Gels Help Tiny Lenses Respond to Stimuli

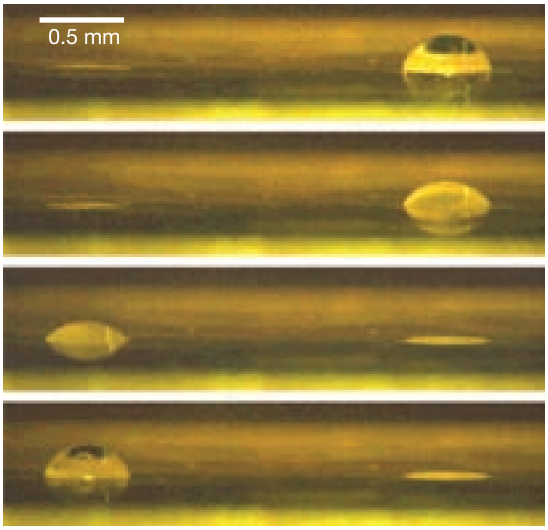
A new type of liquid microlens is "smart" enough to focus itself, thanks to a type of hydrogel that responds to stimuli.

The optical lens, as described by a team from the University of Wisconsin-Madison (Nature **442**, 551), is formed by the meniscus between water and oil. Surrounding the liquid lens is a ring of a stimuli-responsive hydrogel placed within a microfluidic channel system. The side wall and bottom surface of the aperture are hydrophilic and the top surface of the aperture is hydrophobic, so that the meniscus is encircled by the contact line between the hydrophobic and hydrophilic gels.

When the hydrogel senses the presence of stimuli, it pushes up or pulls down the oil-and-water interface, changing the curvature and thus the focal length of the lens, said Hongrui Jiang, assistant professor of electrical and computer engineering at the University of Wisconsin-Madison.

The stimulus could be pH, temperature, light, an electric field, antigens, or other agents, depending on the particular application of the microlens. The stimulus makes the hydrogel ring expand or contract, which in turn changes the volume of the water droplet inside the lens and adjusts the curvature of the meniscus.

The lens in the Wisconsin team's experiments was 1 mm wide, although the team will work on scaling it down in the future, Jiang said. There is a good reason for trying to shrink the lens size down to a few tens of microns: The response time of the hydrogel determines the response time of the lens. At the millimeter scale, the response time is on the order of tens of seconds; however, if the team can scale the lens down to tens of microns in diameter, its response time will drop to hundreds or even tens of milliseconds.



A pair of pH-sensitive microlenses using two pH-responsive hydrogels to monitor different areas. When pH-12.0 buffer is replaced with pH-2.0 buffer, the two lenses exhibit opposite changes in shape. Images from top to bottom correspond to intervals of 0, 13, 30 and 56 s, after pH-2.0 buffer replaces the pH-12.0 buffer.

The novelty of this system lies in its ability to adjust to its environment automatically, Jiang said. Other adaptive lens systems have been based on liquid crystal molecules or mechanical or electrical means for changing the lens surface, but the Wisconsin team's microlens doesn't require an external stimulus. The hydrogel structure embedded in the lens itself serves both as sensor and as actuator.

The likely first application of the technology will be in sensors that are sensitive to multiple environmental parameters, Jiang said. Another likely use for the microlenses is medical imaging. Sub-second response times will be good enough for these applications.

According to Jiang, these adaptive microlenses might find a use in so-called lab-on-a-chip technology. The idea of lab-on-a-chip is to shrink the tools of biochemical analysis down to make the process faster and cheaper. Large bench-top instruments are very expensive, and much of the biochemical analysis is labor-intensive, he said.

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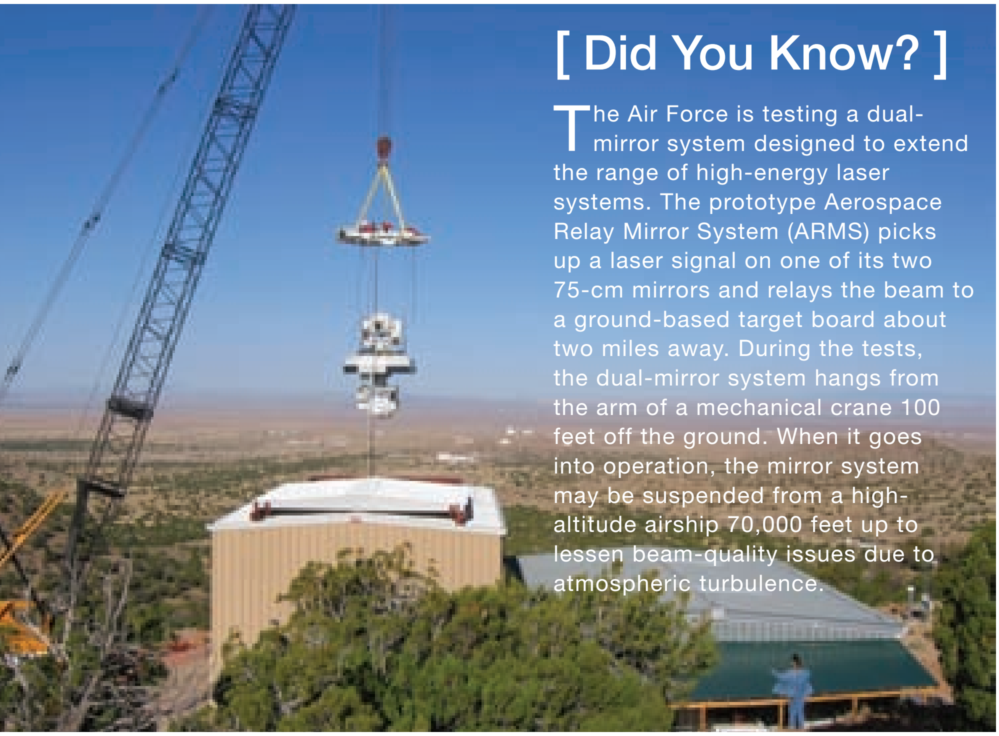

[Did You Know?]

The Air Force is testing a dual-mirror system designed to extend the range of high-energy laser systems. The prototype Aerospace Relay Mirror System (ARMS) picks up a laser signal on one of its two 75-cm mirrors and relays the beam to a ground-based target board about two miles away. During the tests, the dual-mirror system hangs from the arm of a mechanical crane 100 feet off the ground. When it goes into operation, the mirror system may be suspended from a high-altitude airship 70,000 feet up to lessen beam-quality issues due to atmospheric turbulence.