Bianisotropic Metasurface for Asymmetric Second-Harmonic Generation: a Nonlinear Plasmonic Pseudo-Diode

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Bianisotropic metasurfaces enable planarized optical devices with diverse functionalities that are not amenable to conventional optical components [1]. In particular, bianisotropy gives control over spatial dispersion and allows to engineer both spectral and directional responses simultaneously. Furthermore, bianisotropic metasurfaces empower nonlinear optical devices with subwavelength thickness and various unconventional properties [2,3].

In this work, we demonstrate a nonlinear bianisotropic metasurface that features asymmetric second-harmonic generation (SHG) [4]. The concept of the device is schematically depicted in Fig. 1a: SHG from the metasurface occurs only upon excitation in the forward direction, whereas backward excitation does not result in efficient SHG, effectively making the metasurface perform as a nonlinear pseudo-diode. Such functionality is achieved by employing two common plasmonic materials – aluminum (Al) and silver (Ag). Apart from exploiting the stronger second-order nonlinear response of Al [5], we show that the combination of these two metals provides an elegant and simple approach to engineer spatial dispersion, which is required to achieve the asymmetric response. The metasurface unitcell (see inset in Fig.1b) has a "T"-shape and is comprised of two metallic layers that are embedded in glass (SiO_2). The geometrical parameters of the nanostructure are optimized to exhibit SHG maximum in transmission, upon forward excitation at 800 nm wavelength (resulting in SHG peak at 400 nm).

Next, we demonstrate the experimental implementation of the metasurface and discuss the fabrication method. Scanning electron microscope (SEM) image of the fabricated metasurface sample is shown in Fig. 1c, where Al and Ag layers can be clearly identified. Fig. 1d shows experimentally measured nonlinear spectra upon forward and backward excitations, revealing strong asymmetry in SHG. To further substantiate our findings, we perform a homogenization analysis, which allows extracting the effective susceptibility tensors and unambiguously reveals bianisotropic response of our metasurface. Finally, we discuss the implications of our results from the more fundamental perspectives of reciprocity and time-reversal asymmetry.

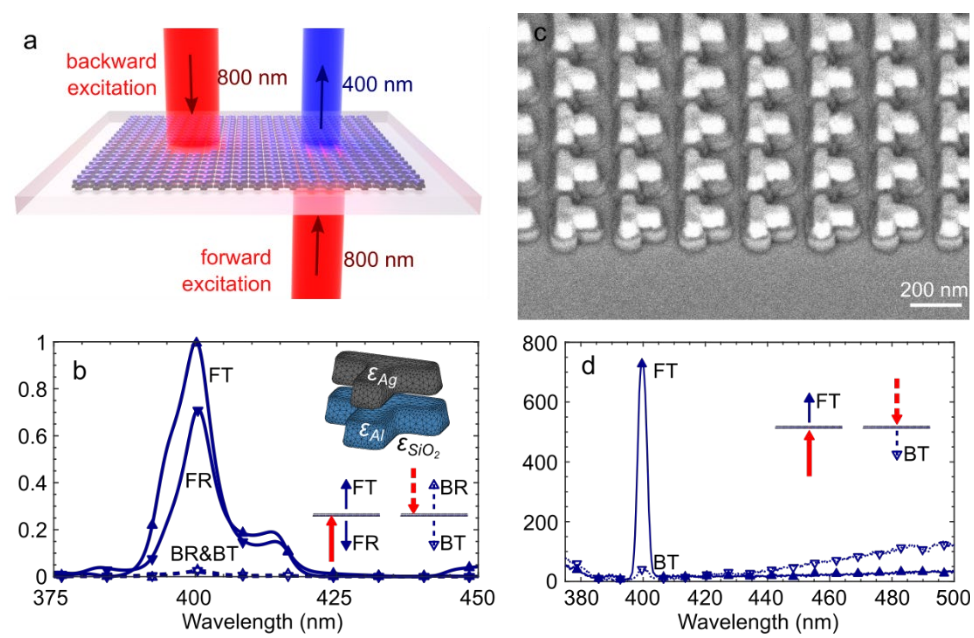

Fig. 1 (a) Schematic illustration of the device concept; (b) Simulated SH response of the metasruface in forward transmission (FT), forward reflection (FR), backward transmission (BT) and backward reflection (BR) cases; inset shows metasurface unitcell; (c) SEM images of the fabricated metasurface sample; (d) Experimentally measured nonlinear spectra for FT and BT cases.

References

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