New technology looks into the eye and brings cells into focus

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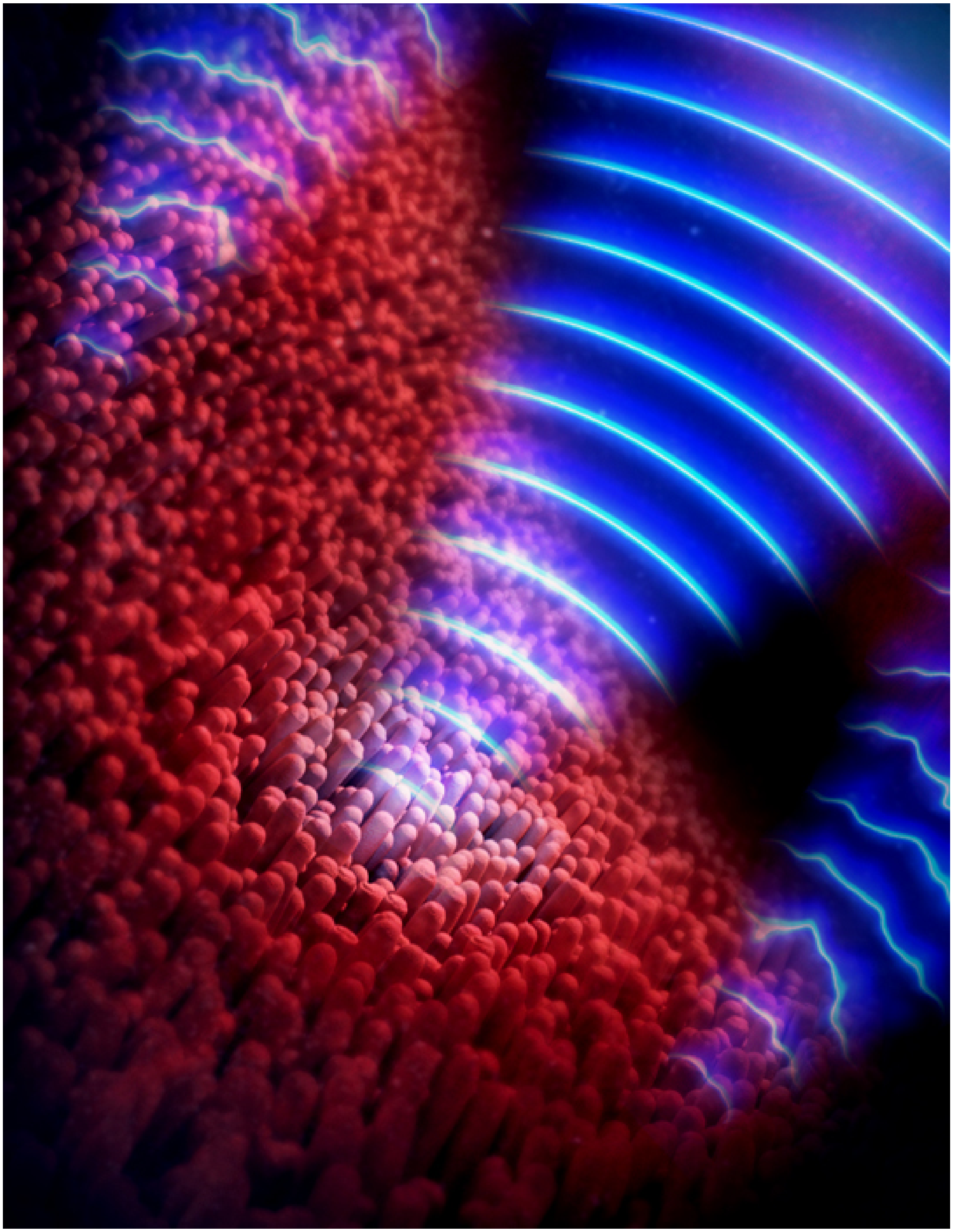


