Is Vibration Control Really Necessary for Microscopy?

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As a supplier of vibration control equipment, we at Newport are frequently asked if vibration control is really necessary for microscopy applications, and you might expect the answer to be "of course." However, the correct response is slightly more complex because the need for vibration control lies between the environmental conditions in the laboratory and the requirements of the experiment.

The lab environment

Identifying and quantifying the potential noise sources in your lab are the first steps toward understanding what vibration control solutions may be required to achieve acceptable results.

Most laboratories will contain some nominal level of floor vibration due to automotive traffic, building sway or large machinery such as elevators, HVAC equipment or pumps. The magnitude of these disturbances is usually proportional to their proximity, the type of building construction and their location within the building. Laboratories located on lower levels or, better yet, in basements typically will experience lower levels of vibration compared with upper levels of that same building. A common practice to understand potential vibration problems is to conduct a vibration site survey to quantify the levels of vibration.

Figures 1 and 2 represent vibration site survey data for two different laboratories. The lab in Figure 1 was located on the second floor of a concrete structure and is shown to have approximately 58-dB noise at 7.8 and 62 Hz, a combination of building resonance and rotating equipment. The lab in Figure 2 experiences significantly lower levels of vibration overall (VC-E), but you can still see signature peaks at 4.9, 8, 31.5, 60 and 250 Hz. The lower frequencies are typical of building resonances, while the higher frequencies are typical of rotating equipment. In each of these locations, the site survey data should be compared to vibration standard criteria to assess whether the measured and anticipated vibration levels would allow imaging to the desired resolution.

For years, the vibration criteria curve, like the one shown in Figure 3, has been used to perform this assessment. Each curve along the graph represents maximum vibration levels in terms of both decibel and velocity. Also shown with each curve is the minimal detail size that could be imaged at each level. For instance, the lab in Figure 1 had a maximum level of 58 dB at 7.8 and 62 Hz, which puts it at a VC-B environment. At this level, the minimum feature size you could expect to image is 3 μm, and optical microscopes could achieve a 1000× magnification with acceptable image quality. If this research group's application required imaging details below 3 μm – let's say to 0.3 μm – they would certainly need to incorporate some vibration isolation products that would reduce this noise level by at least 12 dB (VC-B to VC-D).

However, vibration disturbances can sometimes be sporadic events that may not occur during site surveys. Consider occasional deliveries of new equipment or supplies, or an air compressor that would operate only when the main pressure tank reaches a specified level. In both instances, the generated vibrations may disturb imaging system results that may have been undetected by a previous vibration site survey. It is important to consider the measured vibrations and to anticipate additional sources that may affect imaging results in the future.

Experimental setup

Consider the requirements for coherent anti-Stokes Raman scattering (CARS) microscopy. CARS was first reported in

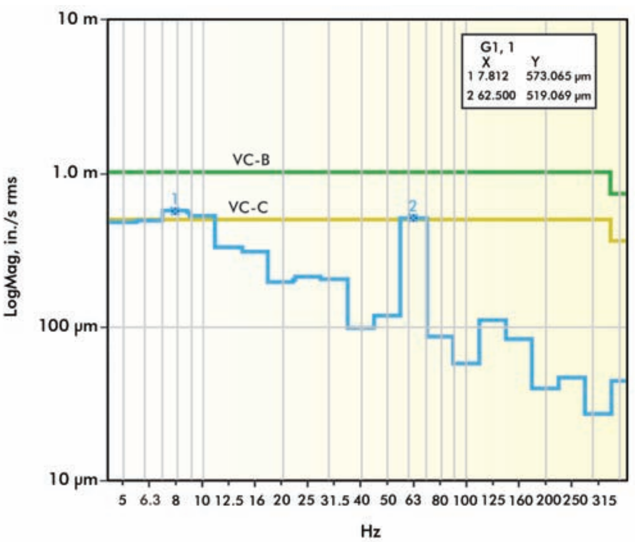


Figure 1. This graph shows vibration data from a VC-B level lab that generally would be considered above average. Images courtesy of Newport Corp.

