Robust quasi-BIC modes in a four cuboid cluster metasurface

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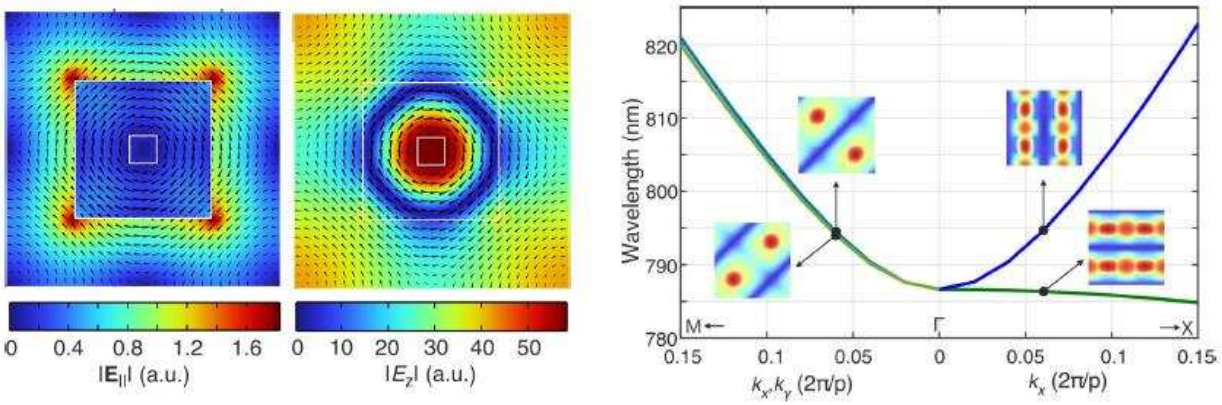
Abstract: A metasurface with a unit cell composed of a cluster of four hollowed cuboids to work at the VIS spectrum is proposed. By shifting the hole asymmetrically, a qBIC resonant mode that is very robust to perturbations of the cuboid structure is produced thanks to its particular electric field profile.

Metasurfaces have emerged as a promising platform for engineering BICs. In these structures, symmetry-protected BICs are eigenmodes situated above the light cone, possessing different symmetries than the incoming wave, rendering them unexcitable within the continuum of radiation modes. By introducing some kind of perturbation, pure BICs transform into quasi-BICs with a finite lifetime, narrow linewidth and arbitrarily high radiative Q-factor. Indeed, quasi-BICs have been intensely investigated in dielectric metasurfaces with symmetry breaking, such as by introducing geometrical asymmetry or using anisotropic materials [2]. Although in most cases the resonant near fields are mainly confined to the interior of the high-index subwavelength scatterers, thus providing limited light-matter interaction with the surrounding material, it is still feasible to achieve interaction at the interface, allowing for biosensing and integration with 2D materials [3], as well as in slotted regions [4]. Furthermore, it has been recently reported that asymmetric dielectric particles arranged in clusters can be used to achieve greater flexibility in obtaining the desired near-field configuration [5] and enhancing the sensing capabilities for refractometry [6]. The operation principle in the latter case is based on plasmon-like surface waves, which are delocalised over a wide area to provide a large interaction volume with the matter but are excited in an all-dielectric structure.

In this work, we investigate a GaP metasurface supporting delocalised quasi-BIC modes. The metasurface comprises a periodic array of hollow nanocuboids patterned on a glass substrate and designed to produce ultra-high Q-factor delocalised resonances. The authors previously demonstrated this structure for toroidal responses [7,8], but the cluster arrangement has advanced features. The perturbed quadrumer arrangement retains C4v symmetry, thus allowing for polarization-independent optical response for normally incident planewaves [9]. By shifting the cuboids or a hole in the middle asymmetrically, the Brillouin zone is doubled producing a qBIC resonant mode with an antiferroelectric field configuration, which is very robust to large perturbations of the cuboid structure thanks to its particular electric field profile [9]. In addition, the resonant mode dispersion is investigated, revealing interesting features, such as low birefringence along the ΓM contour of the metasurface Brillouin zone and very low dispersion for the TM polarization along the ΓX direction [9]. Finally, this metasurface operates close to 785 nm, which is highly relevant for Raman spectroscopy.



(a) (b) (c)

Figure 1. Field structures for the investigated electric dipole mode in a metasurface with a single cuboid unit cell: magnitude of the (a) in-plane and (b) out-of-plane electric field vector. The arrow plot in both cases shows the distribution of the inplane magnetic field. (c) Band diagram of the investigated supermode along the ΓX and ΓM contour of the irreducible Brillouin zone. For oblique incidence (off-Γ point) the band splits in two branches corresponding to different polarization. The insets show the norm of the electric field calculated at $\{kx = 0.06, ky = 0\}$ and $\{kx = 0.06, ky = 0.06\}$ in units of $(2\pi/p)$ [9].

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