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Nonreciprocal Metasurfaces due to Enhanced Optical Nonlinear Effects

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Nonreciprocal transmission is the fundamental operation mechanism behind optical isolators, circulators, and diodes. The breaking of Lorentz reciprocity law usually requires bulky magnets or complicated time-modulation dynamic techniques [1]. Nonreciprocity by optical nonlinear effects is a more appealing technique due to the absence of any kind of external bias or active materials, avoiding instabilities or other quantum noise problems stemming from gain [2]. Fano resonators are commonly used due to their narrowband transmission spectra. However, it has been proven that a single nonlinear Fano resonator has a fundamental bound between the insertion loss and the nonreciprocal intensity range [3]. Furthermore, the majority of the previously proposed nonlinearity-based nonreciprocal photonic devices have a thick and bulky geometry. Moreover, they usually exhibit poor nonreciprocal transmission contract and/or require impractical very high input intensity excitations.

In our presentation, we will demonstrate a simple passive nonreciprocal device of a bifacial dielectric metasurface made of silicon spheres embedded in a glass substrate [4]. It is composed of two passive silicon-based metasurfaces exhibiting Fano and Lorentzian resonances, respectively. The narrowband resonant response, as well as the boosted field enhancement, lead to very low required input intensity values to obtain significant nonreciprocal transmission. Cascaded metasurface designs will also be presented to further improve the geometric asymmetry and self-induced nonreciprocal performance. Finally, it will be demonstrated that large nonreciprocal transmission still occurs when two input waves are simultaneously illuminated from opposite directions, as long as their input intensities do not exceed a moderate value, hence, relaxing the ‘dynamic’ reciprocity problem [5] of nonlinear nonreciprocal devices.

References

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