Zeitschrift: Helvetica Physica Acta

Band: 65 (1992)

Heft: 2-3

Artikel: Electron phonon interactions in a disordered 2d electron gas in a magnetic field

Autor: Benedict, Keith A.

DOI: https://doi.org/10.5169/seals-116423

Electron Phonon Interactions In A Disordered 2d Electron Gas In A Magnetic Field

Keith A. Benedict, Department of Physics, University of Nottingham NG7 2RD U.K.

abstract: The role of disorder in the interaction of a two- dimensional electron gas with the bulk phonons of the system in which it is formed is considered with particular reference to the case of strong perpendicular magnetic fields. The disorder acts to broaden the sharp Landau levels of a pure system and hence removes many of the singularities in the response functions. The emission of phonons from a 2deg heated by the passage of a current is considered using the self-consistent Born approximation for the treatment of the disorder which is assumed to be in the form of a randomly fluctuating potential with only short ranged correlations. Results are shown for the spectrum of emitted phonon energies and the field dependence of the fraction of power emitted as ballistic phonons.

Recent experiments [1] have used a variety of "direct" methods to study the interaction of bulk phonons with the 2d electron gas formed at an interface in a semiconductor device at low temperature. A mathematical model for the description of such experiments in strong magnetic fields has been described in [2] and in this paper it will be applied to the calculation of the frequency spectrum of phonons emitted by a 2deg in a strong field which is heated by the passage of a current. The assumptions and approximations in the calculation are as follows. The vibration frequency is assumed sufficiently high that the interaction of the electrons with the lattice modes is well described by the emission and absorption of phonons. There is an applied magnetic field normal to the plane of the two-dimensional electron gas of suffiecient strength that the Landau level separation is greater than the level broadening due to disorder, ie $\omega_c\tau \gg 1$. The interaction of the phonons with the two-dimensional electron gas is taken to be via the bulk deformation potential. Azimuthal averaging of the phonon dispersion and deformation potential is assumed, this omits the effects of phonon focussing which are now well understood. Detailed Fermi liquid effects are neglected, it is simply assumed that there is an inelastic scattering time τ_{in} over which the two-dimensional electron gas comes to thermal equilibrium which is assumed to be shorter than the inelastic time associated with electron-phonon interactions, this is valid at low enough temperatures. The calculation is performed to lowest order in the deformation potential and the treatment of the disorder which gives rise to elastic scattering of the 2d electrons is via the self-consistent Born approximation of Ando et al[3].

The results shown below are plots of the spectral distribution of emitted phonons $G(\omega)$ in 2 cases, firstly at low temperatures with the chemical potential in the centre of the lowest Landau level and secondly at higher temperature with the chemical potential between the $n = 0$ and $n = 1$ Landau levels.

It can be seen from the left hand diagram that the intra-Landau level processes dominate at low temperature especially when the Fermi level lies at the centre of a disorder broadened Landau band. The right hand diagram however shows that at higher

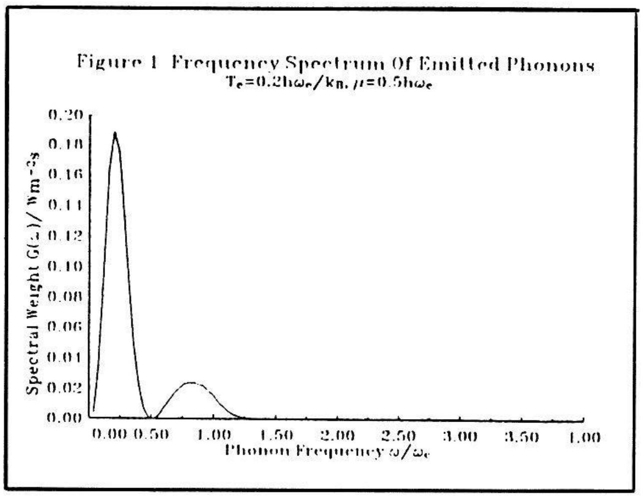

Figure 1 Frequency Spectrum Of Emitted Phonons

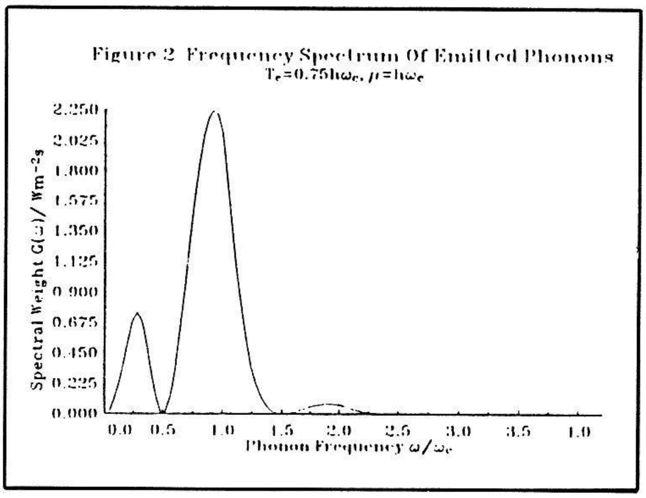

Figure 2 Frequency Spectrum Of Emitted Phonons

temperatures the fundamental ($\delta n = 1$) inter-Landau level transitions dominate. Higher harmonic phonon generation is suppressed by the $\mathbf{q}$ dependence of the matrix elements for such transitions so that the fundamental always dominates.

An experiment to investigate this spectrum is in progress [4] which utilizes the fact that the isotopic impurities in the Si lattice act as a low pass filter for ballistic phonons with frequencies below $\sim$ 1200GHz ($\omega_c = \omega_{cutoff}$ at $B \sim 8T$). The expected dependence of the fraction of the emitted phonon power which is transmitted ballistically α as a function of magnetic field at fixed electron temperature and sheet density is shown here. As can be seen below $8T$ almost all of the emitted power is transmitted but as ω_c becomes greater than the cutoff frequency the cyclotron phonons become strongly scattered and only the phonons from intra-Landau level processes in the 2deg are transmitted hence the transmitted fraction drops to a low value.

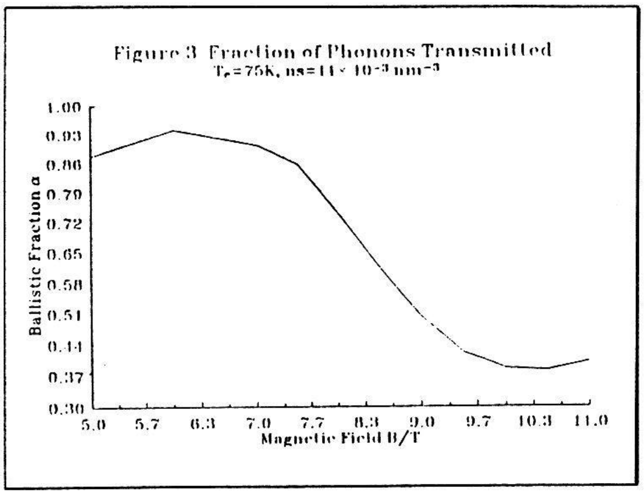

Figure 3 Fraction of Phonons Transmitted

References

[1] Challis LJ, Kent AJ and Rampton VW, Semiconductor Science and Technology, **6**, 1197 (1990)

[2] Benedict KA, J Phys Condensed Matter, **3**, 1279 (1991)

[3] Ando T, Matsumoto Y and Uemura Y, J Phys Soc Jpn, **39**, 279 (1975)

[4] Cooper J, Ouali F and Challis LJ, in preparation