Spatiotemporal Manipulation of Optical Fields enabled by Metasurfaces

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Over the last decade, flat optical elements composed of an array of deep-subwavelength dielectric or metallic nanostructures of nanoscale thicknesses – referred to as metasurfaces – have revolutionized the field of optics and nanophotonics. Because of their ability to impart an arbitrary phase, polarization or amplitude modulation to an optical wavefront as well as perform multiple optical transformations simultaneously on the incoming light, they promise to replace the traditional bulk optics in applications requiring compactness, integration and/or multiplexing. The primary focus of research in this area has been on applications requiring arbitrarily manipulation of light in the spatial domain such as high numerical aperture focusing or generation of novel polarization states.

In this talk, we discuss the ability of metasurfaces to arbitrarily shape instead the temporal evolution of ultrafast optical pulses. This requires independent control over the amplitude, phase and/or polarization of the spectral lines covering the entire bandwidth of an optical pulse. We achieve this by designing a metasurface to operate on the spectral components of an ultrafast pulse that are separated spatially using a Fourier transform setup (Fig. 1). By designing metasurface elements to act as individual half wave plates, and combining it with an integrated broadband polarizer – we demonstrate the ability to shape <10 fsec pulses with a spectral resolution of approx. 140 GHz. We discuss the advantages of the metasurface approach to pulse shaping over the more traditional use of spatial light modulators to do the same.

Finally, we demonstrate the versatility of spatial shaping metasurfaces to be directly integrated on integrated photonic chips for their applications as an interface to quantum or biological systems. Through spatial multiplexing of metasurfaces integrated with grating out-couplers directly on a nanophotonic chip, we show the ability to create arbitrary optical fields in the far-field that may enable applications such as optical traps, biosensing or LIDAR.

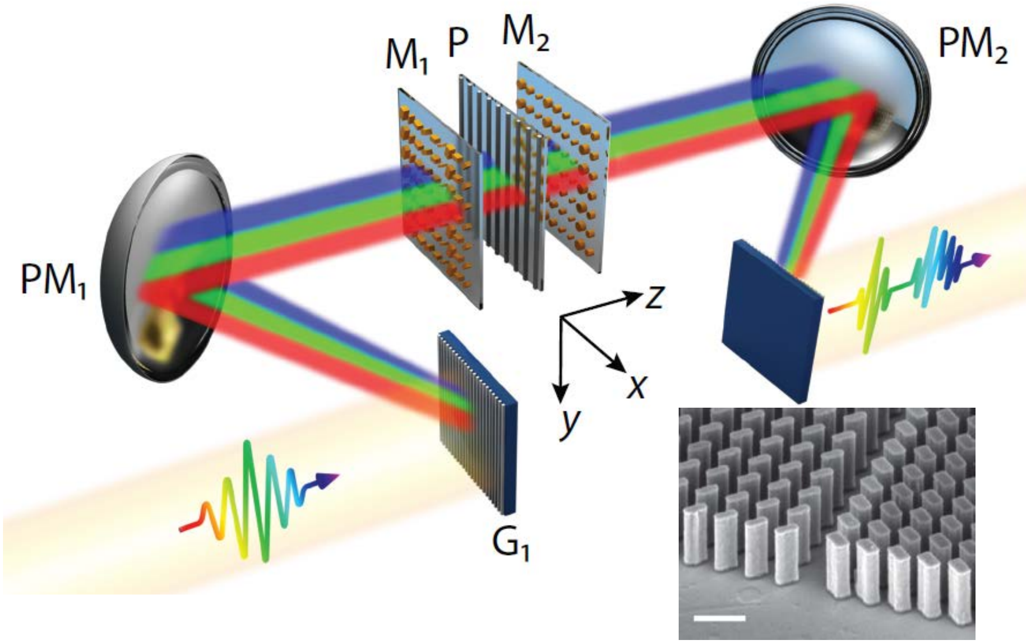

Figure 1: Metasurface-enabled Fourier-transform optical pulse shaper embedding one or more metasurfaces and a polarizer. Inset shows the SEM image of a typical metasurface composed of Si rectangular pillars on a fused-silica substrate. Scale bar represents 500 µm.