Serrano Mini Workshop Series on Nanophotonics, Quantum Technologies and Information

Bound States in the Continuum

4th June 2024

Sala de Conferencias CFMAC

C/ Serrano 121, Madrid

Program

10:00-10:10 **Rafael Molina** (IEM) "Introduction: BICs in Serrano".

10:10-10:30 **Luis Cerdán** (IQF) "Excitation of BICs in periodic arrays of dipoles using structured beams".

10:30-10:50 **Juan José Álvarez Serrano** (IO) "Normal incidence excitation of out-of-plane lattice resonances".

10:50-11:10 **Alberto Muñoz de las Heras** (IFF) "Non-linear-enabled localization in driven-dissipative photonic lattices".

11:10-11:30 Coffee break

11:30-11:50 **Alexis Legón** (IFF and Universidad Técnica Federico Santa María, Chile) "BICs in whispering gallery resonators".

11:50-12:10 **Beatriz Castillo López de Larrinzar** (IEM) "Superchiral light emerging from quasi-BICs in Si nanorod dimer metasurfaces".

12:10-12:30 **Álvaro Buendía** (IEM) "Long-range molecular energy transfer mediated by strong coupling to plasmonic topological Edge states".

12:30-12:50 **Diego R. Abujetas** (Universidad de Castilla La Mancha) "Understanding BICs in periodic metasurfaces through a coupled electric and magnetic dipole model".

12:50-13:10 **Dunkan Martínez Camacho** (UCM) "Playing hide-and-seek with Bound States in the Continuum in InSb nanowire networks".

Abstracts

Luis Cerdán

Instituto de Química-Física Blas Cabrera

Excitation of BICs in periodic arrays of dipoles using structured beams

Abstract

Periodic arrays of vertically oriented dipoles sustain a symmetry protected Bound State in the Continuum (BIC) that cannot be accessed under excitation with a normally incident plane wave. Here we show that this BIC can be excited using structured beams, in particular those with radial polarization, even under normal incidence conditions. We will analyse the effects of the beam size, the presence of non-radiative losses, or the extend of the array (finite vs infinite), in the quality factor and extinction efficiency of the arrays.

Juan José Álvarez-Serrano

Instituto de Óptica

Normal Incidence Excitation of Out-of-Plane Lattice Resonances

Abstract

Lattice resonances are collective modes supported by 2D periodic arrays of nanostructures. Among them, out-of-plane lattice resonances correspond to those for which the nanoparticles are polarized in the direction orthogonal to the plane of the array, counting with particularly interesting optical properties. With minimal losses, substantial field enhancements and extremely high Q-factors, this type of resonances is optimal for applications in biosensing and nano-lasing. Consequently, an efficient excitation of these modes is of great interest. To do so, traditional methods have employed oblique incidence, a method that degrades the properties of the resonance and adds experimental complexity. Therefore, excitation under normal incidence would be desired, solving all deficiencies of traditional approaches.

In this talk, we present a methodology to excite out-of-plane lattice resonances in bipartite arrays under normal incidence. Our theoretical analysis is based on a rigorous coupled dipole model in excellent agreement with full solutions of Maxwell's equations. Our approach capitalizes on the electric-magnetic interaction between the nanoparticles, and highlights the importance of their relative position within the unit cell. We provide substantial proof of the criticality of the magnetic response, and show that our approach is general and applicable to more complex array geometries and *particle shapes. Moreover, we also analyze a potential implementation of our findings, employing an array of nanodisks that incorporates a substrate and a coating. In this context, our study introduces a novel method to excite out-of-plane lattice resonances more efficiently, paving the way for the harnessing of their properties in a myriad of applications.*

Alberto Muñoz de las Heras

Instituto de Fisica Fundamental

Non-linear enabled localization in driven-dissipative photonic lattices

Abstract

Spatial photon localization holds great significance for the control of light-matter interactions, showcasing fundamental implications in quantum information, communication, and simulation. A recent experimental work [1] has shown how driving lossy photonic lattices with multiple, spatially separated, laser spots can produce localization with dynamically tunable spatial dependence. However, an important drawback of this method is that it only works for specific combinations of laser frequencies and/or distant spots. Here, we examine this localization regime in the presence of standard optical Kerr non-linearities, such as those found in polaritonic lattices, and show that they stabilize driven-dissipative localization across frequency ranges significantly broader than those observed in the linear regime. Moreover, we demonstrate that, contrary to intuition, in most situations this driven-dissipative localization does not enhance non-linear effects like optical bistabilities, due to a concurrent reduction in overall intensities. Nevertheless, we are able to identify certain parameter regions where non-linear enhancement is achieved, corresponding to situations where emission from different spots constructively interferes [2].

