Metasurface design platform for highly efficient wavefront engineering

Maksim Makarenko1, Arturo Burguete-Lopez1, Fedor Getman1, Andrea Fratalocchi1†
1PRIMALIGHT, Faculty of Electrical Engineering; Applied Mathematics and Computational Science, King Abdullah University of Science and Technology, Thuwal 23955-6900, Saudi Arabia
∗ These authors contributed equally to this work.
† Contact author: andrea.fratalocchi@kaust.edu.sa

Abstract

In this work, we propose a universal design platform for the development of wavefront engineering structures. We demonstrate this approach’s efficiency by producing a series of highly efficient common optical devices.

The design of optical resonant systems for controlling light at the nanoscale volume is an exciting field of research in nanophotonics. While significant progress has been done in matters of functionality in the past decade, a review of the existing literature reveals that the average working efficiency of a metasurface in the visible range is below 60%, suffering from high power losses due to designs that are 477 nm thick on average from a heavy reliance on propagation effects to operate [1-4].

These performance limitations and the lack of an on-demand structure design framework remain important challenges for practical applications. To tackle this problem we developed a new formulation of the Maxwell equations by using the theory of generalized functions [5], reducing the dynamics to an intuitive set of coupled mode equations that are fully exact and sufficiently simple to analyze light-matter interactions of any type. Using this reformulation coupled with an AI-driven optimization framework, we developed a novel universal flat optics design platform. By suitably engineering the resonances of the system, our platform was able to find highly efficient dielectric metastructures for arbitrary optical responses.

We experimentally validate this approach by manufacturing a variety of common optical components in a flat optics form factor that exceed 90% operational efficiency over the full visible range. We demonstrate polarizers, dichroic mirrors and the basis of a display technology that creates full color images by using only two metasurface sub-pixels, rather than conventional LED/OLED technologies that employ three sub-pixels. The manufacturing process for all devices created with this platform is CMOS compatible and industry ready for the mass production of ultra-flat optical devices.

Fig. 1 (a) Experimental polarization efficiency for four polarizing beam splitters designed at common laser lines. (b) SEM micrograph showing the structure of the 600 nm polarizing beam splitter. (c) Flat-optics two sub-pixel display technology.

References