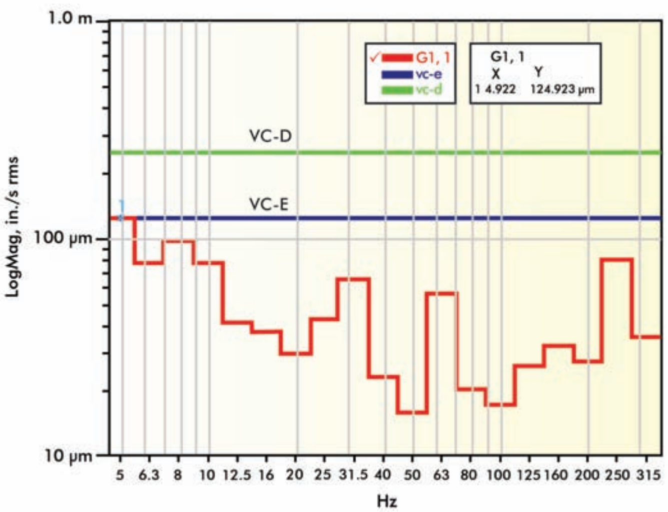


Figure 2. This graph shows vibration data from a VC-E level lab that generally would be considered exceptional.

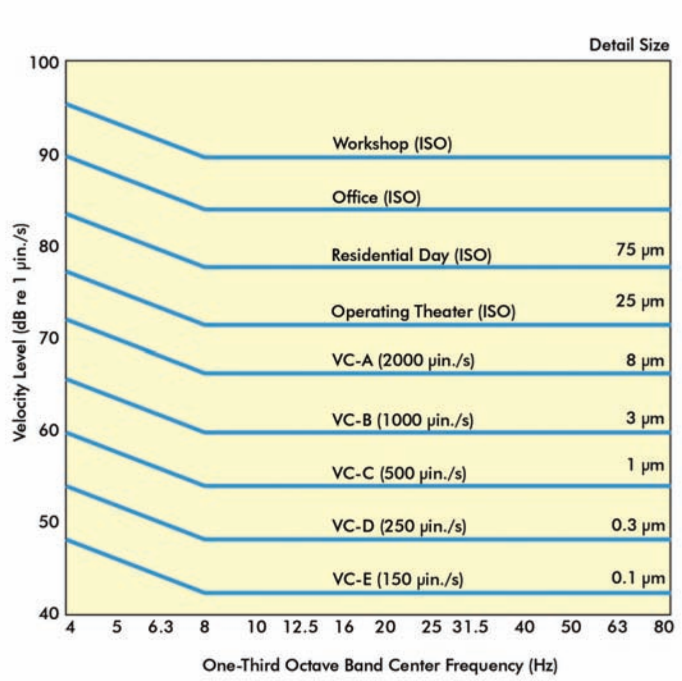
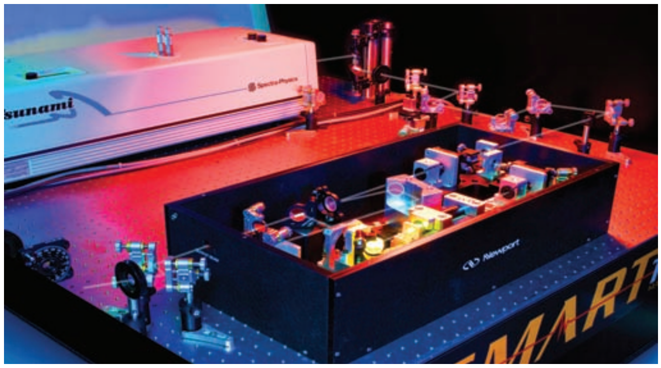


Figure 3. Shown are vibration criteria curves.



