

ABSTRACT:

Ultrafast quasi-Bound States in the Continuum-Based Tunable Metasurfaces

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Metasurfaces are engineered, two-dimensional arrays of subwavelength structures that allow manipulating electromagnetic waves in ways not possible with natural materials. The size, shape, and arrangement of these "meta-atoms" allow for control over the amplitude, phase, and polarization of incident waves over an extremely thin, planar layer. Consequently, metasurfaces can create novel, compact devices such as flat lenses (metalenses), holograms, invisible cloaks and tailored resonances.

Ordinary metasurfaces have fixed optical responses determined during fabrication, severely limiting their post-production functionality. Dynamically controlling light is critical for modern applications. Tunable metasurfaces (TMs) address this limitation by e.g. integrating active materials whose optical properties can be modified using external stimuli like electrical or thermal signals. TMs thus enable the creation of more compact, versatile, and efficient integrated photonic devices for cutting-edge technologies.

One drawback of such kind of TMs is the slow response times, not faster than a few GHz. In this contribution, I will introduce the concept of quasi-Bound States in the Continuum (qBIC) resonances and show how tunable qBIC-based nanofabricated TMs can be realized using ultrafast laser pulses (~200 fs long) as external tuning knob to achieve TMs response times in picosecond scales. In one case, Mie resonances are used for selectively modulating the refractive index of a specific meta-atom of the TM unit cell [1], exploiting the consequent creation of permittivity asymmetric unit cells which support qBIC resonances [2]. In the other case, relying on the same principle, I will show how a non-nanofabricated, homogeneous amorphous Si thin film can be used to produce qBIC resonances with ultrafast response times when illuminated with structured light [3].

[1]. A. Aigner et al., Nature 644, 896 (2025).

[2]. R. Berté et al., Nano Lett. 23, 2651 (2023).

[3]. R. Berté et al., Light: Sci. & Appl. 14, 185 (2025).