Laboratorytalk

Vibration isolation is key to accuracy

A Minus K Technology product story
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Yale University has put into place a vibration isolation system specifically tuned to the precision level of the research into brain activity that the lab is undertaking

Led by professor Lawrence Cohen of Yale University's department of cellular and molecular physiology, the small lab in room BE58 at the Yale School of Medicine has been conducting research on neuronal activity in brain cells to develop methods for imaging brain activity, and then uses these methods to study the brain.

The university has been developing the method for imaging brain activity for 42 years, but it was not until several years ago that the lab opted to move to a higher level of vibration isolation technology to support its microscopy imaging which it conducts at the micron level. It is not unusual for universities, and industry for that matter, to have to deal with problems in site vibration which compromise to a greater or lesser degree the imaging quality and data sets which they acquire through microscopy.

Although it is certainly the desire of every lab to rid the unwanted vibration, conventional systems such as air tables which many universities and industry labs still use, have not been successful in providing an adequate level of vibration isolation for ultra-sensitive equipment measuring at the Angstrom and micron levels. Such was the case with Cohen's lab at Yale, where air tables had been the mainstay for the lab's vibration isolation for many, many years. But now, for adequate isolation to conduct its neuronal research at the micron level, the air tables were not able to provide the vibration isolation needed for the lab's research.

Measuring brain activity.

"One reason the brain is difficult to study is that many individual neurons or brain areas are active at once, and conventional electrode techniques allow monitoring of only one or a few neurons or locations at a time," says Cohen. "We have worked on several variations of an optical method for measuring brain activity, utilising both voltage-sensitive and calcium-sensitive dye methods to study neuron activity, and in favourable preparations the spike activity of about 500 individual neurons or thousands of brain regions can be monitored simultaneously. "These methods have good temporal (msec) and spatial (10s of microns) resolution. "Monitoring many neurons or regions simultaneously can improve our understanding about how nervous systems are organized," continues Cohen.

"Recently, we have used these methods to study the processing of olfactory information in the turtle and mouse. "We have obtained maps of the input to the olfactory bulb which define the responsiveness of individual olfactory receptor proteins. "In the future, we hope to obtain maps of the output of the bulb. "A comparison of the two maps can provide a powerful description of the role of the olfactory bulb in processing olfactory signals.

"Basically, depending on the dye, we are viewing the voltage across the neuron membrane or the calcium concentration inside the neuron. "When the action potential travels along the nerve and comes to the nerve terminal it releases a chemical that acts on the adjacent nerve cell. "In order to release that chemical it opens a calcium channel."Calcium comes into the nerve terminal, and that calcium causes a vesicle - which is filled with chemical substances, to fuse with the membrane, and the transmitter substance is released. "The voltage is the signal that the cell uses to carry information from one end to the next. "For example, the cells in your spinal cord have to get information from your toe, and also send information to your toe. "That signal is a propagated electrical wave of membrane potential, and dyeing that membrane can provide an optical signal that is used to measure that propagated wave".

The lab uses a high-speed camera to view these changes. It has a speed of 2000 frames per second with very high quantum efficiency, which is the quantity of photons that get converted into electrons. The camera has a quantum efficiency of about 0.9, which converts almost all the photons into electrons. (In contrast, photographic film has a quantum efficiency of <0.01, converting less than one percent of photons into darkened silver grains). In the lab's optical monitoring of brain activity, each pixel in the recording receives light from a small portion of neurons which have been stained by microinjection of the dye into the brain. After waiting for the dye to spread into the processes, the dye can be used to monitor changes in membrane potential in dendrites and axons.

When a low magnification objective is used to form an image of a vertebrate preparation on the lab's 464 element photodiode array or 80x80 pixel CCD camera, each pixel receives light from hundreds or thousands of neurons. The signals are the population average of the membrane potential or calcium concentration changes in those neurons. These population signals monitor coherent activity - those events that involve simultaneous changes in activity of a substantial fraction of the neurons in the imaged region. It is also using a variety of microscopes to conduct this research including a laser scanning two-photon microscope, and an optical microscope.

At this time, only the optical microscope is set on the Negative-Stiffness vibration isolation system, built by Minus K Technology. "Measuring in the dimension of microns still requires vibration isolation because it is so small," says Cohen. "Any small movement in the lab environment makes a big effect. "If you are viewing at ten microns, and it vibrates by ten microns, then you are in big trouble. "We were using air tables before, but the Negative-Stiffness isolator is much better. "It reduces the vibration by a larger faction because it reduces the vibration in the X/Y plane just as well as in the Z plane, where the air table does not do well at all on the X/Y plane.

"For years we have worked hard to get rid of vibration noise, with only partial success," Cohen adds. "Our lab is located one floor above the basement. "Having been in the business a long time I know if we were in the basement it would be better. "I have had my lab in places that are quieter. "Since we put in the Negative-Stiffness system several years ago, we have not had to think about vibration noise at all. "Before, there was always vibration noise, and I would spend five to ten percent of my time worrying about vibrations".

Negative-stiffness vibration isolation.

Negative-Stiffness isolators employ a unique - and completely mechanical - concept in low-frequency vibration isolation. Vertical-motion isolation is provided by a stiff spring that supports a weight load, combined with a Negative-Stiffness mechanism.

The net vertical stiffness is made very low without affecting the static load-supporting capability of the spring. Beam-columns connected in series with the vertical-motion isolator provide horizontal-motion isolation. The horizontal stiffness of the beam-columns is reduced by the beam-column effect - a beam-column behaves as a spring combined with a Negative-Stiffness mechanism. The result is a compact passive isolator capable of very low vertical and horizontal natural frequencies and very high internal structural frequencies. The isolators (adjusted to 1/2Hz) achieve 93% isolation efficiency at 2Hz; 99% at 5Hz; and 99.7% at 10Hz.

Vibration isolation in bio-research.

It is critical that researchers apply the correct vibration isolation solution to their sites.

Putting up with lab vibration noise problems for any amount of time, let alone for a period of years, can only be costly in terms of lost production, and will certainly inhibit the progress of the research. Bio-research is expanding at a huge rate into scores of different disciplines and literally hundreds of diverse applications.

This will inevitably mean a sizable increase in the number of non-optimum, high-vibration-prone labs sites that will be in desperate need of truly functional vibration isolation.