Researchers confront optics and data-transfer challenges with 3D-printed lens

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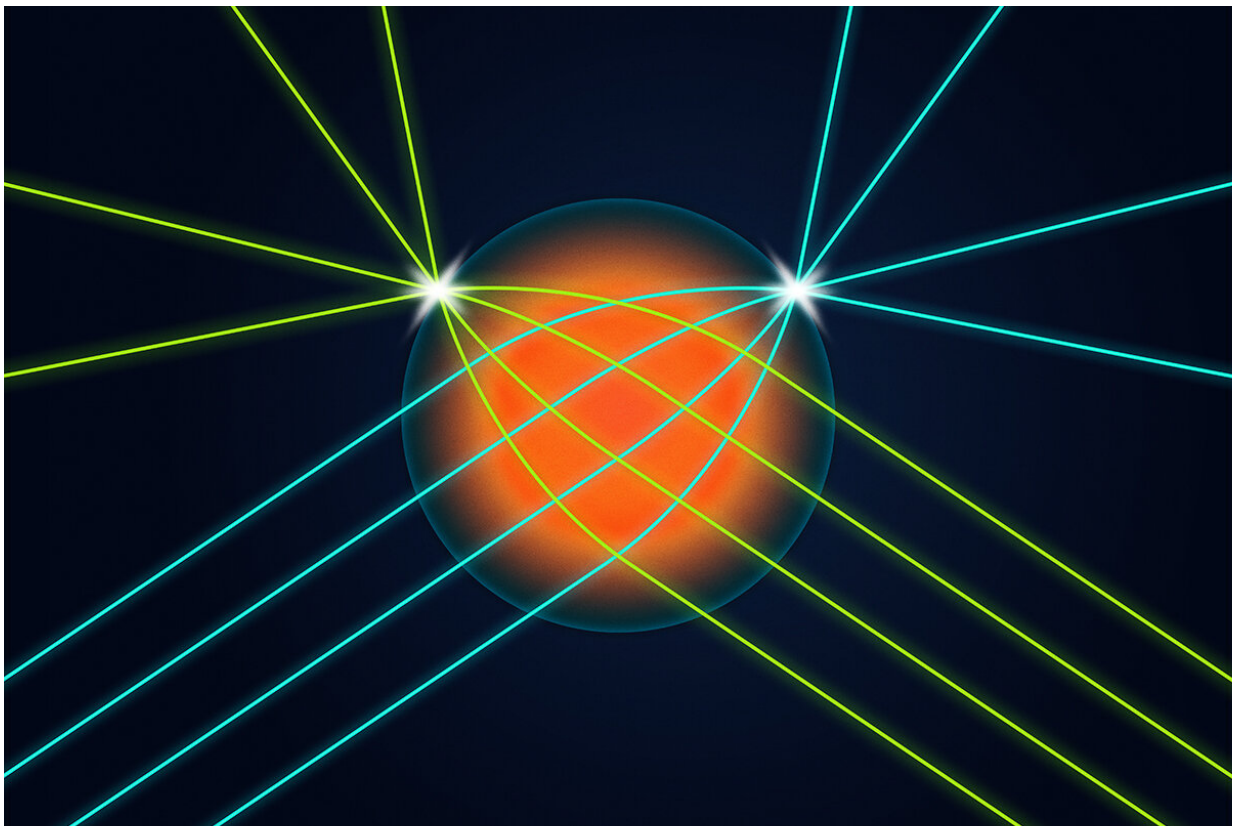

Illinois researchers developed a spherical lens that allows light coming into the lens from any direction to be focused into a very small spot on the surface of the lens exactly opposite the input direction. This is the first time such a lens has been made for visible light. Credit: Graphic by Michael Vincent

Researchers have developed new 3-D-printed microlenses with adjustable refractive indices—a property that gives them highly specialized light-focusing abilities. This advancement is poised to improve imaging, computing and communications by significantly increasing the data-routing capability of computer chips and other optical systems, the researchers said.

The study was led by University of Illinois Urbana-Champaign researchers Paul Braun and Lynford Goddard and is the first to demonstrate the ability to adjust the direction in which light bends and travels through a lens with sub-micrometer precision.

The results of the study are published in the journal *Light: Science and Application*.

"Having the ability to fabricate optics with different shapes and optical parameters offers a solution to common problems faced in optics," said Braun, who is a professor of materials science and engineering. "For example, in imaging applications, focusing on a specific object often results in blurry edges. Or, in data-transfer applications, higher speeds are desired without sacrificing space on a computer chip. Our new lens-fabrication technique addresses these problems in one integrated device."

As a demonstration, the team fabricated three lenses: a flat lens; the world's first visible-light Luneburg lens—a previously impossible-to-fabricate spherical lens with unique focusing properties; and 3-D waveguides that may enable massive data-routing capabilities.

"A standard lens has a single refractive index and therefore only one pathway that light can travel through the lens," said Goddard, who is a professor of electrical and computer engineering. "By having control over the internal refractive index and the shape of the lens during fabrication, we have two independent ways to bend light inside a single lens."

In the lab, the team uses a process called direct-laser writing to create the lenses. A laser solidifies liquid polymers and forms small geometric optical structures up to 100 times smaller than a human hair. Direct-laser writing has been used in the past to create other microlenses that only had one refractive index, the researchers said.

"We addressed the refractive index limitations by printing inside of a nanoporous scaffolding support material," Braun said. "The scaffold locks the printed micro-optics into place, allowing for the fabrication of a 3-D system with suspended components."

The researchers theorize that this refractive index control is a result of the polymer-setting process. "The amount of polymer that gets entrapped within the pores is controlled by the laser intensity and exposure conditions," Braun said. "While the optical properties of the polymer itself do not change, the overall refractive index of the material is controlled as a function of laser exposure."

Team members said they expect that their method will significantly impact the manufacturing of complex optical components and imaging systems and will be useful in advancing personal computing.

"A great example of the application of this development will be its impact on data transfer within a personal computer," Goddard said. "Current computers use electrical connections to transmit data. However, data can be sent at a significantly higher rate using an optical waveguide because different colors of light can be used to send data in parallel. A major challenge is that conventional waveguides can only be made in a single plane and so a limited number of points on the chip can be connected. By creating three-dimensional waveguides, we can dramatically improve data routing, transfer speed and energy efficiency."

More information: Christian R. Ocier et al, Direct laser writing of volumetric gradient index lenses and waveguides, *Light: Science & Applications* (2020). DOI: 10.1038/s41377-020-00431-3

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