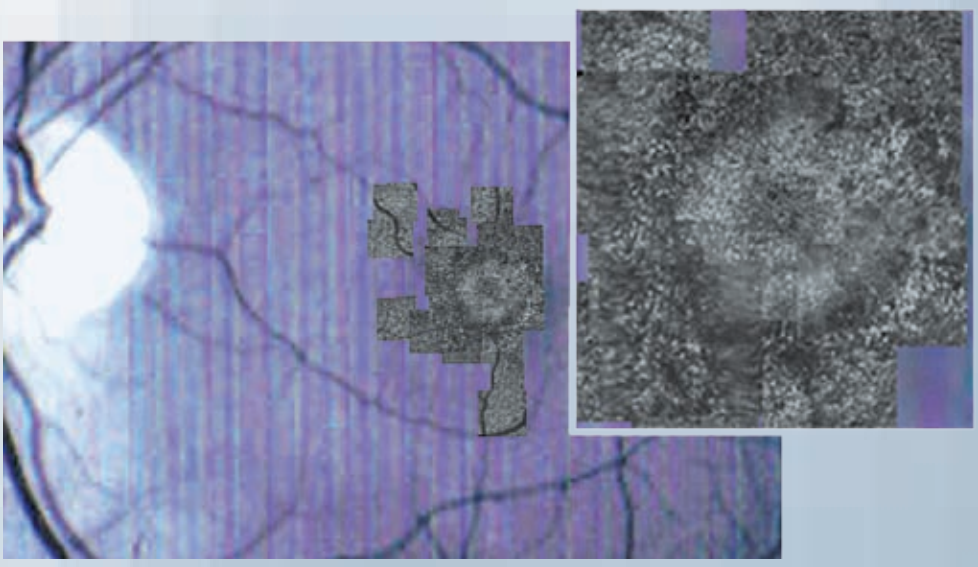
Retinal Camera Captures Early Stages of

LAWRENCE Livermore researchers, in collaboration with universities, medical centers, and industry, have developed an ophthalmoscope that uses adaptive optics and microelectromechanical systems (MEMS) technology to improve retinal imaging. With the MEMS-based adaptive optics scanning laser ophthalmoscope (MAOSLO), clinicians can visualize microscopic cellular structures in the eye—a major advancement over current ophthalmoscopes and retinal cameras. The Livermore collaboration received an R&D 100 Award for this new technology.

The research team, led by Livermore physicist Scot Olivier, used an adaptive optics system similar to that pioneered by the Laboratory for use in large telescopes, such as those at the W. M. Keck Observatory in Mauna Kea, Hawaii. Instead of viewing astronomical objects, the MAOSLO system sharpens images of the retinal cell layers in a patient's eye to provide enhanced details. Livermore's Laboratory Directed Research and Development Program funded early research efforts for the ophthalmoscope.

Clinical trials showed that clinicians using the system can diagnose the early stages of retinal diseases such as macular degeneration (an age-related disease in which the center of the eye's lining thins and atrophies), diabetic retinopathy (damage to the retina resulting from diabetes), and retinitis pigmentosa (a group of inherited diseases that cause the retina to degenerate). The MAOSLO system can also be used to monitor a patient's treatment.



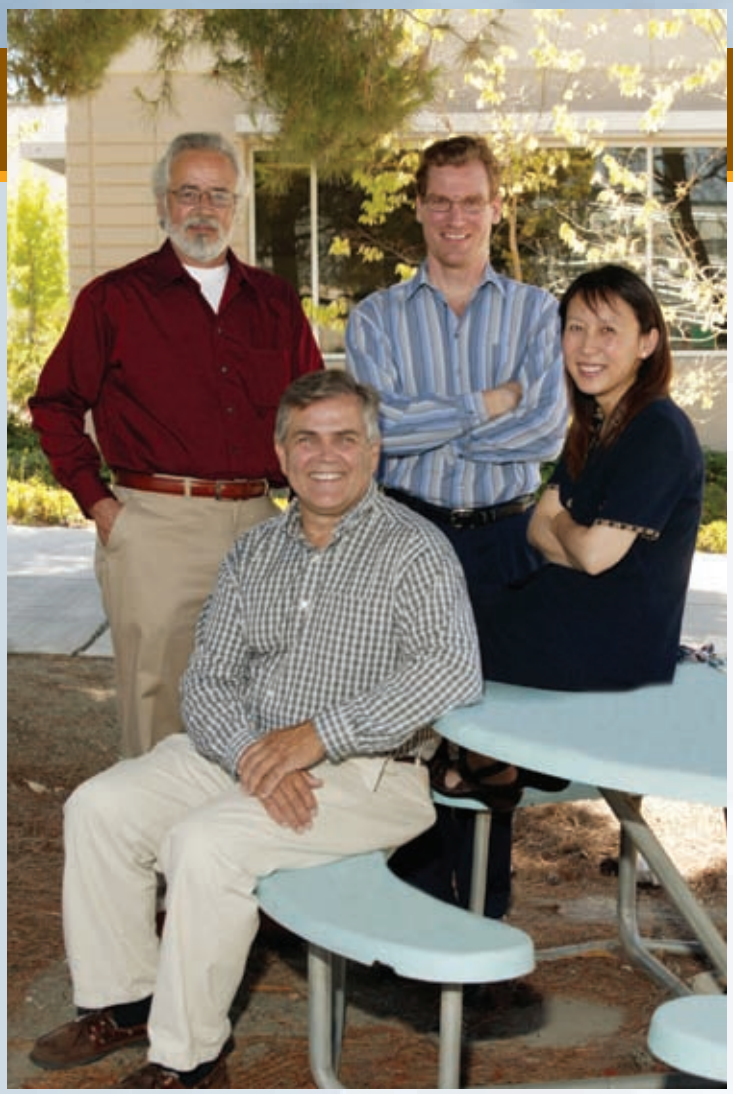
The microelectromechanical systems– (MEMS-) based adaptive optics scanning laser ophthalmoscope captures images of the individual cellular layers of the retina. The ringlike pattern in the inset indicates photoreceptor cell loss, which causes visual disturbances in a patient's line of sight.

