Comment on "Magneto Infrared Absorption in High Electron Density GaAs Quantum Wells"

In a recent Letter [1] Poulter *et al.* studied cyclotron resonances (CR) of high density and high mobility electron space-charge layers in thin GaAs quantum wells in Faraday geometry at frequencies covering the GaAs reststrahlen regime. No coupling of the CR to the bulk longitudinal-optical (LO) phonon was observed, and from weak shifts of the CR position and a simultaneously observed enhanced line broadening occurring close to the transverse-optical (TO) phonon frequency they deduced that the CR instead couples to a collective magneto-plasmon-phonon mode. We argue that the evidence for such a coupling is not convincing and criticize that the collective charge-density excitations of the quasi-two-dimensional electron systems (Q2DES) were discussed with reference to a model appropriate only for bulk systems. Such an approach even being considered as tentative cannot be justified since the collective modes of Q2DES and the bulk differ significantly. The collective modes of Q2DES represent surface-type waves that can be distinguished as intersubband and intrasubband plasmons with dispersions depending on a wave vector transfer $\mathbf{q}$ parallel to the layer plane. If a magnetic field is applied perpendicular to the layer plane the intrasubband excitation is commonly referred to as a magneto plasmon. In the limit of vanishing wave vector the magneto-plasmon frequency approaches the CR frequency; i.e., one can consider the CR as the $\mathbf{q} \rightarrow 0$ limit of the magneto-plasmon excitation. A coupling of the CR to the magneto plasmon at finite $\mathbf{q}$ is a higher order effect and allowed only in case of an appropriately perturbed electron system [2]. It is not allowed by momentum conservation for sufficiently clean electron systems, i.e., the high mobility samples studied here. The intersubband plasmon resembles collective transitions between subbands arising from the confinement perpendicular to the layer plane. In Faraday geometry the intersubband plasmon cannot couple to the CR. This is due to the fact that in GaAs the parallel and perpendicular motions are well decoupled, so that a current excited in the layer plane will not simultaneously induce a current perpendicular to it. In the presence of appropriate longitudinal optical phonons the intrasubband and intersubband plasmons will form coupled plasmon-phonon modes [3]. However, the coupling of the CR to the intersubband plasmon phonon as suggested by Poulter *et al.* does not provide an explanation for the absence of a resonant polaron effect at the bulk LO phonon frequency. The magneto-plasmon-phonon mode with frequency close to the one of the GaAs TO phonon derived by Poulter *et al.* by applying an inappropriate bulk model does not exist for Q2DES. In the $\mathbf{q} \rightarrow 0$ limit the mode frequencies of the intersubband plasmon coupled to bulk LO phonons are given by

$$\omega_{\pm}^2 = \tfrac{1}{2}\Big[\omega_{\rm LO}^2 + \tilde{\omega}_{10}^2 \pm \sqrt{(\omega_{\rm LO}^2 + \tilde{\omega}_{10}^2)^2 - 4\omega_{10}^2(\omega_{\rm LO}^2 + \gamma_{10}\omega_{\rm TO}^2)}\Big], \tag{1}$$

where $\tilde{\omega}_{10} = \omega_{10}\sqrt{1+\gamma_{10}} > \omega_{10}$ and ω_{10} are the intersubband transition frequency and subband separation from the ground to the first excited subband, respectively. Subband separations are, respectively, 65 and 105 meV for the 13 and 10 nm wide quantum wells; i.e., they are much larger than the LO phonon energy $\hbar\omega_{\rm LO}$. Consequently the intersubband plasmon-phonon modes will have frequencies close to $\omega_{\rm LO}$ and $\tilde{\omega}_{10}$. There will be no mode with a frequency close to or even below the one of the TO phonon. The absence of a CR splitting at the bulk LO phonon frequency could simply mean that the resonant polaron coupling is quenched. It is well known that screening, the population effect, and the finite width of the space-charge layer can reduce the polaron coupling. A further reduction can be expected from the electron-electron interaction coupling of the transitions between the Landau levels [4]. On the other hand, one can certainly question the meaning of a bulk LO phonon for a thin quantum well. In a more complete treatment of the polaron coupling as well as the collective modes instead confined and interface phonons should be considered. The interplay of confined and interface phonons in the polaron coupling is certainly not well understood yet. However, previous CR experiments performed on thin quantum wells suggest that an important contribution arises from interface phonons [5]. The resonant polaron coupling in Q2DES is a complex subject that demands a sophisticated analysis including also possible influences of optical origin [6]. Presently, there is no compelling evidence for the coupling of the CR to a collective mode.

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