Confinement and amplification of terahertz acoustic phonons in cubic heterostructures.

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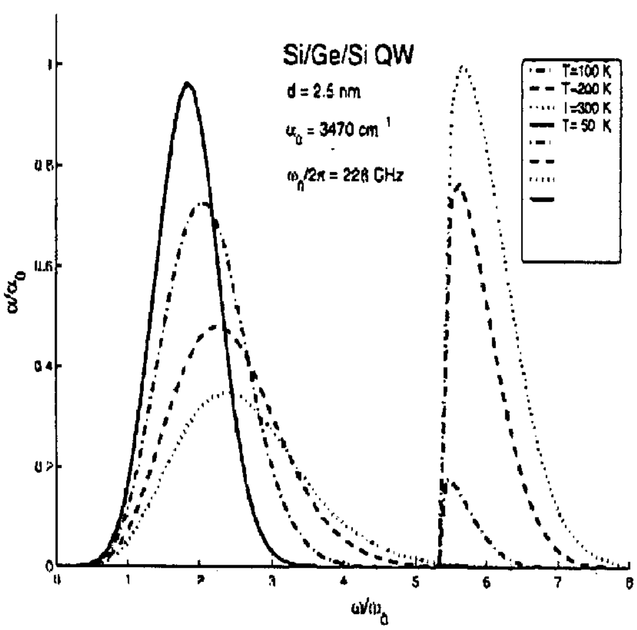
Recently, it was suggested that confined high-frequency phonons (CHFPs) can be amplified by the drift of two dimensional electrons [1]. Realization of this effect would open up new perspectives for the electric generation of coherent CHFPs.

In Ref. [1] CHFPs were studied for the case of a simple model of *elastically-isotropic* media. In this work, we use the model of *elastically-anisotropic (cubic)* media for the layers constituting the heterostructure. The results are applied to $Si/Si_{1-x}Ge_x/Si$ and AlAs/GaAs/AlAs QW heterostructures. We calculate the dispersion curves for the confined phonons. For all structures analyzed we show that the lowest-order phonon branches behave quite differently from those in the model of isotropic media. We have studied the displacement fields corresponding to these phonons and discovered their complex internal structure. In the terahertz frequency range, these phonons are almost confined inside the QWs. The results support the experimental observation [2] of the reduction of the dimensionality of acoustic phonons efficiently coupled to the two-dimensional holes in Ge-base quantum wells.



For p-Si/SiGe/Si and n-AlAs/GaAs/AlAs quantum well heterostructures, we have studied the effect of amplification of the CHFPs by the drift of low-dimensional carriers. Two mechanisms of electron-phonon interaction were taken into account: the deformation potential (SiGe and AlGaAs) and the piezoelectric interaction (AlGaAs). Both existing types of the CHFPs, shear-vertical and shear horizontal phonons, were studied. It was found that the amplification coefficient of the order of hundreds of cm^{-1} for the AlGaAs heterostructures and thousands of cm^{-1} for the SiGe (see the Figure) heterostructures in the terahertz phonon frequency range.

[1] S. M. Komirenko et al., Appl. Phys. Lett., v. 76, n. 14, 1869 (2000); Phys. Rev. B 62, n. 11, 7459 (2000). [2] S. H. Song et al., Appl. Phys. Lett. 70, 3422 (1997).