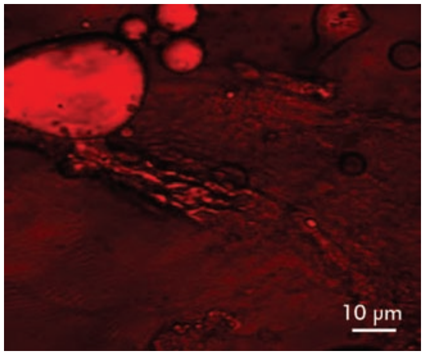


Figure 4. (Top) A CARS microspectrometer system illustrates the long beam paths that can be sensitive to platform vibrations. The slightest deviations in path length or spatial alignment will cause image degradation. (Left) A CARS image of bovine muscle taken at Newport's Technology and Applications Center Lab in Irvine, Calif.

1965 by Maker and Terhune[1] as a method of spectroscopy for chemical analysis. CARS as a method of microscopy was first reported in 1982[2] and later revisited by the Xie group in 1999.[3] Being a nonlinear process, it allows image sectioning similar to two-photon excited fluorescence microscopy without the need for sample labeling.

An experimental setup of a CARS spectrometer system from Newport's Technology Applications Center is shown in Figure 4. The most challenging part of constructing a CARS setup is correct timing between the pump and Stokes pulses, as they must overlap in both time and space. This requires not only precision components to execute but also a stable platform to maintain the temporal and spatial distances during imaging. Relative changes of the optical path length between pump and Stokes beam by tens of microns, or spatial misalignment of the two beams, leads to significant degradation of the anti-Stokes signal. A typical CARS imaging system provides a resolution down to 500 nm, so even the smallest amount of platform vibration could dramatically affect image quality. To reach this level of performance, the laboratory environment would need to be at a VC-D level, which is better than typical research labs, or incorporate both pneumatic isolation and damped optical surfaces.

Figure 5. Tight hoses hanging off platforms like those shown can transmit vibrations directly onto the table surface. These cables should have some type of foam isolator placed under them or be supported so they do not touch the table.

In addition to understanding the lab environment and experimental needs, users also must be aware of system design and construction issues that would also affect imaging results. One common issue seen with microscopy vibration problems occurs when users accidentally couple floor vibrations directly into their table via rigid hoses or rotating devices, or when systems are installed under air ducts.

In any lab environment, the most effective and economical method of vibration control is eliminating the vibration source. Asking a facilities team to move a noisy pump room is probably a little too extreme, but making sure that no unnecessary sources of vibration are being introduced into the table surface is much more

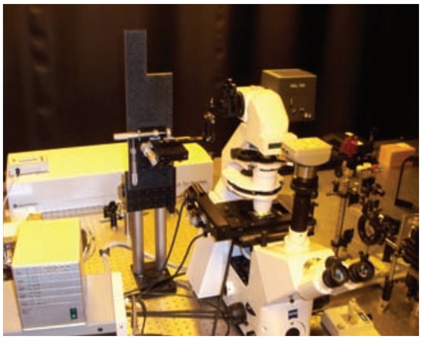


Figure 6. The use of a dual damped rod structure improves image quality by reducing unwanted vibrations. The use of undamped posts or poorly constructed vertical supports is a common cause of image degradation.

Figure 8. The new Vision IsoStation is available in multiple sizes from 24 × 24 up to 36 × 72 in. and two load capacities, 500 and 1300 lb. All models reduce transmitted vertical and horizontal vibrations by 70 percent (−10 dB) or more at 5 Hz and by more than 95 percent (−26 dB) at 10 Hz. The multiple storage and work surface options also help provide areas to store nonessential items or instrumentation that might otherwise induce vibrations.

Figure 7. Air duct baffles redirect airflow and will help reduce tabletop disturbances while maintaining proper lab temperatures.

Figure 9. Choosing field-upgradable vibration control solutions like the SmartTable OTS platform isolator shown here can help meet near-term budgetary requirements and long-term performance needs.

manageable and economical. This includes isolating rigid compressor or pump hoses from the table surface through the use of service loops or soft foam (Figure 5). Also, minimizing the height of beam steering paths or assuring that they are sufficiently rigid or damped will help improve image quality (Figure 6). Air ducts are another common problem, since they can induce both mechanical motion and thermal changes that would affect image quality (Figure 7). Wherever possible, systems should not be located in the path of supply ducts, and ducts should be baffled if possible so that airflow is not directed into the system.

