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## Resonant Raman Scattering in Quantum Wells under high magnetic fields.

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**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.<sup>1</sup> 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.<sup>2</sup> 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  $\omega_0$  is given by:<sup>2</sup>

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

where  $n_l$  ( $n_s$ ) and  $\omega_l$  ( $\omega_s$ ) 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,  $|\mu\rangle$  ( $|\beta\rangle$ ) refers to the intermediate uncorrelated electron-hole pair state,  $E_\mu$  ( $E_\beta$ ) and  $\Gamma_\mu$  ( $\Gamma_\beta$ ) 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  $4 \times 4$  Luttinger Hamiltonian. The eigenfunctions of our physical problem are:

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

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

$$\vec{\Psi}_{\alpha,n} = \frac{1}{L} \begin{pmatrix} e^{ik_y 1y} \phi_1^{\alpha,n}(z) u_{n-3}(x-x_0) v_1 \\ e^{ik_y 2y} \phi_2^{\alpha,n}(z) u_{n-1}(x-x_0) v_2 \\ e^{ik_y 3y} \phi_3^{\alpha,n}(z) u_{n-2}(x-x_0) v_3 \\ e^{ik_y 4y} \phi_4^{\alpha,n}(z) u_n(x-x_0) v_4 \end{pmatrix}. \quad (3)$$

The Bloch functions  $v_i$  are  $|\frac{3}{2}, \frac{3}{2}\rangle$ ,  $|\frac{3}{2}, -\frac{1}{2}\rangle$ ,  $|\frac{3}{2}, \frac{1}{2}\rangle$ ,  $|\frac{3}{2}, -\frac{3}{2}\rangle$  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 classified according to their heavy or light hole character in the  $B \rightarrow 0$  limit.<sup>2</sup>

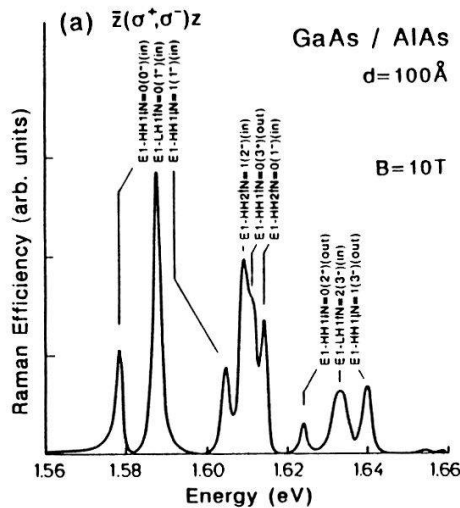


Fig. 1.  $dS/d\Omega$  as a function of energy via DP

## 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

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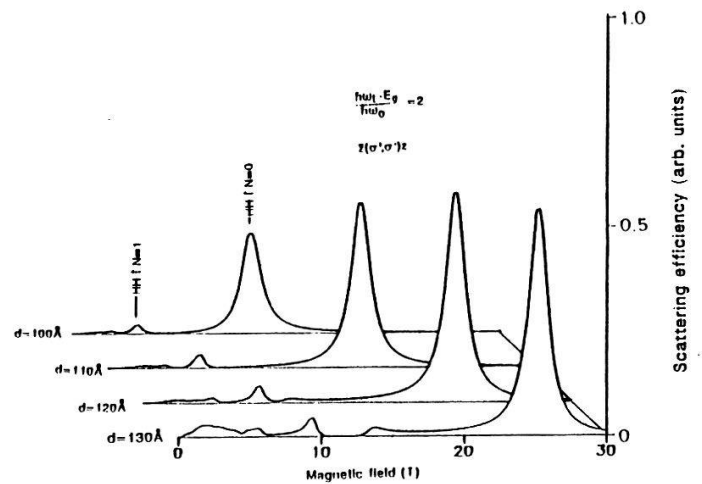


Fig. 2.  $dS/d\Omega$  as a function of  $B$  via F without HH-LH admixture