Conversion of Unpolarised to Polarised Light with Metasurfaces

Neuton Li, Shaun Lung, Jihua Zhang, Dragomir N. Neshev, and Andrey A. Sukhorukov
ARC Centre of Excellence for Transformative Meta-Optical Systems (TMOS),
Research School of Physics, Australian National University, Canberra, ACT 2601, Australia

Changing the degree of light polarisation is a fundamentally and practically important task. In particular, the cheapest and widely available LED light sources most commonly emit unpolarised light, while fully polarised states may be required for various applications spanning from 3D movies to glare suppression in imaging. Whereas this task can be accomplished with conventional optical polarisers, at least half of the input light would be lost. A higher-efficiency approach could rely on polarisation splitters, yet the output states would usually have different polarisations.

In this work, we show that ultra-thin dielectric metasurfaces can convert unpolarised light to a single predefined polarisation state at the output. Over the last decade, it was shown that metasurfaces can flexibly convert the polarisation of incident light on a sub-wavelength scale, exceeding the capabilities of conventional bulky optics [1, 2]. However, similar to conventional optics, there remained a 50% efficiency limit for single-layer metasurfaces, which are suitable for mass-production, in converting unpolarised light to one specific output polarisation state.

We reveal a novel configuration of meta-gratings that can convert unpolarised input into multiple outputs, all having identical pure polarisations, as sketched in Fig. 1(a). To realize this concept, we design dielectric metasurfaces with the spatially nonlocal response, where the polarisation transformations depend on the emission angle. We employ the topological optimisation approach [3], where the gradient of the figure-of-merit function is efficiently calculated through adjoint simulations. We have fabricated the metasurfaces on crystalline silicon (1000 nm thick) chip with a sapphire substrate [Fig. 1(b)]. Our numerical simulations predict a combined polarisation efficiency of ∼80% in [Fig. 1(c)] to the target left circular polarisation. We then experimentally demonstrate the metasurface's ability to convert unpolarised light to polarised light with the efficiency of ∼60%, exceeding the 50% limit of previous approaches [Fig. 1(d)]. The experimental performance can be further improved by introducing anti-reflection coatings. We anticipate that such metasurfaces can find many applications, including imaging with basic unpolarised sources such as LED and multimode fiber lasers.

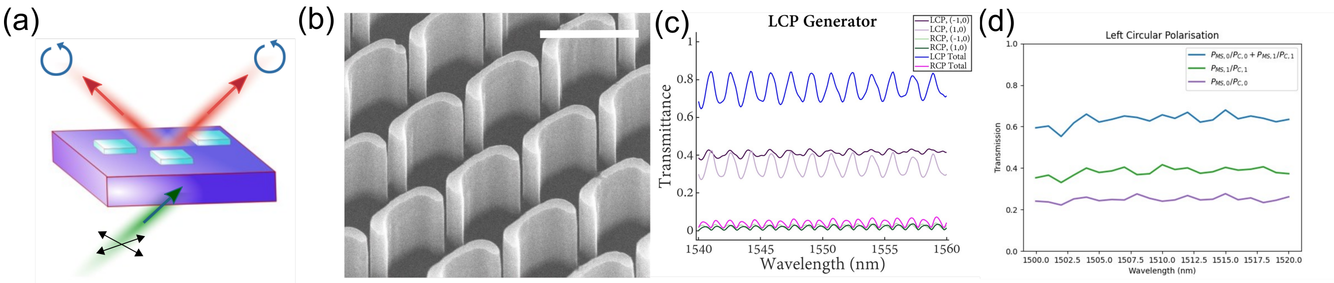

Figure 1: (a) Schematic of single-layer metasurface converting unpolarised light into pure polarised one (b) SEM image of fabricated metasurface. Scale bar is 1 µm. (c,d) Simulated and experimental polarisation transmission, respectively.

[1] Z. J. Shi, A. Y. Zhu, Z. Y. Li, *et al.*, Sci. Adv. **6**, eaba3367 (2020).
[2] F. Ding, B. D. Chang, Q. S. Wei, *et al.*, Laser Photon. Rev. **14**, 2000116 (2020).
[3] M. M. R. Elsawy, S. Lanteri, R. Duvigneau, *et al.*, Laser Photon. Rev. **14**, 1900445 (2020).