Excitation of Bound States in the Continuum with Radially Polarized Beams

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The last decade has witnessed an effervescent interest in exploiting Bound States in the Continuum (BIC) in both dielectric and plasmonic metasurfaces for many applications [1,2]: lasing, nonlinear optics, electromagnetically induced transparency, polarization conversion, and sensing, among others. These states – which are strongly resonant eigenmodes with eigenfrequencies laying within the radiation continuum- remain perfectly confined and cannot couple to the far-field, thus giving rise to infinite Q-factors. Nevertheless, small perturbations, like absorption losses or finite size effects, can destroy pure BICs and result in quasi-BICs, modes with large, but finite, Q-factors that can couple to the far field. But the same physical mechanism that gives rise to their diverging Q-factors makes their excitation from the far-field notoriously difficult.

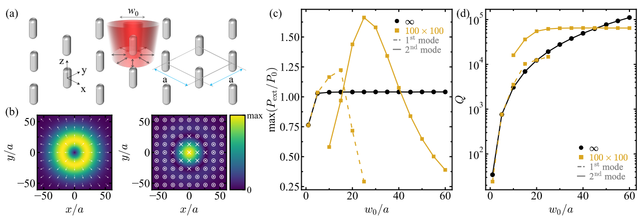

Figure 1: (a) The system under consideration consists of z-oriented loss-less elongated polarizable objects arranged in a square array of period a, which is excited by a radially polarized beam. (b) Spatial distribution across the array plane for the in-plane (left panel) and out-of-plane (right panel) components of the electric field for a radially polarized beam. (c) Maximum extincted power P_{ext} normalized to the incident power P_0 for infinite and finite arrays as a function of beam width. (d) Q-factor for infinite and finite arrays as a function of beam width

Here, we report the excitation of quasi-BICs in periodic arrays of z-oriented elongated polarizable objects using structured beams (Figure 1a). Exploiting a semianalytical approach based on the combination of the coupled dipole model and the angular spectrum representation of a light beam [3], we demonstrate that tightly focused radially polarized beams are capable of exciting quasi-BICs more efficiently than any tilted plane wave [4]. For infinite square arrays (lattice period a) of loss-less objects with resonant wavelength $\lambda_r = 1.5a$, we show that increasing w_0 (a variable proportional to the beam width) leads to stronger and spectrally narrower collective resonances (Figures 1c and d). Nevertheless, while the extinction efficiency saturates, the Q-factor increases exponentially with w_0, evidencing the excitation of a quasi-BIC. For finite arrays the behaviour is significantly different (Figures 1c and d). For beam widths smaller than the array size, two different quasi-BICs are excited. The first mode initially follows the behaviour of the infinite array, to later vanish. For the second mode, the extinction efficiency and the Q-factor grow and significantly surpass those of the infinite array. More importantly, these conditions lead to much more efficient quasi-BIC excitation than for any tilted plane wave. For larger beam widths, the Q-factor saturates and the extinction efficiency worsens, eventually vanishing. Our results provide a solid theoretical framework to analyse, understand, and optimize the excitation of quasi-BICs in finite arrays by means of radially polarized beams.

References

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