Scattering of THz Phonons

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Currently there is renewed interest in understanding the quantitative details of THz phonon scattering processes. One motivation is for modelling the response of composite low temperature detectors, where the particle or photon energy is deposited in an absorbing substrate, separate from but coupled to the energy sensor itself [1]. The deposited energy is transported via a flux of high frequency phonons to the sensor, typically a bolometer or superconducting tunnel junction. Scattering of the phonons degrades both responsivity and resolution of the detector.

Data on phonon scattering in the THz range are difficult to obtain. In this paper we report the utility of the heat pulse back-scattering technique, in which the heat pulse generator and bolometer are placed next to each other on the same face of a sample, in this regime. The magnitude of the phonon flux scattered within the bulk of a sample due to anharmonic down-conversion and Rayleigh point defect scattering is compared with that of the specular reflection from the opposite crystal surface. We have derived an analytic model of the detailed time-dependence of the signal arriving at the bolometer, by means of which the contributions of different scattering processes can be separated. If single-event scattering is assumed, the Peierls-Boltzmann equation can be used to model the phonon propagation and hence the time dependence of the bolometer signal as a function of input power.

The application of the method to studying THz phonon scattering in sapphire, a commonly used substrate for low temperature detectors, will be described. We measured the generator power level at which phonon back-scattering could just be observed in a 2 mm thick wafer, equivalent to an elastic scattering rate at for fast transverse phonons of $3\times10^{6}\,s^{-1}$. If only Rayleigh scattering was present, this figure would correspond to a point defect concentration of approximately twice the intrinsic isotope concentration. However, the frequency dependence of the scattering cross section determined from the variation of the bulk scattered flux on generator power, was found to be ω, rather than ω^{4} at a frequency of around 2THz. We believe this is due to collinear down-conversion which reduces the dominant frequency of the phonon flux.

[1] A.Poelaert, C.Erd, A.Peacock, N.Rando, P.Verhoeve, A.G.Kozorezov and J.K.Wigmore J. Appl. Phys. **79** 7362 (1996)

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