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Control Technology Helps Reduce Errors

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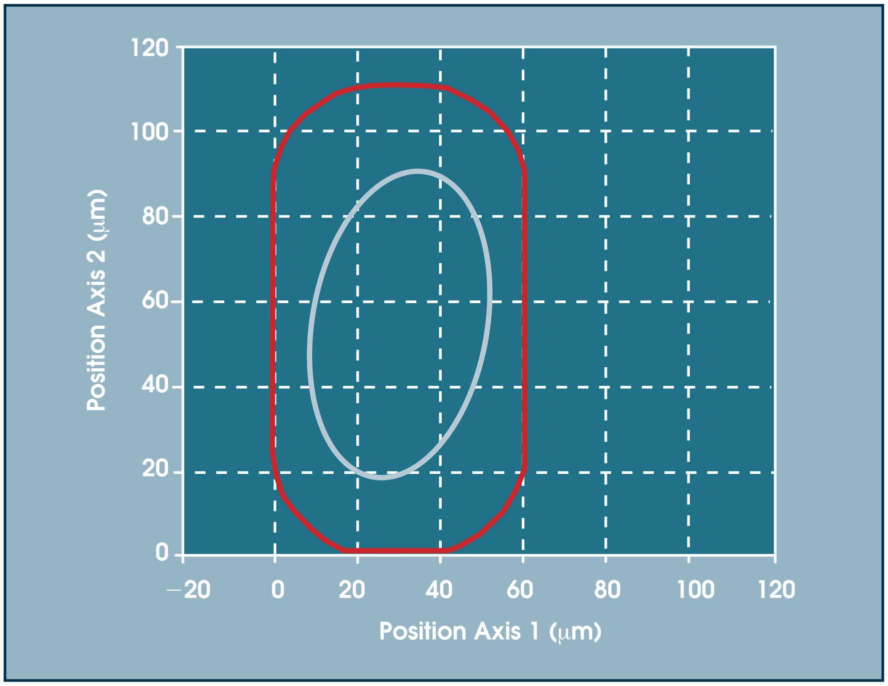
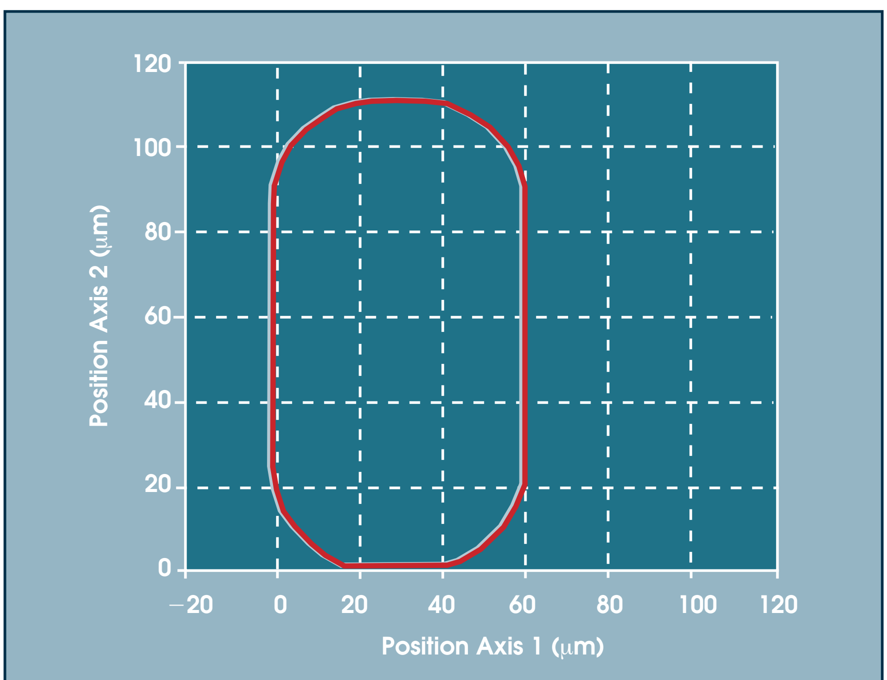


Lag time between the desired scanning position and the actual position can create following error (above), but automatic optimization technology, called digital dynamic linearization, can reduce the error (below).

