Zeitschrift: Helvetica Physica Acta

Band: 65 (1992)

Heft: 2-3

Artikel: Resonant Raman scattering in quantum wells under high magnetic fields

Autor: Cros, A. / Cantarero, A. / Trallero-Giner, C.

DOI: https://doi.org/10.5169/seals-116428

Resonant Raman Scattering in Quantum Wells under high magnetic fields.

A. Cros, A. Cantarero, C. Trallero-Giner* and M. Cardona*

Dept. de Física Aplicada, Universitat de València, Burjassot, E-46100 València, Spain

* *Max-Planck-Institut für Festkörperforschung, Heisenbergstraße 1, D-7000 Stuttgart 80, FRG*

Abstract. The effect of high magnetic fields on the one-phonon resonant Raman scattering in III-V semiconductor quantum wells (QW's) has been studied. The theory gives the Raman efficiency as a function of the QW thickness, laser energy or magnetic field. Selection rules for deformation potential and Fröhlich interaction are deduced.

Introduction.

Resonant Raman scattering under high magnetic fields has allowed the exploration of the conduction and valence band structure of semiconductors as has been recently shown in bulk III-V compounds.[1] The complicated structure of the Raman profiles due to the valence band mixing typical of III-V semiconductors increases significantly in a QW due to the fact that phonons can couple different subbands. Recent experimental results on a 100Å GaAs/AlAs-MQW show that analyzing the Raman data as a function of the magnetic field (B) double resonances notably simplify the Raman profiles.[2] We present here a theoretical model that allows us to understand the complexity of the Raman profiles and the appearance of double resonances.

Theoretical model.

The scattering efficiency per unit crystal length and solid angle with creation of a phonon of frequency ω_0 is given by:[2]

$$\frac{dS}{d\Omega} = \frac{\omega_l \omega_s^3 n_l n_s^3}{(2\pi)^2 c^4} \frac{V}{(\hbar\omega_l)^2} \left| \sum_{\mu,\beta} \frac{< F|H_{ER}|\mu >< \mu|H_{EP}|\beta >< \beta|H_{ER}|I >}{(\hbar\omega_s - E_\mu + i\Gamma_\mu)(\hbar\omega_l - E_\beta + i\Gamma_\beta)} \right|^2 , \quad (1)$$

where n_l (n_s) and ω_l (ω_s) are the refractive index and frequency of laser (scattered) light, c is the speed of light, $V = L^2 d$ the volume of the QW, $|\mu >$ ($|\beta >$) refers to the intermediate uncorrelated electron-hole pair state, E_μ (E_β) and Γ_μ (Γ_β) being their corresponding energy and lifetime broadening. H_{ER} and H_{EP} are the electron-radiation and electron-phonon interaction Hamiltonians. The basic Hamiltonian of our system is given by the bulk Hamiltonian plus the QW potential. The heavy-light valence band admixture has been taken into account through a 4×4 Luttinger Hamiltonian. The eigenfunctions of our physical problem are:

$$\Psi_{n,l} = \frac{1}{L} e^{ik_{ye}y} \phi_l(z) u_n(x - x_0) c \quad (2)$$

for electrons, where u_n is the harmonic oscillator wavefunction, c the Bloch function, and ϕ_l the electron wave function. For the holes we have:

$$\vec{\Psi}_{\alpha,n} = \frac{1}{L}\begin{pmatrix} e^{ik_{y1}y}\phi_1^{\alpha,n}(z)u_{n-3}(x-x_0)v_1 \\ e^{ik_{y2}y}\phi_2^{\alpha,n}(z)u_{n-1}(x-x_0)v_2 \\ e^{ik_{y3}y}\phi_3^{\alpha,n}(z)u_{n-2}(x-x_0)v_3 \\ e^{ik_{y4}y}\phi_4^{\alpha,n}(z)u_{n}(x-x_0)v_4 \end{pmatrix} . \tag{3}$$

The Bloch functions v_i are $|\frac{3}{2},\frac{3}{2}>$, $|\frac{3}{2},-\frac{1}{2}>$, $|\frac{3}{2},\frac{1}{2}>$, $|\frac{3}{2},-\frac{3}{2}>$ for $i = 1,4$. The $\phi_i^{\alpha,n}$'s are linear combinations of the QW functions and are chosen to be zero for $n < 0$. The Raman scattering efficiency has been calculated using Eqs. (1) to (3) and H_{EP} for the deformation potential (DP) and Fröhlich (F) interactions. From this calculation, the corresponding selection rules have been derived. In Figs. 1 and 2 we present the results obtained in the $\bar{z}(\sigma^+,\sigma^-)z$ and $\bar{z}(\sigma^+,\sigma^+)z$ configuration. The energy levels have been clasified according to their heavy or light hole character in the $B \to 0$ limit.[2]

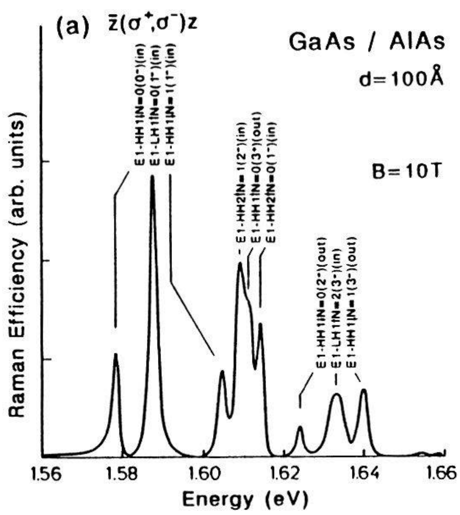

Fig. 1. dS/dΩ as a function of energy via DP

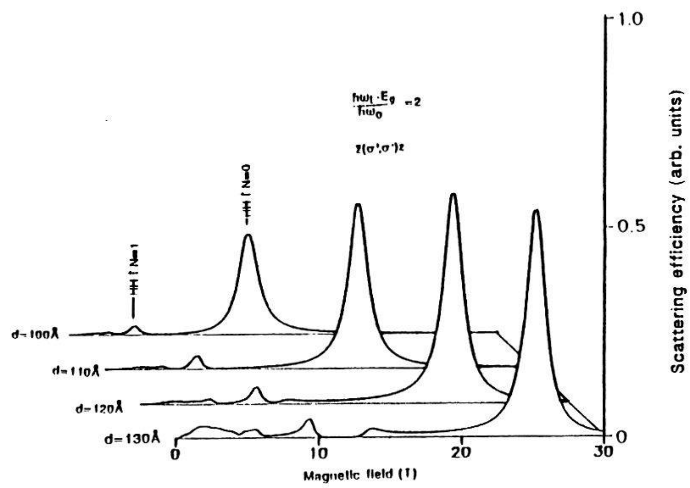

Fig. 2. dS/dΩ as a function of B via F without HH-LH admixture

Conclusions.

A theory of one-phonon Raman scattering in QW's which incorporates the effect of a magnetic field has been developed. It is shown that the Raman scattering efficiency increases with the magnetic field as B^2 while it varies as d^{-2} with the well thickness. The mixing of the heavy and light hole valence bands influences strongly the Raman scattering profile.

References

1. T. Ruf, R. T. Phillips, A. Cantarero, G. Ambrazevičius, M. Cardona, J. Schmitz, and U. Rössler, Phys. Rev. B **39**, 13 378 (1989), and references therein.

2. A. Cros, A. Cantarero, C. Trallero-Giner, and M. Cardona, unpublished.