Algorithmic Design of Terahertz Silicon Metaoptics

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***Abstract*—Patterning dielectric materials at the near- or sub-wavelength scale unlocks a versatile design-space for optical components. These components, often termed "metaoptics", have been widely explored in two-dimensional architectures such as high-contrast gratings (HCGs) and metasurfaces. More recently, volumetric (i.e., 3D) metaoptics designed through multi-objective inverse design have been explored that are capable broadband multifunctional behavior. This talk discusses the design of these 3D metaoptics, their fabrication using silicon microfabrication, and their integration into THz systems. Furthermore, we discuss the shortcomings of the various metaoptics, and how the integration of 3D metaoptics, HCGs, and metasurfaces together can address these shortcomings.**

Keywords—Metaoptics, inverse-design, metasurfaces, high-contrast gratings

I. Introduction

A principle of optical design that has long been used by designers is that optical systems must be built from a modular arrangement of elements. This principle is of course not a physical law, but rather a tool to break large problems down into reasonably sized sub-parts (lens, gratings, etc.) which that can optimized. However, modular arrangements inevitably must be comprised of many discrete components to reach high-performance for complex tasks. Particularly with regards to space technology, this convenient tool becomes a limitation to realizing compact systems.

Approaching optical design with more holistic procedures can enable the synthetization of multiple discrete optical elements into single elements. In fact, the number of degrees of freedom available in even a single sub-wavelength layer is sufficient to enable high-efficiency multi-functional elements such as polarizing beam splitters with simultaneous focusing capabilities [1], [2], albeit over a relatively small bandwidth [3], [4]. More degrees of freedom can be introduced by increasing the thickness of the device, thus allowing greater bandwidth and functionality. To access the degrees of freedom, the volume should be patterned with subwavelength precision in 3D. The primary design questions are: what is the optimal shape of a device, and how can it be fabricated?

This talk focuses on answering these two questions, specifically for THz frequencies. A relatively new class of 3D metaoptics comprised of stacked, patterned Si wafers is introduced that is designed with adjoint-based inverse-design techniques to allow for extremely versatile functionality, allowing the control of all fundamental properties of light over broad spectral bands [5]. Practically, these devices must be small or periodically tiled with small periodicity due to computational limitations. In recent years, these devices have been studied in isolation, rather than integrated into systems. This talk will therefore delve into the unexplored area of coupling these devices with algorithmically designed metasurfaces, high-contrast gratings, and other optical components to enable extremely compact optical systems for space technology.

References

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