WHITE PAPER

PRECISION STARTS AT THE FOUNDATION
SELECTING THE RIGHT OPTICAL TABLE AND ISOLATION SYSTEM

In the field of photonics, even the slightest vibrations can disrupt laser beam alignment, compromising both experimental accuracy and manufacturing efficiency. To maintain the integrity of optical systems, it is essential to isolate the optical path from environmental disturbances. Optical tables serve as the foundation for building stable and highly precise optical setups. In this white paper, we explore the key parameters to consider when selecting an optical table system for advanced photonic applications demanding exceptional stability and vibration isolation.

Optical tables function as a common base for complete optical-mechanical assemblies. The precision-engineered platforms provide a stable and vibration-isolated surface for conducting sensitive optical experiments and maintaining accurate alignment for reliable performance of optical systems including lasers, detectors, and optical components such as mirrors and lenses.

Over the past decade, the rapid advancement of quantum technologies has intensified the demand for high-performance optical tables in cutting-edge scientific applications. Given the extreme sensitivity of modern photonics setups and the considerable effort invested in their design, optical tables must adhere to the highest standards of precision and mechanical stability.

Fig. 1. New lab at the German Max Planck Institute of Quantum Optics with Newport™ optical tables by MKS and temperature stabilization [©MPQ/Aidelsburger].

Design Concepts

An optical table system refers to a vibration-isolation assembly comprising of a tabletop and a support structure (see Figure 2). The primary goal of an optical table system is to minimize relative motion between position-sensitive components across the table work surface. The vibration isolator support is designed to filter floor vibration before it can reach the tabletop and disturb an optical beam path. The honeycomb structure of the optical table is designed to resist deflection from moving loads or any vibration that passes through the isolation system.

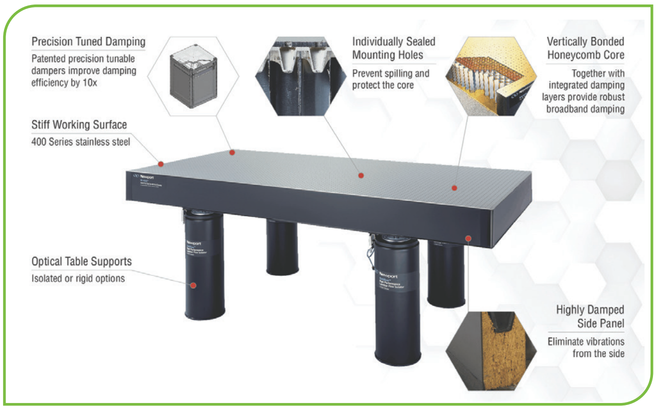


Fig. 2. An optical table combines a tabletop and a support system ©MKS Inc.

Depending on the application, several critical aspects must be considered when selecting an optical table:

- **Vibration damping and isolation –** The ability to isolate the experimental setup from any disturbances
- **Material properties –** An appropriate material selection to ensure mechanical stability and environmental/application compatibility
- **Customization and flexibility –** Tailored configurations, flexible modification options and accessories to meet specific experimental requirements and spatial constraints

Optical Tabletop and Damping

The optical tabletop is a stiff platform supporting vibration-sensitive equipment. The intention is to create a perfectly rigid body – an idealized theoretical concept – where the distance between any two points remains constant in time. In other words, the size and the shape of the platform do not change while experiencing forces induced by vibrations, static loads, or temperature changes. When all the elements are mounted together as an ideal rigid body, they will not move relative to each other and system performance will not be impaired.

The most critical vibration characteristic of an optical table is its resonant frequencies. As the table is designed for maximum stiffness, it acts as a rigid body when its resonant frequencies are not excited. A typical optical table exhibits one or two major resonances and several minor ones. Therefore, damping is needed to reduce the resonance amplitudes and minimize the system deflection when ambient vibrations excite these frequencies. Three types of damping methodologies are available for optical tables: broadband, narrowband, and active/hybrid.

Broadband damping absorbs and dissipates vibration energy across a wide range of frequencies. It is widely used in anti-vibration tables due to its affordability and suitability for applications that do not require high damping performance.

A Tuned Mass Damper (TMD) for **narrowband damping** consists of a mass and spring assembly attached to a structure to reduce its dynamic response. It is tuned near a structural resonance such that, when the system is excited, it reduces the primary resonance peak and splits the response into two adjacent peaks with significantly lower amplitudes. TMDs are the most effective method among all known passive damping methods, as they concentrate damping efforts where it's needed at the frequencies of dominant resonance modes. Different from broadband damping which absorbs a moderate amount of vibration energy equally over a broadband, TMDs target resonances and as a result are much more effective.