The Science behind the Image

The Livermore ophthalmoscope is the first clinical instrument that automatically measures aberrations, makes the necessary corrections, and allows both clinician and patient to view the compensated image immediately. MAOSLO's optical system has tiny telescopes that relay light to two deformable mirrors and into the patient's eye. Horizontal and vertical scan mirrors focus a light beam onto the patient's retina in a raster, or uniform, pattern at the standard video rate of 24 frames per second. Light scattered by the retina follows the path of the incoming light but in the reverse direction. A wavefront sensor measures optical aberrations in both the incoming and outgoing paths, and a MEMS-based deformable mirror corrects the distortions. The light then passes through a confocal pinhole and into a photomultiplier tube, which produces a high-resolution, digital video of the retina.

As with other retinal imagers, MAOSLO provides digitized, permanent records that can be used to track changes in a patient's eyesight over time. The device also performs functions that other instruments do not. For example, having a second deformable mirror enables the system to correct for large refractive errors and quickly shift the focal depth in the retina. This feature produces clear views of distinct retinal cell layers, allowing clinicians to examine specific areas such as photoreceptors, blood vessels, or nerve fibers. The MEMS-based deformable mirrors also reduce the size and cost of the system without sacrificing speed or accuracy.

Eye Disease



Development team for the MEMS-based adaptive optics scanning laser ophthalmoscope (from left): Dennis Silva, Steven Jones, Scot Olivier, and Diana Chen.

Imaging the Unexpected

Researchers at the University of Southern California's Doheny Eye Institute conducted clinical trials of the device. Results from these studies demonstrated that MAOSLO identifies abnormalities in patients who show no symptoms of disease. One study examined several members of a family affected by Stargardt's disease, an inherited genetic retinal disorder.

As expected, MAOSLO revealed varying degrees of missing photoreceptors. The high-resolution images also exposed an unexpected defect in the photoreceptor layer of a family member who had no obvious symptoms and an otherwise normal clinical exam. This observation highlighted the device's potential for early disease detection and intervention and for helping researchers better understand how a disease originates and progresses.

Another clinical study involved a patient who complained of a visual disturbance in his central vision. A ringlike pattern of photoreceptor cell loss found in the MAOSLO images correlated with the patient's complaints. Researchers believe the patient has a rare retinal disorder known as coffee and doughnut maculopathy. The MAOSLO study may be the first to demonstrate the anatomic basis for this poorly understood disorder.

Positive Prognosis

MAOSLO gives eye doctors an affordable system to diagnose retinal disease in its early stages and effectively monitor treatment. It can also be used for vision research in animals, and it can be enhanced with additional light sources and detection channels to image fluorescent signals from the retina. In addition, the system can be designed to test pharmaceutical and molecular therapies developed for blinding diseases.

MAOSLO is available for licensing and has been in clinical operation at the Doheny Eye Institute for approximately one year. As the baby boomer population continues to age, their risk of age-related retinal diseases will increase. MAOSLO will be an important tool for ophthalmologists, optometrists, and scientists who are combating vision loss and blindness in their patients. It has the potential to improve the quality of life for millions of people.

—Caryn Meissner

Key Words: deformable mirror, microelectromechanical systems– (MEMS-) based adaptive optics scanning laser ophthalmoscope (MAOSLO), optical aberrations, R&D 100 Award, retinal imaging, wavefront corrector.

For further information contact Scot Olivier (925) 423-6483 (olivier1@llnl.gov).