Nonlinear frequency up-conversion in high-Q GaP metasurfaces

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Abstract - We demonstrate enhanced visible sum-frequency generation in doubly resonant GaP metasurfaces. Record conversion efficiency is achieved in the metasurface by the excitation of high-quality factor Q bound state in the continuum (BIC) resonances with non-trivial polarization dependence.

The up-conversion infrared (IR) imaging process transfers the spatial information of an IR image to the visible domain, using the nonlinear optical process of sum-frequency generation (SFG) [1]. In metasurfaces, the efficiency of the SFG is limited by the low Q factor of Mie-type resonances and by the absorption of visible light in the metasurface material. Here, we design a GaP high-Q resonant metasurface to enhance the SFG emission and prevent the absorption of the generated nonlinear emission in the semiconductor material.

We design and fabricate a double resonant GaP metasurface based on leaky-waveguide type BIC resonances. In our design, the BIC resonances are supported by a long-bar and excited by the two small nanodisks of different radii. The calculated transmission spectrum of the metasurface, exhibits two narrow resonances around the pump (λ_p=880 nm) and signal (λ_s=1550 nm) wavelengths. This resonant behaviour is originated by the excitation of TE_{10} and TM_{10} waveguide resonant modes, having an estimated Q of 800 and 160. The fabricated metasurface is simultaneously illuminated by pump and signal beams, generating a strong visible SFG at 558 nm. We show that in contrast to harmonic generation, the SFG process is enhanced when using non-parallel polarized input-beams. We measure a conversion efficiency of 2.5×10^{-4} [W^{-1}] in the forward SFG, two orders of magnitude higher than the one reported in Mie-type resonant metasurfaces [2]. Our results open new opportunities for infrared to visible up-conversion and light sources.

[1] J. E. Midwinter, *Image conversion from 1.6 μ to the visible in lithium niobate*, Appl. Phys. Lett. **12**, 68 (1968).

[2] R. Camacho-Morales et al., *Infrared upconversion imaging in nonlinear metasurfaces*, Advanced Photonics **3**, 036002 (2021).