Active damping senses vibration in real time and sends out signals to actuators to counteract and cancel the vibrations. It effectively addresses the resonances of optical tables by incorporating a pair of sensors and actuators in the optical table design and uses an external controller for signal processing, enabling the fast and accurate damping response for optical tables. It has a much shorter settling time than a passive system and reduces all table resonances within the entire active bandwidth.

Hybrid damping combines the advantages of both active damping and tuned mass damping and is the most advanced damping technique for optical tables, ideal for the most demanding applications. The active system can further reduce vibrations on top of a good foundation created by precision tuned dampers, delivering optical tables and systems with minimum resonance peaks. High-quality suppliers often provide the option to upgrade optical tables at a later stage, which ensures flexibility for evolving experimental needs. This capability allows laboratories to start with a cost-effective solution and seamlessly enhance performance without replacing the entire setup.

Fig. 3. The MKS Newport SmartTable® HD with hybrid damping uniquely combines the powerful IQ Damping Technology® with the passive precision tuned damping used in RS2000 series tables.

To assess the dynamic rigidity characteristics of an optical table, manufacturers typically provide the table's compliance curve. It shows the dynamic response of the tabletop in a free space condition to an external force, i.e., it gives an indication of how the surface will change shape in response to vibration. Compliance curves are transfer function curves that show the position response of a point on the table surface to a time variant force applied at the same point.

Compliance curves tell you the frequency range over which the optical table acts as an essentially rigid body. The curve also provides the frequency of primary resonance modes and an indication of their relative amplitudes, which gives information about the damping built into the structure.

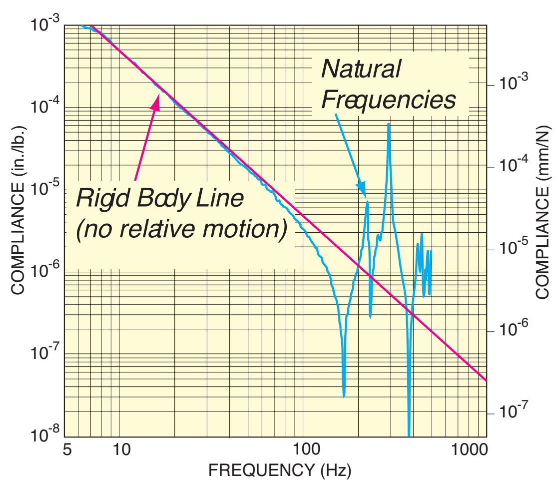


Fig. 4. Example of a compliance curve of an MKS Newport optical table ©MKS Inc.

Vibration Control and Isolation

In addition to tabletop damping methods, optical table supports can filter vibrations before mechanical noise reaches the working surface. While rigid legs without additional vibration control may be sufficient for non-critical applications, freestanding isolating legs, such as MKS Newport S-2000 pneumatic isolators, are an excellent choice for vibration-sensitive setups.

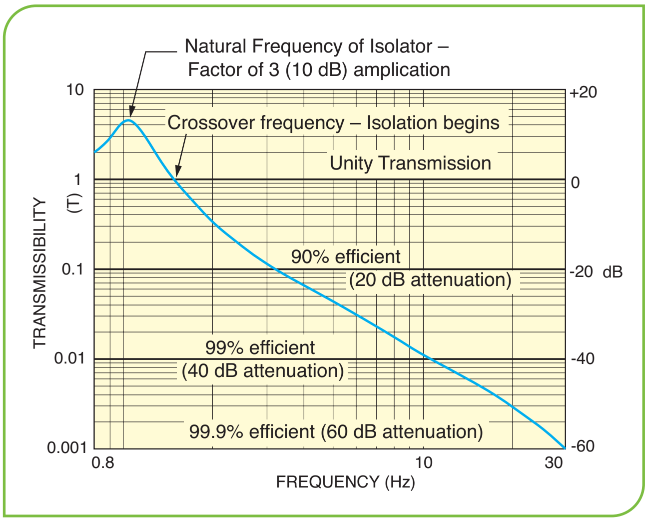
Fig. 5. MKS offers high-performance optical table supports with the Newport S-2000A Series Stabilizer™ pneumatic vibration isolators. Featuring uniquely engineered elements such as a hybrid chamber, laminar flow damping technology, and adjustable height, the S-2000A is a superior choice for meeting demanding isolation specifications while ensuring ease of use.

