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Electricity tunes liquid microlens

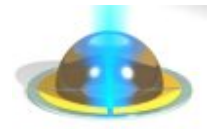
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Applying a voltage to a liquid microlens alters its position and focal length.

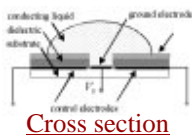
Researchers at [Bell Labs](#), US, have made a 2mm-diameter liquid microlens with a position and focal length that can be adjusted by applying a voltage. The team is now using the lens in optical switching and optical signal processing. (*Applied Physics Letters* **82** 316)

The lens is made from a droplet of a transparent conductive liquid placed on a substrate covered with a special coating. A set of electrodes underneath the substrate controls the position and shape of the lens.

"The method we use to control the liquid droplet can be applied to a wide range of materials," Tom Krupenkin of Bell Labs told *Optics.org*. "Using polymeric liquids, which can be solidified by UV radiation, allows us to convert a liquid lens to a custom-made solid lens and lock in its optical properties."



[Microlens concept](#)



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The microlens sits on a layered structure. The base layer is indium tin oxide (ITO) glass containing four control electrodes with an outer diameter of 3mm. The ITO is covered by a 150-nm layer of silicon nitride and a 1- μ m layer of a fluoropolymer, which provides a low-energy, low hysteresis surface.

This approach overcomes a phenomenon called contact-angle hysteresis where factors such as chemical contaminants and surface roughness pull the liquid lens away from the natural angle it should make with a solid substrate.

To eliminate this effect, Krupenkin and colleagues use a thin layer of lubricating fluid (silicone oil) to isolate the liquid droplet from surface inhomogeneities. "Our droplet "floats" on this thin lubricating layer and never directly interacts with the rigid substrate," he says.

To date, a 6 μ l droplet of potassium sulfate has been used to create a lens that is approximately 2 mm in diameter. But Krupenkin says that, in principle, diameters between several tens of microns and several millimeters are possible.



[Tunable microlens](#)

Voltages as low as 10V can induce changes in the lens's focal length. "The maximum change in focal length in this experiment was about 20%," he says. "But in other experiments we changed the focal length over 100%. Further refinement should allow changes of several hundred percent."



[Electrode pattern](#)

The radius of the electrode pattern determines the maximum lateral displacement of the lens. Krupenkin says there is no intrinsic limitation on this. "It's basically a design choice that can be tailored to the application," he says. By applying biased voltages to neighboring electrodes, the team saw the lens's position adjust by about 35% of its diameter.

The time response of the microlens is approximately 5 ms. The team also say all behaviour is fully reversible and reproducible.

Having successfully demonstrated a proof-of-principle microlens, Krupenkin and colleagues are now building optical components such as tunable optical filters and attenuators. They are also using polymeric liquids to obtain "lockable" microlenses as well as organic molten salts.

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