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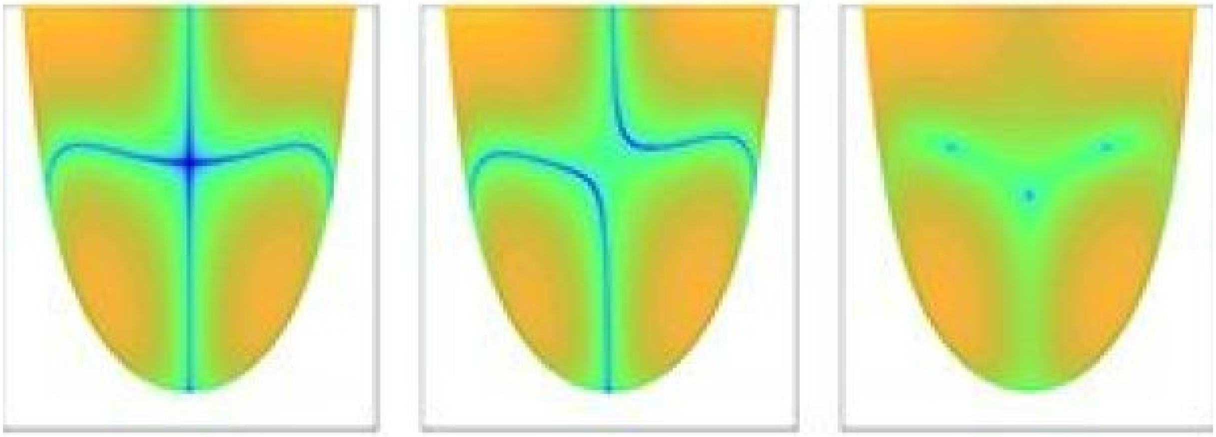

PhD Thesis Defense SAMYOBRATA MUKHERJEE 'Bound States in the Continuum in Planar Anisotropic Structures'

SAMYOBRATA MUKHERJEE

October 05, 2021
11:00
ICFO Auditorium and Online (Teams)

PhD Thesis Defense, October 5, 2021, 11:00. ICFO Auditorium and Online (Teams)

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Bound states in the continuum (BICs) are modes that remain radiationless though they exist in the part of the spectrum that corresponds to radiating waves. They are a general wave phenomenon and following initial theoretical predictions and subsequent landmark experimental demonstrations of the existence of BICs in photonic systems, there has been an explosion of interest in photonic BICs. Planar anisotropic waveguides containing uniaxial materials support the existence of full vector BICs.

In this thesis we study the properties of these full vector BICs using the leaky mode formalism. We start by studying a structure with an isotropic cover, a uniaxial core/film and a uniaxial substrate, where one of the basis waves in the substrate provides the radiation channel. We find that the orientation of the optic axes of the two materials has substantial impact on BIC existence. This allows us to define regimes of anisotropy-symmetry based on the orientation of the optic axes relative to the direction of propagation and the interface plane. Varying the offset between the film and substrate optic axes in the interface plane, or azimuthal anisotropy-symmetry breaking, leads to the distortion of the BIC lines of existence on the leaky mode. Moving either optic axis out of the interface plane, or polar anisotropy-symmetry breaking, leads to the BIC lines of existence collapsing to points. The collapse of the BIC lines of existence to discrete points when polar anisotropy-symmetry is broken also leads to a transformation from lines of phase discontinuity to phase singularities in the radiation channel amplitude which can be assigned winding numbers. The BICs are robust and cease to exist only when two BICs with opposite winding numbers merge in the parameter space or the BIC moves beyond the leaky mode cutoff.

We also study the impact of the variation of the constitutive parameters of this waveguide on the existence of BICs. We find that varying the refractive indices of the different components of the waveguide have varying degrees of impact on the BIC lines of existence but in all cases results in their continuous transformation, allowing us to construct bands of BIC existence. The sensitivity of BICs to changes of the refractive index also suggest possible applications in sensing.

We then move on to studying structures where the cover, the film and the substrate are all uniaxial with radiation channels available in the cover and the substrate. The structure supports lines of BIC existence when the structure is mirror symmetric and therefore the radiation channels are equivalent. Breaking the mirror symmetry of the structure in any way leads to distinct radiation channels and the added constraint of a second radiation channel also having to be zero leads to the lines of BIC existence collapsing to discrete points. These discrete BIC points are robust and tunable and characterised by phase singularities in both radiation channels. Breaking polar anisotropy-symmetry in addition to the mirror symmetry leads to the formation of unidirectional guided resonances, which are unbound modes that radiate only via one radiation channel even when other channels are available. UGRs are characterised by phase singularities in the amplitude of the radiation channel where they do not radiate.

Finally, we study the surface modes at an interface between a positive uniaxial material and a negative uniaxial material. We find that this interface can support standard, guided D'yakonov surface waves (DSWs). Moreover, it can also support leaky DSWs and even a surface D'yakonov BIC when coupling of the leaky DSW to the radiation channel is cancelled.

We have thus improved the understanding of the hybrid leaky modes and full vector BICs supported by such structures and developed the concept of anisotropy-symmetry which has substantial impact on the existence of BICs and UGRs in these structures.

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Thesis Directors: Prof. Dr. David Artigas and Prof. Dr. Lluis Torner

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