# Simulating the Response of Planar Photonic Structures Under the Strain of Surface Acoustic Waves

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## Abstract

In this contribution, we simulate the optical response of piezoelectric planar optical microcavities (POMCs) under the modulation introduced by a propagating surface acoustic wave (SAW). The physical picture of the model is shown in Figure 1. A metallic interdigital transducer (IDT) is placed on the sample surface and, via inverse piezoelectric effect, is responsible for the generation of SAWs on piezoelectric materials. The layered structure below the IDT is a λ/2 POMC designed to resonate in the visible/infrared region of the optical spectrum.
In the COMSOL Multiphysics® software, the problem is solved in two dimensions and is addressed in three steps. First, we simulate the generation of SAWs in arbitrary layered structures. By applying continuity periodic condition to the particle displacement at 2D boundaries and using a PML to force an exponential decay of the mode to the substrate, we are able to search and characterize SAWs modes on our systems. Figure 2 shows a frequency sweep used to find acoustic resonances in a piezoelectric ZnO/SiO2 POMC. In this type of sweep, no bulk mode is found due to the presence of the PML. The results agree very well with values found in literature. After finding the resonances we calculate the modulation profiles (particle displacements, strain, and piezoelectric field distribution) using eigenmode studies.
In the second step, we use one of the Electromagnetic Waves physics interfaces to simulate the optical spectra in POMCs. By applying Floquet periodic condition to the electromagnetic fields at the borders of the 2-port 2D model, we calculate the reflectivity and transmission curves of this type of system. Figure 3(a) shows the reflectivity spectrum of a ZnO/SiO2 POMC designed to resonate at 800nm. This result agrees very well with transfer matrix calculations. Figure 3(b) shows the spatial distribution of the light electric field at the cavity resonance and demonstrates the 2D character of the mode, as expected. From these calculations, we are also able show how quality factors depend on the number of layers and refractive index contrast.
In the final step, the two models are merged. Figure 4 shows the refractive index modulation induced by two different SAW modes in two types of POMCs: ZnO/SiO2 and LiNbO3/SiO2. Our model allows us to show how this propagating optical grating modulates and changes the optical response of these two particular types of POMCs. We also discuss the possibility of tuning optical resonances with SAWs. By calculating the photon dispersion, we predict the formation of optical superlattices under high strain amplitudes, in good agreement with experiments [1]. In this contribution, we simulate the optical response of piezoelectric planar optical microcavities (POMCs) under the modulation introduced by a propagating surface

acoustic wave (SAW). The physical picture of the model is shown in Figure 1. A metallic interdigital transducer (IDT) is placed on the sample surface and, via inverse piezoelectric effect, is responsible for the generation of SAWs on piezoelectric materials. The layered structure below the IDT is a $\lambda/2$ POMC designed to resonate in the visible/infrared region of the optical spectrum.

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## Reference

[1] de Lima Jr., M. M, et. Al, Phonon-induced optical superlattice, Phys. Rev. Lett., 94, 126805 (2005)

## Figures used in the abstract

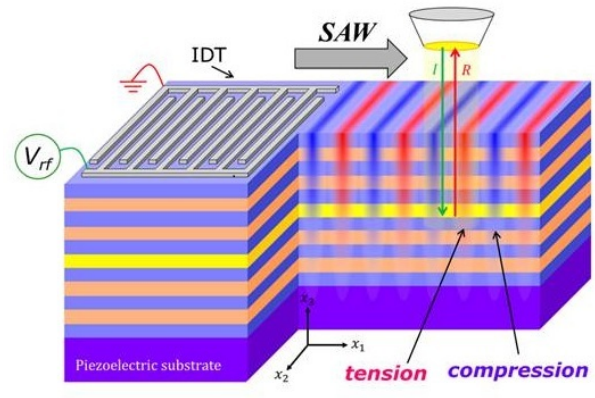


**Figure 1**: Representation of a POMC modulated by a SAW propagating along x1 direction. At the same time, reflectance measurement is performed. The SAW-induced strain field deforms the POMC and the regions of tension and compression are represented in red and blue, respectively.

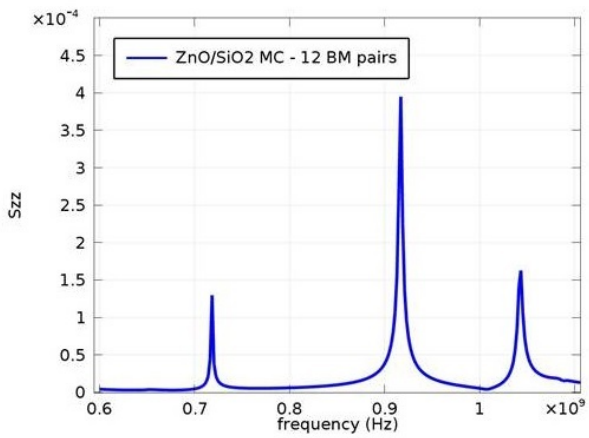


**Figure 2**: Frequency sweep used to determine SAW mode resonances for a 12 Bragg mirros POMC.

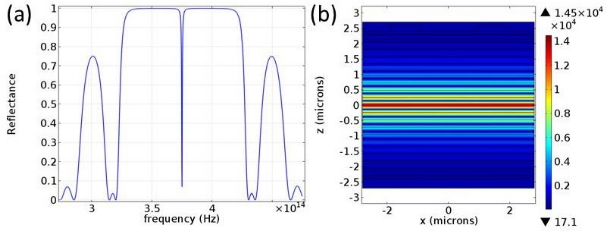


**Figure 3**: (a) Calculation of the reflectivity spectrum for a 12 Bragg mirrors POMC resonating at 375 THz (800nm). (b) Spatial distribution of the electric field mode at the resonance showing the 2D character of the mode.

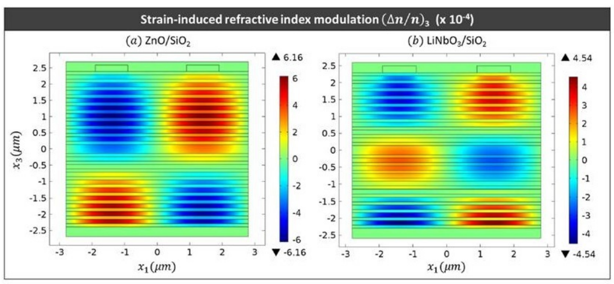


**Figure 4**: 2D color plots for the refractive index modulation in (a) ZnO/SiO2 and (b) LiNbO3/SiO2 POMCs at 821 MHz and 1170 MHz Rayleigh SAW eigenfrequencies, respectively.