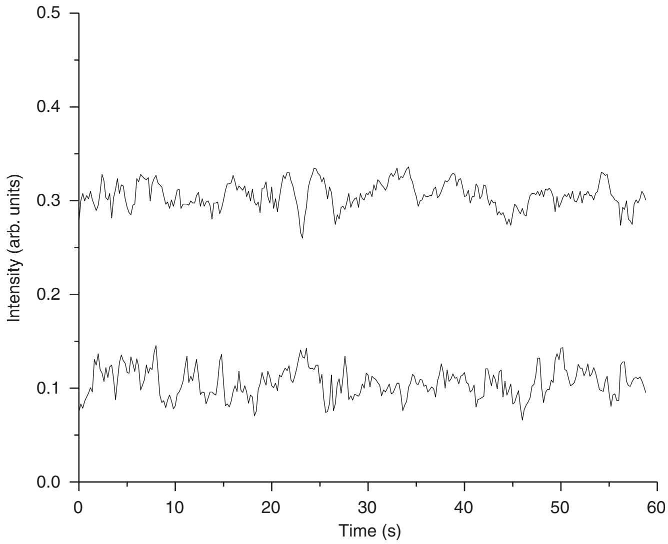

Fig. 2. The top plot shows a graph of intensity versus time for the center fringe in a Michelson interferometer with both arms located on the same optical table. The bottom plot shows the intensity versus time of the center fringe with the arms on different tables. The two plots are offset for clarity.

motion between the mirrors. Since the fringe drift in trial two was comparable to that in the first trial, it can be concluded that the motion of the mirrors (and therefore the tables) relative to one another were comparable, implying that the two tables joined together were indeed as stable and quiet as one of the tables floating individually. The coupled system floated for almost four months before the tank needed to be recharged.

In conclusion, we have demonstrated a simple, safe, inexpensive method of stably floating coupled optics table systems without the need for an in-house compressed air supply. We believe this may be useful for optics researchers who lack access to a reliable and clean compressed air supply in their building, or who may need to connect two optical tables of different table-top thicknesses in a simple non-disruptive manner.

Acknowledgements

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