In general, vibration isolation in the table supports can be achieved with passive or active isolation. Active isolation systems use piezoelectric or electrodynamic components while passive options include springs, rubber pads, air-filled bladders, or pneumatic self-leveling isolation legs. Each method offers different levels of performance, capability, and, naturally, cost. Active isolation can cost up to 10 times more than pneumatic isolation. Such an investment is typically only warranted for applications sensitive to sub-Hz vibrations, such as atomic force microscopy. The most common type of isolators used in photonics are pneumatic systems since they offer self-leveling and minimize the effect of varying mass on isolation.

The performance of the isolator is defined primarily by its natural frequency and damping characteristics:

- **Natural frequency** (natural mode, resonance) – The pneumatic isolator is essentially a simple harmonic oscillator that uses the “fast roll-off” at higher frequencies to act as a low pass mechanical filter. Below the natural frequency of the harmonic oscillator the isolator is essentially rigid, and vibration is passed directly to the platform. At the natural frequency vibration is amplified. Therefore, a primary goal is to lower the natural frequency, as this shifts the isolation region to lower frequencies and overall isolation bandwidth.
- **Damping** – Another primary goal is to damp the harmonic oscillator amplitude at resonance. This lowers the magnification of vibration at low frequencies and improves system stability. Unfortunately, there is a compromise between the natural frequency and damping: as damping is increased, the isolator natural frequency moves slightly higher, and higher frequency isolation is decreased.

Another important differentiator when it comes to pneumatic isolation is the way to filter horizontal “noises”. With some manufacturers, pneumatic isolators only cover isolation in the vertical direction, while horizontal isolation is achieved through mechanical filter systems with some form of a bearing surface to provide a pivot or rolling surface for vibration filtering.



Advanced isolators, as provided by MKS, incorporate frictionless trifilar pendulum systems for horizontal vibration isolation. Since the system operates by flexing, it offers no frictional resistance to motion and can isolate very low amplitude mechanical vibration.

To compare the isolation "quality" of an isolator, manufacturers typically provide a transmissibility curve. It shows the mechanical filtering properties of the isolator leg and provides an indication of how much floor vibration will be transmitted to the tabletop. It is a relative measure given as a ratio of vibration at two points: one on the top of the isolator and one on the floor. These curves also give some indication of the damping present in the design.

Fig. 6. Example of transmissibility curve ©MKS Inc.

How Sensitive is the Application?

What requirements does the specific application impose? This is a question that users must clarify in advance before selecting an appropriate optical table. The two most critical aspects to consider when purchasing an optical table are your primary application and the lab environment. The requirements for introductory first-semester experiments with students are far less demanding than those in quantum labs, where researchers spend years building their setups and aligning laser beams with nanometer-level precision, or for biologists aiming to capture a clear image of neural networks using two-photon imaging.

As a first step, potential sources of noise should be analyzed and quantified. In very demanding applications, the amount of vibration reduction necessary is ideally determined through a measurement analysis of the environment and the actual elements within the application. This would include a vibration site survey using low-noise seismic accelerometers and possibly noncontact vibration analysis using laser Doppler vibrometers. The latter is an expensive and timely process reserved for only the most precise and demanding applications such as semiconductor wafer fabrication, interferometry, and holography. Generally, these applications need at minimum a pneumatic isolation system and highly damped optical table. In extreme cases an active isolation system or actively damped table may be required depending on whether the source of vibration is emanating from the floor or the table surface, respectively, and the magnitude of these disturbances.

However, for most of the applications, evaluating the cost-benefit-ratio of conducting such extensive surveys may indicate they are not required. High-quality suppliers often provide the option to upgrade optical tables at a later stage, which ensures flexibility for evolving experimental needs. This capability allows laboratories to start with a cost-effective solution and seamlessly enhance performance without replacing the entire setup.

"Generic vibration criteria curves" are commonly used as guidance for customers selecting vibration isolation solutions. These generic criterion curves have been developed based on data from individual systems and measurements made in facilities both before and after vibration problems had been solved. Moreover, they have been used extensively by leading vibration consultants e.g. for the semiconductor manufacturing industry for almost 20 years and have been extended and refined as the industry has moved to narrower line widths.

The curves consider that equipment used for the most demanding tasks (such as manufacturing semiconductors with smaller device geometries) is stiffer and better isolated. It is, however, important to note that these criteria are for guidance only.