References:
[1] O. Jamadi et al., Reconfigurable photon localization by coherent drive and dissipation in photonic lattices, Optica 9, 706–712 (2022).
[2] A. Muñoz de las Heras, A. Amo, and A. González-Tudela, arXiv:2401.10788 (2024).

Alexis Legón

Instituto de Fisica Fundamental y Universidad Técnica Federico Santa María, Chile

BICs in Whispering Gallery Resonators

Abstract

Bound states in the continuum (BICs) are confined states but in the continuum energy spectra. They are characterized for having infinite lifetime and they co-exist with extended states but without blending with them. They can be seen as resonances with zero width. The whispering gallery resonators allow the exploration of Fano and BIC resonances while varying the system parameters. We show that certain configurations

improve control over interference effects, allowing an efficient access to BICs that may be used in new sensor technology.

Beatriz Castillo López de Larrinzar

Instituto de Estructura de la Materia

Superchiral light emerging from quasi-BICs in Si Nanorod dimer metasurfaces

Abstract

In this work, we investigate the emergence of intrinsic and extrinsic optical chirality associated with the excitation of BICs in various metasurfaces made of Si nanorod dimers on a silica substrate, comparing three cases: parallel (neutral), shifted, and slanted dimers, with/without index-matching superstrate. We analyze both the circular dichroism (CD) of the far-field (FF) interaction and the helicity of the near-field (NF) distribution. We show that the best approach to achieve chiral response in FF based on extrinsic chirality is to exploit quasi-BICs appearing in the case of slanted nanorod dimers. By contrast, the helicity density is enhanced in the case of shifted dimers, as it presents intrinsic chirality, with values two orders of magnitude larger than those of circularly polarized plane waves, thus yielding so-called superchiral electromagnetic fiels.

Álvaro Buendía

Instituto de Estructura de la Materia

Long-range molecular energy transfer mediated by strong coupling to plasmonic topological edge states

Abstract

Strong coupling between light and molecular matter is currently attracting interest both in chemistry and physics, in the fast-growing field of molecular polaritonics. The large near-field enhancement of the electric field of plasmonic surfaces and their high tunability make arrays of metallic nanoparticles an interesting platform to achieve and control strong coupling. Two dimensional plasmonic arrays with several nanoparticles per unit cell and crystalline symmetries can host topological edge and corner states. Here we explore the coupling of molecular materials to these edge states using a coupled-dipole framework including long-range interactions. We study both the weak and strong coupling regimes and demonstrate that coupling to topological edge states can be employed to enhance highly-directional long-range energy transfer between molecules.

Diego R. Abujetas

Universidad de Castilla La Mancha

Understanding BICs in periodic metasurfaes through a coupled electric and magnetic dipole model

Abstract

Periodic metasurfaces are versatile platforms that allow us to control the electromagnetic field in fascinating ways. Among its properties, it is worth highlighting their capability to localize energy through (theoretically) infinite lifetimes states called bound states in the continuum (BICs). In this talk, we will discuss how a coupled electric and magnetic dipole (CEMD) model can retrieve analytical insights of the elemental properties of BICs, crucial to understand their nature and to design metasurface with desired near and far field properties.

Dunkan Martínez Camacho

Universidad Complutense de Madrid

Playing hide-and-seek with Bound States in the Continuum in InSb nanowire networks

Abstract

Bound states in the continuum (BICs) have been found in several optical devices, but not yet in an electrical device. With this in mind, we have simulated an InSb hashtag nanowire network in which we find the BICs as resonances or anti-resonances when the magnetic field is switched on.