Case Study

Metasurfaces for ultrathin optical devices

Optical metasurfaces are a single layer or a stack of several layers of nanostructures, which have been used to develop ultrathin optical devices with unusual functionalities. They can control light propagation in a desirable manner. Optical metasufaces enable tasks that aren't possible with classical optics, promising advances in a variety of scientific fields impacting our everyday lives. Applications for optical metasurfaces include imaging, holography, information processing, invisibility cloaking and quantum sciences.

Challenge

Traditional optical elements (e.g., glass lenses) are widely used in our daily lives, but they are not suitable for device miniaturization and system integration. Although diffractive optical elements can shrink the size, they are limited by finite lateral phase control, polarization insensitivity, difficulty in multi-wavelength operation, multiple steps of lithography and limited functionality. Optical metasurfaces have provided a new design methodology for ultrathin (less than light wavelength) optical devices due to their unprecedented capability in the manipulation of amplitude, phase and polarization at subwavelength scale, offering unlimited potential to engineer the optical properties on demand. Optical metasurfaces consist of nanostructures, whose fabrication is challenging due to the precise control of nanoscale feature size and spatially variant orientation.

Solution

The 2D Fabrication Facility at Heriot-Watt University has been developing science and technology for optical metasurfaces since 2014 and has attained world class expertise in this area. Key factors allowing the 2D Fabrication Facility to have a leading position in research and technology are:

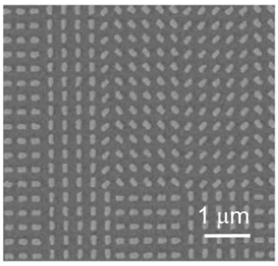
⇒ Strong design capability for novel ultrathin devices

⇒ The availability of high-resolution electron-beam lithography and etching machine for pattern transfer

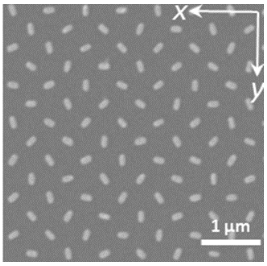
⇒ The availability of high-quality film deposition of a wide range of materials (e.g., gold, silver, aluminium, Titanium, Chromium, SiO_2, MgF_2).

⇒ Fabrication of novel ultrathin devices with unusual functionalities

⇒ Fabrication of ultrathin devices with high efficiency (>80%) and broadband (e.g., visible and NIR).



Electron microscope image of metasurface device that can hide a quick response code in a laser beam at Heriot-Watt University



An ultrathin device with multiple functionalities

Notable achievements from the 2D Fabrication Facility

- First demonstration of image-switchable holograms. (Nat. Commun. 2015, 6, 8241,)
- First demonstration of a multi-channel device that can continuously manipulate the superposition of twisted light beams. (Adv. Mater. 2017, 29, 1603838)
- First demonstration of a high-resolution hidden image in a light beam. (Light Sci. Appl. 2018, 7, 17129)
- A metasurface device that can combine a hologram and a lens. (Adv. Opt. Mater. 2016, 4, 2)
- Demonstration of optical metasurface generated vector beam for anti-counterfeiting (Phys. Rev. Appl. 2018, 10, 034028)
- Multifunctional light sword metasurface lens. (ACS Photon. 2018, 5, 1794)

Conclusion

The 2D Fabrication Facility has developed expertise and capability in optical metasurfaces that are available to researchers and industrial customers in the UK.

We continue to work with academic partners developing the technology further for both fundamental studies and applications.

New directions include arbitrary polarization manipulation based on non-linear optical metasurfaces, twisted light beams for optical tweezers, and ultrathin optical devices for quantum photonics.

To expand our knowledge of the application domain, we are looking forward to the collaboration opportunity in new areas of optical metasurfaces and ultrathin optical devices built on our expertise.