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Topological opto-phononic interface modes by simultaneous band inversion

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The concept of inverted spatial mode symmetries in periodic lattices, often referred to as band inversion, is one of the cornerstones in the field of topological matter. Band inversion leads to the generation of an interface mode inside a bandgap by concatenating two periodic lattices with inverted mode symmetries. The robustness of these modes against chirality preserving perturbations has been exploited for a wide range of excitations (photons, plasmons, phonons, vibrations, polaritons). Most of these realizations explored a single kind of excitation. Despite its potential in the manipulation and control of interactions, the simultaneous topological confinement of multiple excitations remains an open challenge.

In this work, we designed, fabricated, and experimentally studied multilayered structures based on GaAs/AlAs. Due to the simultaneously inverted band structures for light and phonons, colocalized interface modes for both 1.34 eV photons and 18 GHz phonons appear. We achieve band inversion by modifying the internal unit cell structure of the two lattices [1]. Fig.1a shows simulation of the colocalized optical and acoustic fields in the structure. We experimentally validated the concept by optical reflectivity (Fig.1b) and coherent phonon generation and detection through picosecond optical pump-probe spectroscopy (Fig.1c) [2-4]. By comparison with a Fabry-Perot resonator (Fig.1d) we theoretically predict a robust photoelastic interaction between the optical and the acoustic interface mode. This robustness manifests as a much more stable Brillouin cross-section when the structure is subject to chirality-preserving fluctuations.

Potential future applications include the engineering of robust optomechanical resonators in a material system compatible with active media such as quantum wells and quantum dots.

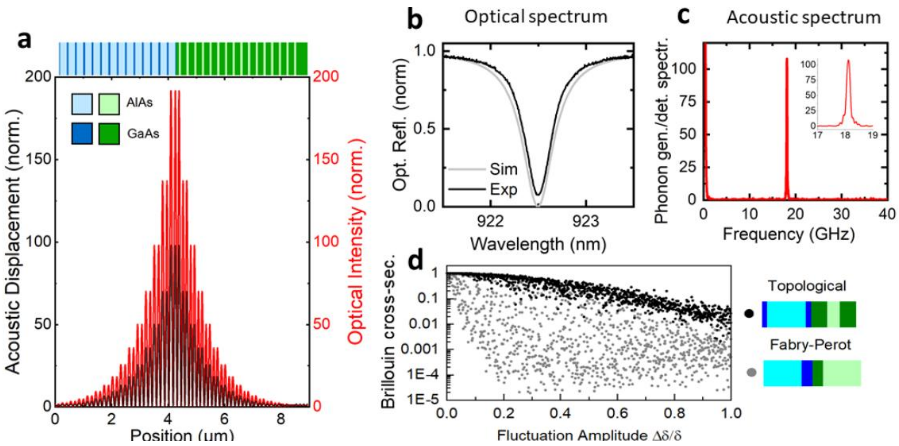

Figure 1 : (a) Simulation of the colocalized topological interface state for light and acoustic phonons. (b) Optical reflectivity spectrum. (c) Pump-probe phonon generation-detection spectrum (d) Simulated robust Brillouin cross-section of the system (black) as compared to a Fabry-Perot resonator (grey).

[1] M. Esmann et al., Phys. Rev. B **97**, 155422 (2018)
[2] O. Ortiz et al., Optica **8**, 598 (2021)
[3] M. Esmann et al., Phys. Rev. B **98**, 161109 (2018)
[4] G. Arregui et al., APL Photonics **4**, 030805 (2019)