Band structure engineering in nanomechanical devices in the 100s GHz regime

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Acoustic phonons in the GHz-THz range appear as a suitable platform to study complex wave phenomena, and the strong interactions with other excitations in solids make them ideal candidates to interface different quantum platforms. In addition, such high frequencies have associated small occupation numbers even at room temperature, enabling the study of mechanical systems in the quantum regime without the need for complex cooling techniques.[1,2] In this work, we engineer one-dimensional acoustic resonators based on GaAs/AlAs multilayers, able to confine acoustic phonons in the hundreds of GHz range. We engineer the phononic band structures associated to periodic superlattices, modifying both the period and thickness ratio. We unveil the possibility of controlling the energy and amplitude of the minigaps, as well as the symmetries of the acoustic modes of the system.

First, by progressively changing the periodicity of an acoustic GaAs/AlAs distributed Bragg reflector, we adiabatically transform the acoustic band diagram of the system.[3] This leads to the generation of a confined mechanical state, in analogy to a quantum well for electrons, as shown in Figure 1. Second, we show that by modulating the thickness ratio of the two materials forming a one-dimensional periodic superlattice we can adiabatically close and reopen a minigap along the structure. This allows us to control the energy and the number of bounded nanophononic modes. This spatial modulation of the effective band structure enables us to control the symmetries of the edge modes, and simultaneously implement a phononic topological transition that changes not only the energy of the confined modes but also their number and nature.[4] Finally, by concatenating two superlattices with inverted band structures, we create a topological interface mode.[5,6]

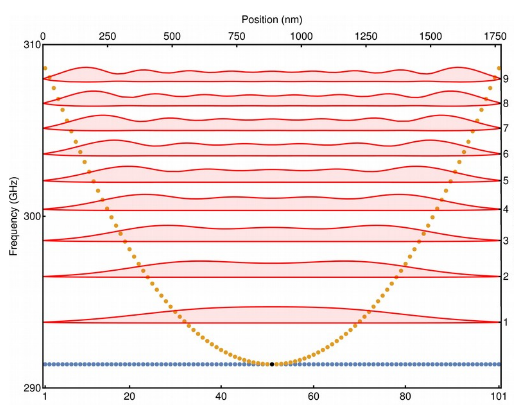

Figure 1: Spatial profile of the acoustic displacement amplitude for the first nine confined modes in a parabolic potential.

References

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