Heat Transport in Suspended Membranes and Phononic Crystals at sub-Kelvin Temperatures

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We have studied experimentally and theoretically the thermal conductance of thin free-standing silicon nitride membranes at sub-Kelvin temperatures as a function of membrane thickness between 40 nm and 750 nm, using normal metal-insulator-superconductor (NIS) thermometry. Effects of the expected dimensionality cross-over from 3D to 2D phonons are seen, however not all observations follow the simplest theory. A more detailed modeling is also presented in the limit where phonon scattering is fully diffusive on the membrane surfaces (Casimir limit) and possibilities for extending the model are discussed.
In addition, we have also studied membranes with a periodic array of perforated holes. These type of samples act as phononic crystals, where the acoustic phonon modes are strongly modified due to the periodic obstacles. Using finite element method based calculations, we have successfully found the proper geometry which has a complete phononic bandgap in the energy range of the dominant thermal phonons at 100 mK, (around 20 GHz). Initial results using sensitive NIS thermometry indicate that thermal conductance is suppressed strongly at the lowest temperature range of the experiment around 100 mK, but recovers towards the full membrane results at higher temperatures. Thus, we have shown that phononic crystals are promising new avenue for controlling the thermal conductance in micro- and nanoscale.