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Accent on Applications | May 2006

Using photonics to solve problems of the real world

Deformable Mirror Improves Microscope's Field of View

by Hank Hogan

Benjamin Potsaid, a research scientist at the Center for Automation Technologies and Systems at Rensselaer Polytechnic Institute in Troy, N.Y., wants to view small objects over long distances. Others at the center who are working on robotic micromanipulation and assembly would like to magnify small objects over large areas.

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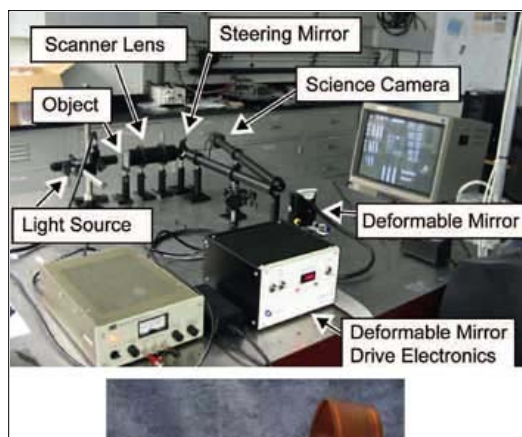
The problem is that physics and real-life optics get in the way. "As the resolution of the microscope increases to observe smaller features, the field of view — the region of the object that can be observed — decreases," Potsaid explained.

To get around this, the researchers turned to deformable mirror technology from Boston Micromachines Corp. of Watertown, Mass. They have constructed an adaptive scanning optical microscope that employs the deformable mirror to correct for off-axis aberrations in a custom scanner lens. Potsaid said that this new technology enables a field of view that is two orders of magnitude larger at the same resolution than a conventional microscope's, citing a design with a 40-mm-diameter field of view at a resolution of 1.5 μm .

There are several traditional solutions to the problematic trade-off between resolution and field of view. These include the use of multiple parfocal objectives, zoom lenses, moving stages, moving microscopes and multiple microscopes. It even is possible to get close-ups over long distances using a high-pixel-count camera and the optics employed in projection lithography. The last approach is costly, however, and the others suffer from such drawbacks as agitating the specimen during scanning, a limited field of view, slow scanning rates or difficult integration with conveyor transport.

As their solution, the scientists at the center had devised an instrument with a scanner lens assembly and a steering mirror. The mirror would move the field of view over a sample, and a camera would capture a series of small, distinct snapshots. These images then would be assembled into a large mosaic. Simulations showed that the approach would work — provided that off-axis aberrations in the optics were corrected.

Then, just as the team was transitioning from simulation to prototype design and production, the Mini-DM from Boston Micromachines became available. A smaller version of a microelectromechanical systems deformable mirror that the company had been offering, the mirror has a 2-mm-diameter aperture and 32 actuators that produce a 2.5- to 3.5- μm stroke. The actuators are spaced 400 μm apart in a grid across the area of the device. On command, the actuators move, thereby changing the mirrored surface slightly at up to 1000 Hz.



The deformable mirror corrects for off-axis aberrations in the adaptive scanning optical microscope, yielding larger fields of view at the same resolution than a conventional microscope provides. Courtesy of Center for Automation Technologies and Systems, Rensselaer Polytechnic Institute.

That capability allows the microscope to correct for off-axis optical aberrations. When the steering mirror is angled properly, the image at the camera comes

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from the center line of the lens assembly and is, therefore nearly perfect. In such a case, the Strehl ratio — a figure of merit that compares the performance of actual and ideal optics — would be 0.97 or 0.98 over the field of view. When the angle of

the steering mirror changes, the field of view shifts. The images then come from an off-axis point and are much worse than the ideal if not corrected.

By adjusting the deformable mirror's shape, the researchers account for these effects, which are known in advance, thanks to measurements and a calibration procedure. As a result of putting the right hills and valleys in the deformable mirror, the researchers keep the adaptive scanning optical microscope's Strehl ratio at 0.97 and higher over a 40-mm range of travel.

In addition to offering a larger field of view than is possible with traditional instruments, the microscope enables scanning speeds 10 to 100 times higher than those achieved by moving stages, Potsaid said. The microscope also is time-efficient in low-light conditions, which is important in biological studies where photo-bleaching of fluorescent labels can occur.

"The pixels are exposed simultaneously, rather than sequentially, as is the case in most confocal or line-scan imaging approaches," he said.

Additionally, the instrument offers different modes of operation, such as imaging regions of interest, tracking multiple moving objects and full-area coverage. A twist to the latter is that the microscope combines low-resolution background monitoring for rare-event detection and high-resolution imaging of the event itself.

There are some disadvantages to the approach, however. For example, a moving stage offers a virtually unlimited field of view, whereas the adaptive scanning optical microscope does not. On the other hand, because the adaptive scanning optical microscope's stage does not move, there is no chance that a delicate specimen will be disturbed or agitated.

The technology could be used in robotic micromanipulation, biotechnology and medicine, industrial quality assurance and automated medical diagnostics. Because of its wide applicability, Potsaid does not see the adaptive scanning optical microscope remaining exclusively at the center. He said that discussions are under way regarding commercialization and licensing of the intellectual property.

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