Spin-flip Raman scattering of electron and heavy-hole in CdTe quantum well enabled by anisotropic exchange

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The dynamics of carrier spins in low-dimensional semiconductor structures attract remarkable interest due to the possibilities of spin storage and transfer and related information processing. For spin electronic and quantum information applications, understanding of the fundamental interactions between confined carrier spins is essential, since these interactions may limit information handling due to spin relaxation. An essential interaction between two confined carrier spins is the exchange interaction arising from the carrier-carrier Coulomb interaction. The exchange interaction can be divided into isotropic and anisotropic contributions. While the isotropic exchange conserves the total spin of both carriers involved, the anisotropic one leads to spin relaxation. In that context, relaxation due to electron-hole exchange and due to exchange interaction between identically charged carriers need to be considered. The effect of anisotropic exchange interactions between an exciton and a resident electron or hole localized by potential fluctuations in a quantum well (QW) has not been addressed in detail yet.

We report on the experimental study of spin-flip Raman scattering (SFRS) in a $CdTe/Cd_{0.63}Mg_{0.37}Te$ QW [1]. The Raman scattering processes of the electron and heavy-hole spins are compared for resonant excitation of the neutral as well as positively and negatively charged excitons. We demonstrate that the spin-flip scattering of a single electron or hole in a neutral exciton becomes allowed when the exciton symmetry is reduced. As a result of the lifting of the angular momentum conservation, electrons and/or holes can mutually interact via anisotropic exchange. Also, a magnetic field tilted with respect to the QW growth axis can provide an electron- or a hole-SFRS process. The scattering via an acoustic phonon or isotropic exchange supports the symmetry-breaking in order to fulfill the required energy conservation. Variations in the resonant excitation energy and lattice temperature demonstrate that localization of resident electrons and holes controls the Raman process probability and is also responsible for symmetry reduction. We show that the intensity of the electron spin-flip scattering is strongly affected by the lifetime of the exciton complex and in tilted magnetic fields by the angular dependence of the anisotropic electron-hole exchange interaction.

[1] J. Debus, D. Dunker, V. F. Sapega, et al., arXiv:1301.3108 (2013).