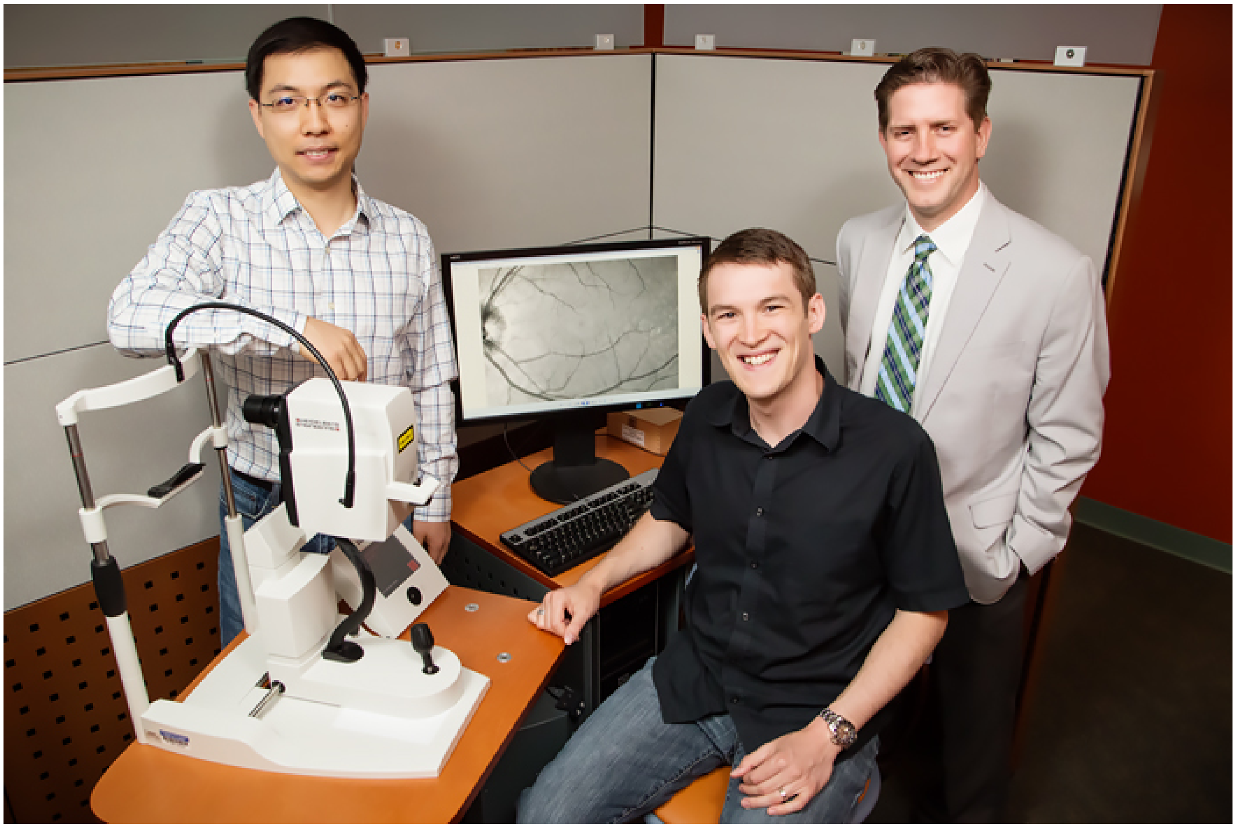
New technology uses computational techniques to more clearly see individual rods and cones, the cells that detect light in the back of the eye. Credit: Alex Jerez Roman

Eye doctors soon could use computing power to help them see individual cells in the back of a patient's eye, thanks to imaging technology developed by engineers at the University of Illinois. Such detailed pictures of the cells, blood vessels and nerves at the back of the eye could enable earlier diagnosis and better treatment for degenerative eye and neurological diseases.

The technique applies adaptive optics – the method astronomers use to correct telescope images so they can more clearly see stars beyond the twinkling – to the instruments that scan the retina at the back of the eye. However, the Illinois team does the correction computationally, instead of using complex hardware. Led by electrical and computer engineering professor Stephen Boppart, the research team published its work in the journal *Nature Photonics*.

"The eye has always been a bit of a challenge to image. It's a very complicated organ," said Dr. Boppart, who also is a medical doctor. "There are many microscopic structures that are hard to see. Many diseases that affect vision also start at the microscopic level, so being able to see those early changes is going to lead to better, earlier treatment."

The prevailing imaging technique in ophthalmology, known as optical coherence tomography or OCT, is useful for general imaging of the eye but cannot focus down to the scale of individual rods and cones, the light-sensitive cells lining the retina that make sight possible. In addition, OCT images are often blurred by the eye's imperfections and constant motion.



Dr. Stephen Boppart led a team that developed a new medical imaging device that can see individual cells in the back of the eye to better diagnose and track disease. From left: postdoctoral researcher Yuan-Zhi Liu, graduate student Fredrick A. South, and professor Stephen Boppart. Credit: L. Brian Stauffer

Computational adaptive optics applies complex algorithms to OCT data correcting for eye aberrations and motion, yielding high-resolution, real-time images that show individual cells and nerves.

Hardware-based adaptive optics systems have been developed to enhance OCT imaging with elaborate setups of lenses, mirrors and lasers, but such systems are so costly and unwieldy that they are impractical for clinical use, Boppart said. However, the new computational approach could be applied to existing OCT systems, with minor hardware updates to older systems for compatibility.

Computational adaptive optics also hold an advantage over hardware setups in that they can tailor themselves to a patient's unique eye structures and shape, and doctors can take one quick scan and afterward focus in on different parts of the eye.

"I think computational adaptive optics can be really helpful to the clinical community," said Fredrick South, a graduate student and a co-author of the paper. "It could give ophthalmologists information that, currently, they have to infer from other measurements. They can't directly look at the photoreceptors and watch them die off during macular degeneration, for example. They just have to guess what's going on. It could be possible to use computational adaptive optics in these real-world applications both for diagnosis of disease and tracking of treatments."

The researchers are initially focusing on using computational adaptive optics to track age-related macular degeneration, a progressive eye disease, and multiple sclerosis, a progressive neurological disease. Since nerve fibers make up the top layer of the retina, the eye could be a unique window into nerve health for multiple sclerosis patients, Boppart said. The researchers hope that the detailed pictures gleaned from applying computational adaptive optics can illuminate how changes in the retina correspond to disease severity and track how cells and nerves respond to treatments.

"The eye is so important, because we rely on sight more than any of our other senses," Boppart said. "Here's a technology that was developed basically to remove the twinkle from stars, and now we want to use it to correct imperfections left by Mother Nature, allowing us to see patients' eyes better and to help them more."

More information: "Computational high-resolution optical imaging of the living human retina." *Nature Photonics* (2015) DOI: 10.1038/nphoton.2015.102

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