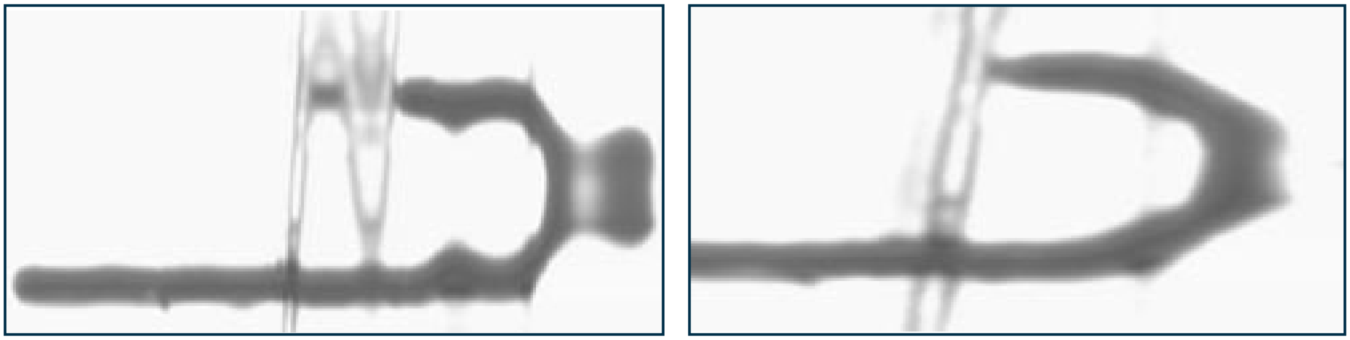


High scanning speed is a critical requirement for many of today's microscopy applications because the specimen under study either is short-lived or goes through rapid transformations. Bleaching of the sample also can be a problem if a scan is too slow. Somehow, this often unpredictable sample must be positioned rapidly under the microscope objective using a precise, repeatable method.

Such trends are fueling the use of direct-drive piezoelectric motion devices in applications including fluorescence spectroscopy and microscopy, optical trapping and near-field scanning optical microscopy. Although even the latest generation of scanning technology can encounter bottlenecks that can limit system performance, many of these issues may be resolved by tweaking the control technology.

In general, scanning applications face two types of potential bottlenecks. One is metrology-related and ties directly to how well the equipment can detect and resolve rapidly changing light levels and then send that data to the scanning mechanism's controller. The second involves limitations in the scanning mechanism itself. For example, the servomotors that drive many scanning devices are, by definition, error-following mechanisms based on feedback. This means that the motor idles unless a position error is detectable, making some lag time between the desired and actual position almost inevitable. This lag time generates what is called following error, which is not always easy to eliminate.

If no technique is available in the motor controller to adjust for following error, another solution is to implement automatic optimization technology called digital dynamic linearization. This firmware option for digital controllers automatically observes the finite following error in high-speed scanning and patterning applications and compensates for them during subsequent movement of the equipment. Reducing this error to an un-



Vibration-nullification software called Input Shaping can eliminate vibration (ringing) in optics, in fixturing and in loads in fast-motion applications, such as the vibration that caused the banded defects (left) in these scanned laser confocal microscopy images of a 3-μm, J-shaped resolution target. Canceling the ringing effect improves accuracy, resolution and available scan area (right).

observable level allows features such as single fluorescent molecules or specific sites of interest in large molecules, such as DNA, to be localized more accurately in fast large-area scans.

Many biological applications also require the simultaneous measurement of optical output while the nanopositioning stage actuates. For example, fluorescent elements in a specimen might be excited during a raster scan as part of the image formation process. And scientists may use optical modulation through a scanned fiber to examine subtle surface features of a specimen.

Use with power meters

As power metrology technology advances, the devices are finding use in these types of applications. This has not been the case until recently, though, because conventional power meters often had limited communications capabilities uncommon for meters to support only a few dozen readings per second, in part because of limited analog bandwidth (20 to 50 Hz was common). The resulting speed limitations produced bottlenecks in scanning, profiling, tuning and aligning applications.

Upgrading instrumentation can help; however, a critical component of the solution is the interface between the metrology and nanopositioning equipment. Engineers at PI (Physik Instrumente)SA in Auburn, Mass., recently used the LabView tool kit from National Instruments to link stages with power meters from Small Planet Photonics in Irvine, Calif. This latest generation of optical power meter offers raw bandwidth of 10 kHz across all scanning ranges.

In addition, use of a patent-pending parallel analog interface makes it possible to optically scan the full field of an X-Y piezoelectric nanopositioning stage in 500 ms with more than six orders of magnitude of dynamic range. This is about two to three orders of magnitude faster than conventional instrumentation.

Another issue that end users of nanopositioning stages have to consider is settling time. The rapid actuation of the stages can cause onboard and neighboring fixtures to ring (vibrate) at their characteristic natural frequencies. Even small vibrations can cause errors in applications demanding tight system resolution. This problem also can be resolved through control software.

One option is Input Shaping vibration-nullification software. The end user or the systems integrator first identifies and measures any resonance that could cause problems with the positioning task, and the software uses this information to ensure that the workpiece and adjacent components settle instantaneously, rather than after many cycles of diminishing oscillation.

Even the most advanced nanopositioning technology can face performance limitations caused by basic bottlenecks such as servo following error, metrology equipment bandwidth and settling time. Often, the solution to the problem may depend on the software capability of the system controller. □

Meet the author

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