Wave excitations of drifting two-dimensional electron gas under strong inelastic scattering

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We have analyzed low-temperature behavior of two-dimensional electron gas in polar heterostructures subjected to a high electric field. When the optical phonon emission is the fastest relaxation process, we have found existence of collective wave-like excitations of the electrons. These wave-like excitations are periodic in time oscillations of the electrons in both real and momentum spaces. The excitation spectra are of multi-branch character with considerable spatial dispersion (see Figure). There are one acoustic-type and a number of optical-type branches of the spectra. Their small damping is caused by quasi-elastic scattering of the electrons and formation of relevant space charge. Also there exist waves with zero frequency and finite spatial periods - the standing waves. The found excitations of the electron gas can be interpreted as synchronous in time and real space manifestation of well-known optical-phonon-transient-time-resonance.

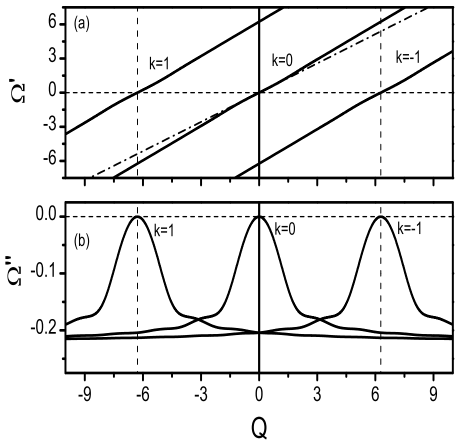

Figure 1: Real (a) and imaginary (b) parts of the dimensionless frequency as functions of the dimensionless wavevector for three branches of the dispersion relation at an electric field corresponding to the streaming regime. Dash-dotted line is for $\Omega' = V_{dr}Q$, V_{dr} is the drift velocity of the electrons. The vertical dashed lines mark wavevectors equal to $Q = \pm 2\pi$. Note that the vertical scales in (a) and (b) are very different.

Estimates of parameters of the excitations for two polar heterostructures, GaN/AlGaN and ZnO/MgZnO, have shown that excitation frequencies are in THz-frequency range, while standing wave periods are in sub-micrometer region. As an example, for AlGaN/GaN heterostructures at T = 50..100 K, the results shown in the Figure correspond to an applied field $\approx 14\, kV/cm$; the frequency of the lowest optical-like branches at $q \to 0$ is found to be $1.5 \times 10^{13} s^{-1}$, its damping equals $6 \times 10^{11} s^{-1}$. Undamped standing waves are realized for a wavevector equal to $\pm 9.4 \times 10^{5} cm^{-1}$.