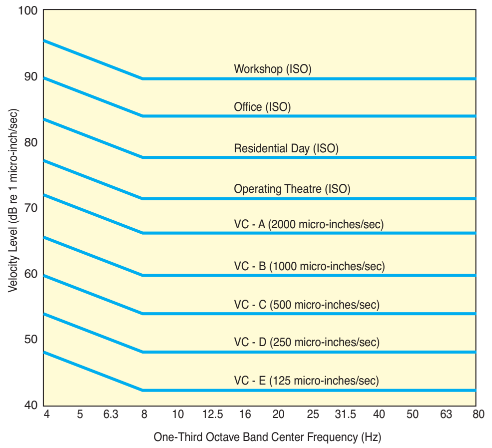


Fig. 7. The generic vibration criterion table is based on the research of Colin G. Gordon and Eric E. Ungar in the 1980s and was first published in a SPIE paper in 1992 [1].

Once the potential sources of vibration and noise have been identified, the next step is to assess the system's specific requirements to determine whether vibration isolation is necessary, and to what extent. A well-considered design that minimizes noise sources and maintains a clean, organized workspace can significantly enhance experimental reliability and lead to successful outcomes, including new discoveries.

Material Properties

Beam path stability is a primary requirement for many optical experiments and processes. In addition to damping and vibration control, optical tables also require both high surface flatness and thermal stability. The tabletop should ideally be produced in one piece adhering to highest production standards to guarantee superior flatness.

Modern optical tables typically use a stainless-steel top skin, in combination with other materials like steel honeycomb and epoxy, because stainless steel provides a rigid, stable, and corrosion-resistant working surface. This construction creates a highly stiff, yet relatively lightweight structure that minimizes vibrations and maintains flatness, which is crucial for sensitive optical experiments. MKS includes other desirable common features like non-corrosive, individually sealed holes to prevent dust and liquids from entering the core of the table, and uses highly damped composite wood side panels to help eliminate vibrations from the sides.

For applications demanding the highest grade of thermal stability, materials such as Super Invar and other advanced alloys are used. Super Invar is a special alloy known for its exceptionally low thermal expansion rate. This allows it to maintain its shape and dimensions even with extreme temperature fluctuations, making it an essential material for precision instruments and scientific equipment.

Applications that are sensitive to magnetism need to be placed on a virtually non-magnetic structure made of 316 stainless steel. These types of optical table tops feature the same broadband damping, while the top and bottom skins as well as the trussed honeycomb core are made of virtually non-magnetic 316 series stainless steel.

To achieve maximum flatness, some suppliers offer granite platforms, granite-epoxy composites, or granite-honeycomb composites. However, granite is generally not the first choice for tabletops, as its mass does not contribute significantly to structural stiffness. Instead, the honeycomb structure provides lower mass, greater stiffness, and superior vibration control performance.

Customization and Flexibility

When evaluating options for optical tables, it's important to consider not only standard configurations but also the flexibility to adapt existing products to meet one's specific application needs. Experienced manufacturers often offer a wide range of customization options to support this. For instance, if your setup involves a substantial load and results in a high center of gravity, achieving stable floatation – especially in vibration-isolated systems – can become challenging.

In such cases, design adjustments like lowering the mounting height or redistributing mass may be necessary to maintain system stability and performance. In cases where large tabletops cannot be moved into the facility as a single piece, doubler systems are available, connected with unique joining interfaces designed to maintain rigidity and strength between individual table sections.

Conclusion

Selecting the right location for your laboratory and minimizing the environmental noises is an important first step. However, in many cases, there is little choice in these matters. The good news is that there are very effective options for damping and vibration control, enabling highly sensitive applications on optical tables even in laboratories near railroad tracks. Consulting an experienced supplier ensures that your optical table and isolation system are tailored to your specific requirements for delivering maximum performance and long-term reliability.

This white paper is based on an article written by Guofeng SUN, MKS Senior Product Marketing Manager Newport Products, and Dalila AIT AMIR, MKS Senior Sales Manager Newport Products France, published in French in Photoniques 136.

References

[1] Gordon, C. G. (1992). *Generic criteria for vibration-sensitive equipment. In Vibration Control in Microelectronics, Optics, and Metrology* (Proc. SPIE Vol. 1619, pp. 71–85). Society of Photo-Optical Instrumentation Engineers. https://doi.org/10.1117/12.56826

Metric Table Top Finder

Compliance and Transmissibility Curves

Optics Based Research - The Need for Vibration Isolated Rigid Support Structures

Optical-Table-Basics.pdf

CONFIGURE THE OPTICAL TABLE PERFECTLY BUILT FOR YOUR APPLICATION

Whether you're setting up a new lab or upgrading existing infrastructure, our experts guide you through key selection criteria – from size and damping performance to mounting options and accessories.

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Contact the Newport Optical Tables team at MKS to discuss your application, request a consultation, or explore configuration tools that help you specify the ideal optical table with confidence.