Relaxation of an Optically Created Phonon Void

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A frequency-selective depletion of phonons has been realized in a confined volume in a single crystal of dilute ruby (Al_2O_3:Cr^{3+}) at 1.8 K. The phonons removed from this phonon "void" are resonant with the one-phonon transition connecting the levels of the metastable $\overline{E}(^2E)$ doublet split in an external magnetic field. The lowest doublet level is initially populated by selective optical pumping, after which phonons are extracted from the lattice by relaxation of the spin system toward thermal equilibrium.

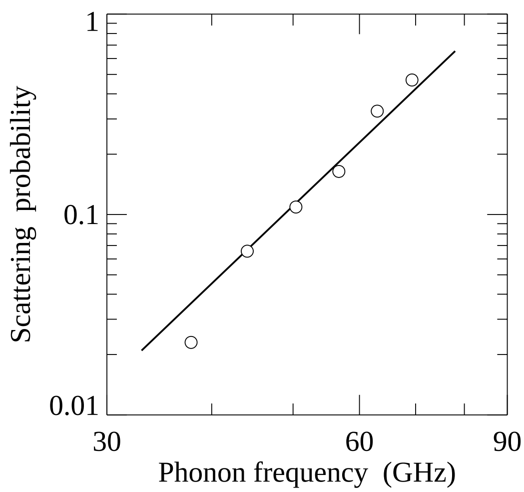

Figure 1. The probability for diffuse phonon scattering into surface Rayleigh waves versus the phonon frequency. The solid line represents a quartic dependence, as predicted by the theoretical calculations by T. Nakayama, Phys. Rev. B **33**, 8664 (1986).

The phonon density is measured as a function of the time in the void as well as in a probe volume at some distance by using the $\overline{E}(^2E)$ doublet as luminescent phonon detector. The void, which is in dynamic balance with the spin system, is observed to be filled by an inward flow of phonons supplied from regions further out in the crystal, and ultimately from the helium bath. Coupled rate equations of the spin system in the void as well as the phonon density throughout the crystal account for the dynamics when combined with a finite probability across the crystal boundary.

In particular, a quartic frequency dependence of the rate for phonon transport across the crystal boundary is found, in accordance with diffuse surface scattering (Figure 1). Furthermore, a sizable departure from the equilibrium phonon distribution is observed just below the crystal surface as a result of Kapitza resistance.