High Performance Silicon Flat Optics at Visible Wavelengths

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Abstract: We present a platform for the design of high efficiency flat optics. Experimentally, we show common components such as polarizers, dichroics, and color filters with over 99% efficiency in the visible in 50nm of silicon.

1. Main Text

Integrating conventional optics into compact nanostructured surfaces is the goal of flat optics. Despite the enormous progress of this technology, there are still critical challenges for real world applications due to a limited operational efficiency in the visible, on average lower than 60% for silicon devices, which originates by absorption losses in wavelength thick ($\approx$ 500 nm) structures [1–4].

Another set of challenges lie in the design process. Historically, the search for new devices has followed what is known as the direct design approach, where the structures are limited by the intuition of the designer. Inverse design, whereby a computer designs the device given the desired optical response, has been investigated as an alternative method. Current approaches however, have been largely focused in the near infrared region [5–7], where absorption is not a concern, and haven't overcome the aforementioned problems in the visible.

In this work, we showcase an inverse design flat optics platform that employs concepts from evolutionary algorithms and deep learning with convolutional neural networks (CNN). The platform leverages the fact that the response of a nanostructured device can be separated into resonance and propagation effects [8]. By suitably engineering the resonances of the system, our platform is able to find designs that accurately produce the desired input optical responses with ultra-thin structures, overcoming the challenge of absorption in the visible and resulting in very high efficiency devices.

To experimentally validate this approach we design, fabricate and experimentally characterize seven different structures. The manufacturing process is the same for all devices and consists of patterning a high refractive index semiconductor, deposited via PECVD onto a glass substrate, with electron beam lithography and a subsequent dry etching process with a chromium mask. We report polarizer beam splitters at 533 nm, 600 nm, 750 nm and 900nm with experimental efficiencies as high as 99.2% and 130 nm bandwidth in the visible, dichroic mirrors with 90% experimental transmission/reflection efficiency and polarization dependent color filters that serve as the basis of a metasurface display technology.

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