Impact of the phononic structure design on the reduction of thermal conductivity

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Energy conversation is an important aspect of the today's technology, and one of the main directions of the research in this field is the thermoelectricity. However, modern thermoelectric devices have rather limited efficiency due to the lack of materials with high electrical and low thermal conductivities at the same time. Recently, a number of works demonstrated that periodic arrays of holes can affect the propagation of phonons in the material, and decrease the value of thermal conductivity as compared to the bulk material. This reduction is often attributed to the appearance of the band gap and the flattering of the bands in phonon dispersion curves at very low temperatures.

In the present work, we theoretically investigate the impact of the phononic crystal membrane design on the phononic effect. We demonstrate that the total power, which can be thermally transported through the photonic structure, decreases as the period to thickness ratio is increased. This finding is in agreement with recent experimental data measured at low temperature [1] and explained by the reduction of group velocity and density of states. On the other hand, we find that radius to period ratio impacts the thermally transported power much less, despite its high impact on the size of the phononic bandgap. However, at higher temperatures the impact of phononic effect plays a less important role as compared to the incoherent scattering processes, for which exactly the opposite period dependence is expected. Therefore, we predict the existence of an optimal design of the phononic structures, with the lowest thermal conductivity.

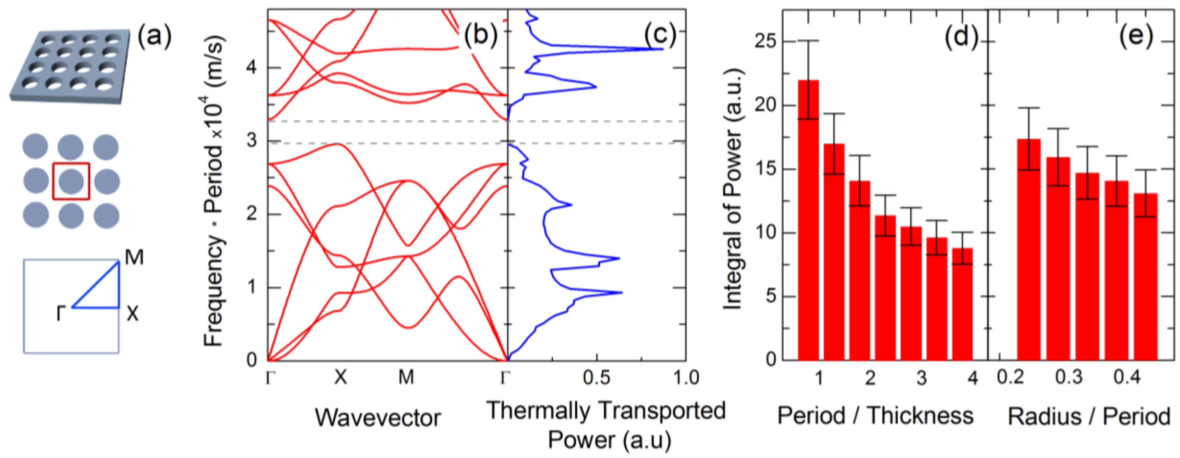

Fig.1: (a) Scheme of the phononic structure with its unit cell and first Brillouin zone. (b) Phonon dispersion and (c) spectrum of the thermally transported power. The integral of the power, calculated at 1K up to the highest available states, as a function of period to thickness (d) and radius to period (e) ratios.

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Reference

[1] N. Zen, *et al*, Nature Communications **5**, 3435 (2014).