Magnetized Plasma in Polar Semiconductors

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Plasma excitations in solids have been intensively studied already at the time of the 1960’s. A significant interest was focused on doped polar semiconductors. In these systems, the nowadays text-book effect of coupling between plasmons and optical phonon modes can be clearly observed as demonstrated, for example, by the pioneering work of Mooradian and Wright [1] on inelastic light scattering in n-type GaAs samples.

The properties of a plasma subjected to a static magnetic field are significantly modified. A magnetic field $B$ applied to a metallic system introduces a characteristic frequency, namely the cyclotron frequency $\omega_c = eB/m$ of motion of the carriers (with an effective mass $m$) in the plane perpendicular to the field direction. In polar-semiconductor plasmas, by changing the magnetic field the cyclotron frequency $\omega_c$ can be made comparable to all important frequencies of the system, namely the plasma frequency $\omega_p$ and the frequencies of longitudinal (LO) and transverse (TO) optical phonons. The physics of coupled plasmon phonon modes under these particular and interesting conditions has never been fully explored in Raman scattering experiments in 3D systems. On the other hand, there exist a number of works, concerning both Raman scattering and far-infrared magneto-spectroscopy which address the issue of coupling between the electronic and phonon excitations in two-dimensional semiconductor structures. The physics of low energy excitations in these structures is far more complex because of the modification of the energy spectrum due to effects of spatial confinement.

The results of high-magnetic-field (up to 28T) inelastic light scattering studies on coupled plasmon-LO-phonon modes in bulk, degenerate n-type GaAs will be presented. [2] The data analysis implies the use of a standard dielectric function approach. Results obtained for samples with high electron concentration are well understood. A strong interaction of coupled LO-phonon-plasmon modes with the collective cyclotron resonance excitations (Bernstein modes) is observed. In samples with lower electron concentration, an unexpected Raman scattering signal in the vicinity of the undressed optical phonon is observed at high magnetic fields. A field induced metal-insulator transition is shown to be observable in Raman scattering experiments in samples with lowest electron concentration. The plasmon-phonon modes which are characteristic of the metallic state are replaced by intradonor excitations in the case of the insulating state. It is very interesting, that the resonant magnetopolaron effect reflecting the interaction between the LO phonon and the 1s-2p intradonor excitation is observed in the insulating state but no coupling between LO-phonon and cyclotron resonance excitations is seen in the metallic state. This result allows us to discuss some aspects of an apparent controversy existing in two-dimensional systems regarding the fundamental problem of Fröhlich interaction: whether it manifests itself as a resonant repulsion between the cyclotron resonance and LO-phononlike modes for a two-dimensional electron gas, or not.