Tunable Broadband Acoustic Gain in Piezoelectric Semiconductors at ε-Near-Zero Response

Piezoelectric semiconductors have emerged as materials capable to amplify sound waves when electrons are set to drift at supersonic speeds. Several experiments have demonstrated this behaviour at moderate amplification levels for some intrinsic semiconductors and carrier concentrations. On a theoretical basis we show that amplification of sound can be significantly enhanced when the materials are operated close to the plasma frequency. If the drifting carriers collectively oscillate with the plasma the electromechanical coupling is enhanced since the permittivity is related inversely proportional to the mechanical stress and vanishes near the bulk plasma frequency. By optically or electrically doping GaAs and InSb as exemplified in this work, we predict that amplification of sound can be achieved effectively for a bandwidth exceeding several decades making this active system very attractive for loss-compensation in metamaterials and applicable for sensing such as nonlinear devices. The paper contains a detailed derivation and discussion of transmission and reflection coefficients for pressure pulses impinging on a semiconductor slab and the acoustic gain enhancement that can be achieved by dynamic switching of the electric field as well as tuning flexibility through dynamic control of the carrier density.