Vibration control solutions

Any vibration control system essentially has two goals. The first is to effectively reduce the impact of environmental noise to a level that will maintain an acceptable relative spatial position of the elements within your system. Examples of this include building vibrations transmitted through the floor that can affect laser beam stability, optical element positioning and target point stability. This is traditionally provided by vibration isolation products such as pneumatic or elastomeric isolators – Newport's S-2000 stabilizer isolator or its NewDamp elastomer isolators, for example.

The second goal is to protect system components from being excited by external sources within the system itself. This includes disturbances residing atop or around the instrumentation that originate from positioning stages or rotating devices, cooling fans or pumps. These types of disturbances tend to propagate along the table surface and excite the natural frequencies of the table or breadboard, or even the microscope equipment itself. The most effective method at reducing these disturbances is through the use of rigid platforms that use tuned mass dampers like those found in Newport RS2000 series tables.

Recall the vibration data shown in Figure 2, where the lab experienced 58 dB of noise at 8 and 62 Hz, and combine that with a need to build a new CARS setup for in vivo imaging of myelin fibers down to 500 nm. With 58 dB of noise (VC-B)

Isolator Type	Vertical Resonant Frequency (Hz)	Vertical Isolation @ 5 Hz	Vertical Isolation @ 10 Hz	Load Capacity (lb per Isolator)
NewDamp elastomers	10 to 20	NA	NA	45 to 450
BenchTop	3.2	NA	86% −17 dB	60
SL-1200	3.2	NA	86% −17 dB	1200
Vision IsoStation	1.5 to 1.9	70% to 86% −10 to −17 dB	95% to 97% −26 to −30 dB	125 to 325
SmartTable OTS	1.5	86% −17 dB	96% −28 dB	1250
S-2000	1	94% −24 dB	98% −34 dB	2000

Table 1. Isolator Performance Comparison

and a requirement of a 48-dB level (VC-D), this facility would have to incorporate a vibration control solution capable of providing a 10-dB reduction in transmitted vibrations at 8 and 62 Hz. The performance data presented in Table 1 illustrates the various isolator options available, depending upon the performance and load capacity. At the targeted frequencies, an elastomeric solution would not provide sufficient reduction, and the performance from an active isolation system would not be worth the price. However, pneumatic isolators like Newport's S-2000, OTS platform or even the SL-1200 would provide sufficient performance for this application. For microscopy applications with a smaller footprint (less than 3 × 6 ft), users could even consider a vibration-isolated workstation system like the new Vision IsoStation (Figure 8).

In some situations, the lab environment may not be well understood or may even change over time as new buildings, roads or rooms are added to the campus. There is also the possibility of entire labs moving to new buildings or floors. Additionally, experiments may change over time, typically becoming more complex than originally planned. Because of these ever-changing situations, the best approach is to focus on near-term needs but also to consider equipment that could be field-upgraded in the future to improve performance.

Newport's SmartTable OTS system was designed specifically to address these needs since the system can be purchased initially as a rigid frame support and can be field-upgraded to a fully pneumatic, active-leveling isolated platform (Figure 9). There are also two upgradable table models available with this system that can also be field-upgraded to a system that is fully, actively damped. Since most imaging platforms are in service for many years, it is important to select equipment that will meet today's requirements but also serve future needs as they arise.

The vibration control solutions that biological imaging applications require are similar to those for laser applications, and both should start with an understanding and quantification of the potential sources of noise. This would be followed by an assessment of the needs of the system to determine what, if any, level of vibration reduction is necessary. Finally, constructing the system in a manner that minimizes noise sources and maintains an organized and quiet work space will result in many successful investigations and, hopefully, new discoveries.

Meet the author

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