Do Free Carriers Influence Polariton Scattering Intensities in GaAs?

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An influence of free carriers in GaAs on polariton scattering intensities is shown to take place due to two mechanismus: a) The altered LO-phonon frequency changes the electrooptic coefficient and b) the macroscopic electric field becomes changed. Both quantities influence the scattering intensities.

It has been shown recently that light scattering intensities of polaritons in undoped GaAs may be verified theoretically with an accuracy of $\lesssim 6\%$ error [1]. This rather high accuracy could be achieved because in diatomic crystals the uncertain quantity ε_∞ (= "high frequency dielectric constant") can be eliminated explicitely by the measured LO-phonon intensity data. The experiments showed that the most severe variations of polariton scattering intensities were recorded for $k > 10^4\ \mathrm{cm}^{-1}$, a k-region where the polariton frequency shifts still remain smaller than the half widths of the Raman lines. The high sensitivity of the susceptibility $\chi(\omega)$ with respect to frequency shifts suggests the question whether free carriers influence χ in a similar way.

It is well known that in doped GaAs the $k=0$ LO-phonon frequency ω_L is raised [2]

$$\omega_L{}^* = \tfrac{1}{2}(\omega_P{}^2 - \omega_L{}^2) + \sqrt{\tfrac{1}{4}(\omega_P{}^2 + \omega_L{}^2)^2 - \omega_P{}^2\,\omega_T{}^2}\,. \quad (1)$$

ω_P denotes the plasma frequency which explicitely contains the concentration n of free carriers. The frequency shift $(\omega_L{}^* - \omega_L)$ can be measured by e.g. IR-spectroscopy in order to determine n. The transverse polariton dispersion branch furthermore does not end up at $\omega = 0$ but at the finite frequency

$$\omega_T{}^* = \tfrac{1}{2}(\omega_P{}^2 - \omega_L{}^2) - \sqrt{\tfrac{1}{4}(\omega_P{}^2 + \omega_L{}^2)^2 - \omega_P{}^2\,\omega_T{}^2}\,. \quad (2)$$

In a first approximation we only regard the distortion of polariton scattering intensities for ω very close to the TO-phonon frequency ω_T. The altered shape of the dispersion curve according to Eq. (2) then can be neglected. This implies that in the formula for the susceptibility [1]

$$\chi(\omega) = a\,\vec{Q}(\omega) + b\,\vec{E}(\omega) \quad (3)$$

the macroscopic electric field $\vec{E}(\omega)$ still is regarded as identical to that in the undoped crystal. The electrooptic coefficient b, however, becomes changed. b can be determined experimentally from

$$b = [a \pm |\chi(\omega_L{}^*)|] \cdot \sqrt{\varepsilon_\infty / 4\pi(\omega_L{}^{*2} - \omega_T{}^2)} \quad (4)$$

where $|\chi(\omega_L{}^*)|^2$ represents the scattering intensity of the frequency shifted LO-phonon.

In a more rigorous treatment also the electric field in Eq. (3) has to be recalculated by means of the new polariton group velocities. They are determined easily from the modified dispersion relation. When using $\varepsilon(\omega)$ as given by [2] it follows

$$E(\omega) = \sqrt{4\pi}\,\omega\,E_0\,[\varepsilon(\omega) + (\varepsilon_0 - \varepsilon_\infty)\,\omega^2\omega_T{}^2 / (\omega_T{}^2 - \omega^2)^2 + \varepsilon_\infty\,\omega_P{}^2\left(1 + i\,\frac{\omega_0}{2\omega}\right)\Big/(\omega + i\omega_0)^2]^{-\frac{1}{2}}\,. \quad (5)$$

This formula replaces Eq. (6) in Ref. [1] when free carriers are present in the material.

Thus there are two well defined mechanisms via which free carriers influence polariton scattering intensities. The observed high sensitivity of $|\chi|$ with respect to ω near the TO-phonon frequency [1] suggests that also polariton intensities should be checked in order to obtain quantitative information on the concentration of free carriers in GaAs — and of course suitable other III—IV semiconductors.

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[1] M. Nippus and R. Claus, Z. Naturforsch. **32a**, 731 (1977).

[2] C. K. N. Patel and R. E. Slusher, Phys. Rev. Letters **22**, 282 (1969).