Resonant harmonic generation from nonlinear dielectric metasurfaces

Kirill Koshelev[a], Yuri Kivshar[a]

[a] *Research School of Physics, Australian National University, Canberra ACT 2601, Australia*

In the past two decades, we observe a remarkable progress in engineering of efficient nanostructured devices for functional flat optics and nonlinear photonics by using resonant dielectric metasurfaces operating through the excitation of multipolar vectorial Mie resonances [1]. The last decade marked a series of intense studies of optical resonances with a giant quality factor (Q factor), *bound states in the continuum* (BICs) [2], promising for further enhancement of optical nonlinearities of Mie-resonant metasurfaces due to a drastic increase of the field intensity inside the material. For realistic metasurfaces with losses and imperfections, BICs are manifested as *quasi-BIC* resonances with a large, yet finite Q factor. Very recently, it was shown that for dielectric metasurfaces composed of subwavelength meta-atoms with broken in-plane symmetry, the Q factor of quasi-BICs can be unambiguously controlled by variation of meta-atom asymmetry parameter [3].

Here, we employ the concept of quasi-BICs for smart engineering of nonlinear dielectric metasurfaces for enhanced harmonic generation (see Fig. 1a) and nonlinear chiroptical response. We design and characterize Si metasurfaces with broken-symmetry meta-atoms of different shape supporting quasi-BICs in the near-IR. By engineering the meta-atom asymmetry, we demonstrate enhancement of third-harmonic generation (THG) at the quasi-BIC wavelength by more than an order of magnitude compared to non-resonant structures (see Fig. 1b). For metasurfaces with chiral L-shaped meta-atoms, we explore an interplay of quasi-BICs and Mie resonances for enhancement of nonlinear chiroptical response depending on the rate of losses in metasurfaces. We observe strong nonlinear signal with high values of third-harmonic (TH) circular dichroism (CD) and demonstrate its tunability from 0.5 to -0.2 with respect to a change of the asymmetry parameter (see Fig. 1c).

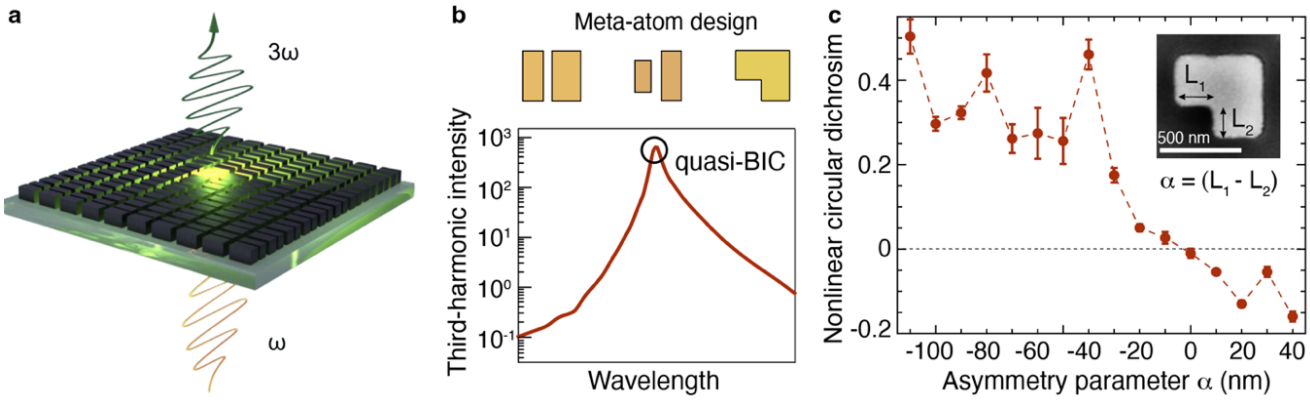

Fig. 1. (a) Schematic of THG in resonant broken-symmetry Si metasurfaces. (b) Designs of meta-atoms and a characteristic spectrum of TH intensity in the vicinity of quasi-BICs. (c) Measured TH CD vs. the asymmetry parameter.

[1] K. Koshelev, Yu. Kivshar, Dielectric resonant metaphotonics, *ACS Photonics* **8**, 102-112 (2021).

[2] K. Koshelev et al., Bound states in the continuum in photonic structures, *arXiv*, 2207.01441 (2022).

[3] K. Koshelev et al., Asymmetric metasurfaces with high-Q resonances governed by bound states in the continuum, *Phys. Rev. Lett.* **121**, 193903 (2018).