

About the shortcomings of using Fang–Howard electron wavefunctions for phonon emission rate calculations in single heterostructures

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When calculating the electron–phonon matrix elements in GaAs/AlGaAs single heterostructures or Si inversion layers the use of Fang–Howard (FH) or other trial electron wavefunctions in the overlap integrals and form factors is a common practice. But up to now there has not been a detailed study, if such an approximation by a trial wavefunctions is an adequate method to explain the effects of angle resolved phonon emission or phonon drag. In particular, despite the large progress during recent years, there are still unexplained differences between the measured and theoretical predicted results of the ratio of emitted longitudinal acoustic (LA) phonons to transverse acoustic (TA) phonons in the case of a (quasi-) two-dimensional electron gas (2DEG).

Therefore we calculated the angular dependence and mode distribution of the acoustic phonon emission by a hot (quasi) 2DEG in a GaAs/AlGaAs heterojunction including the effects of acoustic anisotropy and screening in the usual way with the help of FH–wavefunctions and compared the results to a model, where we used the more exact Airy-functions in the overlap integrals and form factors.

As a general result we find a underestimation of the phonon emission rate for both LA and TA phonon modes within the FH–model. This is a consequence of the slower decrease of the FH–wavefunction leading to a faster drop of the overlap integral with increasing phonon wavevector.

More interesting is the situation for phonon emission close to the normal of 2DEG, particularly relevant for most of the experiments of angle resolved phonon emission. Not only, that the difference in the results between the two models is here more significant (up to a factor 3.5 for the considered electron densities below $5 \times 10^{15} \text{m}^{-2}$), in contrast to the total phonon emission rate we find also the larger changes for the TA phonon modes.

Both corrections compared to the FH model, the higher overall emission rate and the reduced LA/TA–ratio for emission close to the normal of 2DEG, are in good agreement with the experimental observations.