Architecture-inspired nanostructures enable perfect optical metasurfaces

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Optical devices are critical in diverse military and civil applications, whereas traditional optical devices are bulky and heavy because they rely on the phase accumulation on a long optical path. In an article published in *Science Advances*, Prof. Xiangang Luo from the Chinese Academy of Sciences and co-workers have now demonstrated that ultrathin and lightweight optical devices could be constructed using nanostructures catenaries, which were typically used in architecture to construct incredible bridges and arches.

The catenary is the curve that a free-hanging chain assumes under its own weight. It is a "true mathematical and mechanical form" in architecture, described by Robert Hooke in the 1670s. The catenary is found in many circumstances. For example, the silk on a spider's web forms multiple elastic catenaries. The researchers now use optical catenary-shaped structures to convert circularly polarized light to a helically-phased beam carrying a geometric linear phase profile. Similar to the "catenary of equal strength," the phase gradient of the optical catenary is equal everywhere, which is a direct result of its special geometric shape. The catenary structure has applications in optics, architecture, and many other disciplines. "It is a direct result that we could construct novel optical devices with strong similarity to the structures occurring in the natural world," Prof. Luo says.

Many previous methods use discrete nanostructures to generate space-variant phase distribution. The discrete structures lead to strong resonance, which makes the operating bandwidth of these samples

limited. Prof. Luo's group therefore uses the continuous catenary structures to obtain much broader bandwidth. They demonstrated that broadband orbital angular momentum (OAM) could be achieved by using the catenary array. The operating bandwidth of the devices could cover the entire electromagnetic spectrum including microwave. terahertz, infrared, and the visible regime.

The catenaries could be used as a unique building block for optical metasurfaces, which are thought to be the key to next-generation integrated optical systems. According to the metasurface-assisted law of reflection and refraction, many novel optical elements, such as flat lenses, axicons, and prisms, could be obtained with performance far beyond their traditional counterparts.

More information: "Catenary optics for achromatic generation of perfect optical angular momentum." *Sci. Adv.* 1, e1500396 (2015). DOI: 10.1126/sciadv.1500396

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