Dielectric Metasurfaces Based Polarimetry for Satellite Imaging

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Polarisation imaging has a wide range of satellite-based remote sensing applications, from detecting organic aerosols in the atmosphere to removing sun glint from ocean surface imaging [1]. However, conventional polarimetry optics are bulky, heavy, and often involve moving parts, requiring large, expensive satellites.

Optical metasurfaces provide a potential solution to reduce the size and weight of polarisation imaging systems for implementation onto more affordable and accessible microsatellites. Full Stokes polarisation imaging using dielectric meta-optics has been demonstrated previously for a static camera in a brightly lit environment [2]. In this work, we formulate a nontrivial extension of this concept for remote sensing, carefully considering the unique imaging environment of a satellite in orbit. We note that a 2D image may be formed over time by continuously imaging a 1D strip perpendicular to the movement of the satellite, and therefore, we suggest using a diffractive meta-grating to efficiently perform five polarisation measurements of the image in the transverse plane [Fig. 1(a)]. We consider a wavelength of 852 nm that is well suited for detection and the following suppression of glint from water surfaces, and develop an original topology-optimised metasurface using inverse design methods [Fig. 1(b)]. The five measurements form an over-determined system spanning the Stokes space [Fig. 1(c)], allowing the full Stokes polarisation state to be reconstructed with the error in reconstruction monitored remotely.

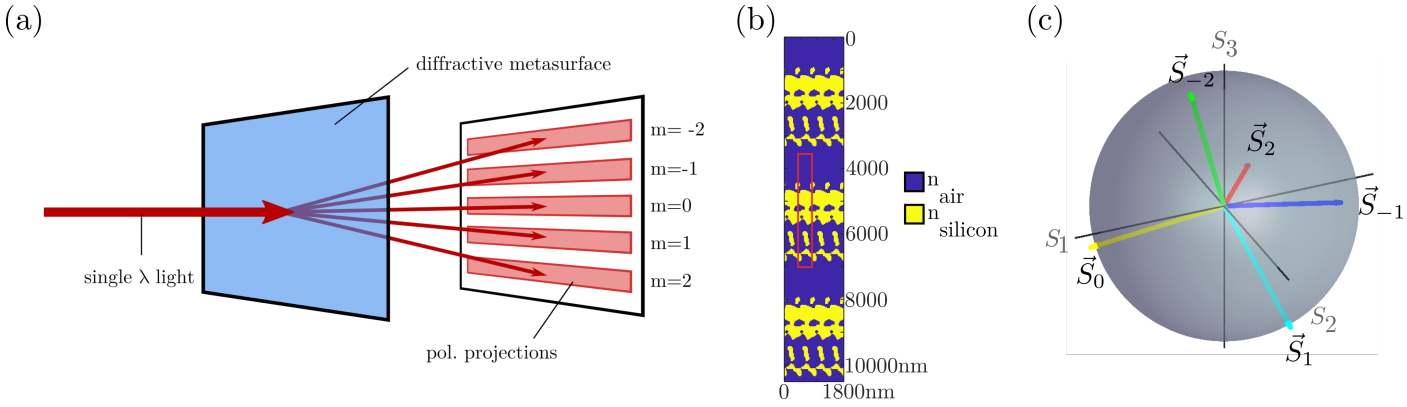

Figure 1: (a) Illustration of metasurface diffraction functionality. (b) Topology-optimised metasurface structure for polarimetry. The design consists of a 1 µm thick patterned silicon structure on a 460 µm thick sapphire substrate. A single period is 450 nm by 3500 nm (c) The normalised Stokes vectors ($\vec{S}_m$) for each polarisation measurement span the full Stokes space, enabling polarimetry.

[1] "NASA Plankton, Aerosol, Cloud, ocean Ecosystem Earth sciences space mission (PACE)," https://pace.gsfc.nasa.gov/.

[2] N. A. Rubin, G. D'Aversa, P. Chevalier, *et al.*, Science **365**, eaax1839 (2019).