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COMPUTING

# An Eyeball Camera, Now with Zoom

*Cameras built using flexible electronics could find many uses.*

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**Eye of the beholder:** Inside this experimental camera, a stretchable sensor array sits below a liquid lens. Water is pumped into both components to change the magnification of the image captured by the camera.
Credit: John Rogers

The burgeoning field of stretchable electronics promises to change the way we think about gadgets. Silicon chips, once confined to flat, rigid shapes, will break out of the planar mold. One experimental example is a camera, modeled after an eyeball, that features a curved array of light sensors.

Now a new design gives this curved camera a boost: the shape of the lens and of its sensor can be changed in synchrony, providing a 3.5x zoom. This provides a key piece of missing functionality for the original camera concept, says John Rogers, professor of materials science and engineering at the University of Illinois, Urbana-Champaign. Rogers led the development of the device. "The result is a complete camera system, with tunable lens and tunable detector, capable of taking pictures," he says. Rogers and his coauthors published details of the work on Monday in the *Proceedings of the National Academy of Sciences*.

A camera with curved sensors—analogous to the curved retina of the eye—has certain advantages over one with a flat sensor. Its field of view is wider, and overall the device can be simpler and more compact. Possible applications include cameras for surveillance, phones, endoscopic imaging, or even tiny video cameras embedded in football helmets, says Yonggang Huang, coauthor and engineering professor at Northwestern University.

The camera is about as wide as a nickel and has two main parts, a lens and a sensor array. The lens consists of a thin membrane stretched over a transparent glass window. The shape of the lens, which corresponds to the camera's focal length, changes when the space between the glass and the membrane is filled with water.



For the camera to produce quality images, its sensor array must adjust to match the lens. Therefore, the detector consists of a 16-by-16 array of ultra-thin silicon diodes, connected by thin wires. The array, originally fabricated on a flat substrate, sits on top of a stretchable sheet and is bonded to a plate with a circular opening. When water is pumped out of a chamber below the plate creating negative pressure, the stretchable sensors are pulled down, producing a concave shape. Modulating the water pressure in the lens and below the sensors, makes it possible to produce a variety of magnifications.



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Data collected by the sensor array is transferred to a computer, where it is used to create an image. The camera has a relatively small number of pixels, so the system uses computational trickery to boost the resolution. By taking multiple pictures from slightly different positions and using special imaging algorithms, the researchers were able to achieve a 100-fold increase in resolution. The same basic technique was used to compensate for damaged pixels.

After years of theoretical modeling and fine-tuning the fabrication and transfer process, Rogers and his colleagues have found effective ways to make silicon stretch into a variety of shapes for various applications. The approach involves connecting ultrathin islands of silicon using precisely patterned wires on a conformable surface. When a surface is stretched, the silicon islands are spared the strain because the wires allow them to separate, and because they themselves are so thin.

Organic and printed materials can also be used to make stretchable electronics, but they can't match silicon in terms of speed. Applications for stretchable silicon circuits range from electrical sensors that sit on top of the brain to wearable solar cells. Rogers's startup MC10 recently announced a collaboration with Reebok to integrate stretchable electronics into sportswear to monitor a person's performance during training or rehabilitation.

The new camera design is "a fantastic demonstration of the technology toolbox that John Rogers and Yonggang Huang have pioneered over the years," says Heiko Jacobs, professor of electrical and computer engineering at the University of Minnesota. Rogers and Huang are able to "integrate high-performance devices on stretchable and curved substrates while maintaining electrical activity," he says. "It will dramatically change the appearance of devices and systems which can take new forms and shapes that a few years ago would have been impossible to build."

The zoomable eyeball camera is still, however, in its early stages. The hydraulics used may not be the most practical for commercialization, says Huang. "In the future," he says, "this mechanism can be replaced by micro actuators or other control strategies.

Huang adds that future versions will be smaller and will have more pixels than the current one. They may even adopt a multiple lens system that resembles an insect's eye. And for commercialization, the researchers will need to show that the approach can be scaled to megapixel-capable photo-detector arrays. "We believe it is possible," says Huang, "with some substantial engineering work."

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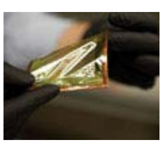

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