SHG enhancement by TiN metasurfaces

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Enhancing the nonlinear frequency conversion efficiency at the nanoscale plays an important role in advanced spectroscopy, material science and sensing. Prior work has shown that plasmonic structures can significantly enhance a nonlinear signal due to the localized surface plasmon resonance (LSPR) [1]. More recently, epsilon-near-zero (ENZ) materials have been shown to enhance optical nonlinearities if pumped at the ENZ wavelength in thin films [2]. Here, we explore a new mechanism to augment nonlinearities by combining the LSPR of nanostructures forming a metasurface and the ENZ enhancement of the nonlinear medium [3]. We probe the second harmonic generation (SHG) in nanofabricated titanium nitride (TiN) split-ring resonators at visible wavelengths, where TiN exhibits an ENZ resonance (Figure 1a). When the excitation polarization is parallel to the ring gap, both the electric mode (high energy), which arises from the electric dipole of the two vertical bars of the resonator, and the magnetic mode (low energy), which arises from the circulating current along the ring, are observed. By increasing resonator size, we can engineer both the electric and magnetic resonances, which are then red shifted. Here, the magnetic resonance of the meta-elements is designed to be resonant with the fundamental wavelength, achieving in this way a double resonance effect. Our experimental results show that the measured SHG signal is most strongly enhanced when the ENZ wavelength matches the SH wavelength, while simultaneously the magnetic resonance matches the excitation wavelength (Figure 1b).
With its refractive nature and CMOS compatibility, our results advocate considerable promise of TiN micro and nanostructures in integrated on-chip nonlinear optical devices.

References

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Figures

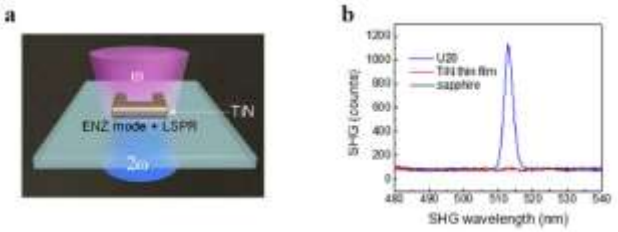

Figure 1. a) Schematic of the SHG in TiN nanoresonators which simultaneously sustain an ENZ resonance and LSPR. b) Comparison between the ENZ-enhanced SHG of TiN film and double resonance (ENZ + magnetic resonance) enhanced SHG in resonators. For TiN spit-ring resonators with a bar width of 20 nm, the SHG signal is much stronger than homogenous TiN thin film. The SHG of the substrate sapphire is displayed in black curve for reference.