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Polarization of magnetopolaritons in a semiconductor microcavity

M. D. Martín[1], **S. Burgas**[1], **M. Alonso**[1], **L. Viña**[1], **F. J. Terán**[2], **M. Potemski**[2], **and E. E. Mendez**[3]

[1] Dpt. Física de Materiales, Universidad Autónoma de Madrid, E-28049 Madrid, Spain
[2] GHMFL, MPI/FKF & CNRS, 25 Av. Des Martyrs, F-38402 Grenoble, France
[3] Dpt. of Physics and Astronomy, SUNY at Stony Brook, N. Y. 11794-3800, USA

Abstract We have studied, by means of low temperature polarization-resolved photoluminescence, the influence of an external magnetic field on the spin properties of microcavity polaritons. Both, Faraday and Voigt configurations have been used. Our results reveal the robustness of the spin alignment in semiconductor microcavities.

Introduction

The optical properties of semiconductor quantum well (QW) microcavities have been the subject of an intense effort in the last decade. These systems offer the possibility of controlling the strength of the radiation-matter interaction since both, excitons and photons, are spatially confined inside them. Although exciton polaritons were postulated in the 60's [1], they were not experimentally observed until 1992 [2]. After the pioneering work of Weisbuch et al., polariton dispersion [3], saturation [4] and recombination dynamics [5] have been reported. More recently, there have been several reports on the optical properties of microcavity polaritons under an external magnetic field [6-8]. In most of these works, the magnetic field was applied in the Faraday configuration ($\vec{B} \parallel \vec{k}$) and the Zeeman shift of the photoluminescence (PL) of magnetopolaritons was studied. In the paper presented here, we concentrate on the spin polarization properties of magnetopolaritons considering both, Faraday and Voigt configurations. The analysis of the degree of polarization of the PL, defined as $\wp=(I^+-I^-)/(I^++I^-)$, where $I^{+/-}$ denotes the PL emitted with +1/-1 helicity, reveals the robustness of the spin in III-V semiconductor microcavities, in agreement with recent reports [9, 10].

Experimental details

The sample consisted of 3 GaAs coupled QWs of 42Å, separated by 17Å $Al_{0.25}Ga_{0.75}As$ barriers, that were placed in the antinode positions of a $3\lambda/2$ $Al_{0.25}Ga_{0.75}As$ microcavity. The microcavity was sandwiched between the top/bottom Bragg reflectors made of 20.5/24 pairs of alternating $AlAs/Al_{0.35}Ga_{0.65}As$ layers. The sample was mounted in a Helium bath cryostat and inserted in the core of a superconducting magnet. Magnetic fields up to 14 Tesla were applied. For the optical excitation of the sample, in the first reflectivity minimum after the stop-band of the mirrors (1.71 eV), the output of a tunable Ti:Sapphire laser was focused in an optical fiber. A linear polarizer and a $\lambda/4$ plate were placed at the end of this fiber. The PL emitted by the sample in both configurations, was analyzed into its σ^+ and σ^- components by means of a second pair of linear polarizer and $\lambda/4$ plate. A second optical fiber was used to collect the light. The experiments were carried focusing the excitation spot on a point of the sample characterized by a slight positive exciton-cavity detuning.

Experimental results and discussion

Voigt configuration

The PL spectra characteristic of the Voigt configuration are displayed in Figure 1, for zero (Fig. 1a) and 14 Tesla (Fig. 1b). Three lines can be observed in the spectra, which are labeled as A, X and C. The lines A and X have an excitonic character since their energies and intensities increase with increasing magnetic field. On the contrary, the high-energy side line (C), remains almost unaffected by the increase of the field, revealing its photonic character. Additionally, this assignment is confirmed by its energy shift when scanning the excitation spot across the sample. The energy of the line X corresponds to the exciton recombination in the QWs. This line shifts ~2 meV with increasing magnetic field

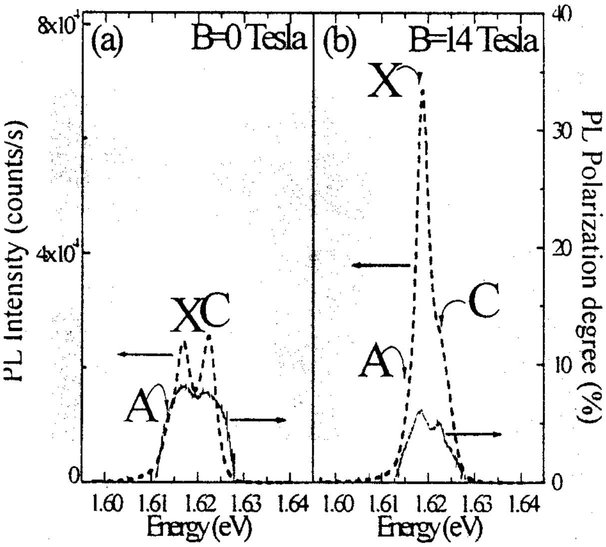

Fig. 1 Microcavity PL (dashed line) and polarization spectra (solid line) at (a) zero Tesla and (b) 14 Tesla. The magnetic field was applied in the Voigt configuration.

up to 14 Tesla. The field induced enhancement of the exciton oscillator strength leads to an increase of its intensity by a factor ~3. The line A has also an excitonic character, as inferred by its magnetic field dependence (similar to that of line X), and it is rigidly shifted by ~5 meV with respect to line X, independently of the field strength. This line A is tentatively attributed to the excitons confined in a thicker QW, due to a monolayer fluctuation.

The degree of polarization is relatively small (<10%), due to the non-resonant excitation. The Hanle effect is responsible of the field-induced reduction of the polarization degree of the PL. One can extract from an analysis of the decrease of the polarization with field, a spin-relaxation time. In our sample, the reduction is very small, what renders very difficult to extract accurate values for this time. However, our experiments reveal the stiffness of the spin orientation in microcavities, in agreement with recent reports [9, 10].

Faraday configuration

Characteristic PL spectra for the Faraday configuration are depicted in Figure 2. There are some evident differences between these spectra and those presented in Figure 1, which are related with the different geometry of the collection of light by the fiber inside the magnet. The three lines are more clearly resolved in the Faraday configuration. Line C does not shift with increasing magnetic field, giving a further experimental evidence of its photonic character. Lines A and X shift with increasing magnetic field due to the Zeeman effect. The energy shift amounts to ~4 meV for both lines. The enhancement of the exciton oscillator strength due to the shrinkage of the wave function into the QW leads to an increase in the emission intensity by a factor ~4. Although line A shifts ~4 meV with increasing magnetic field, it remains almost uncoupled of the cavity because their energy difference is too large.

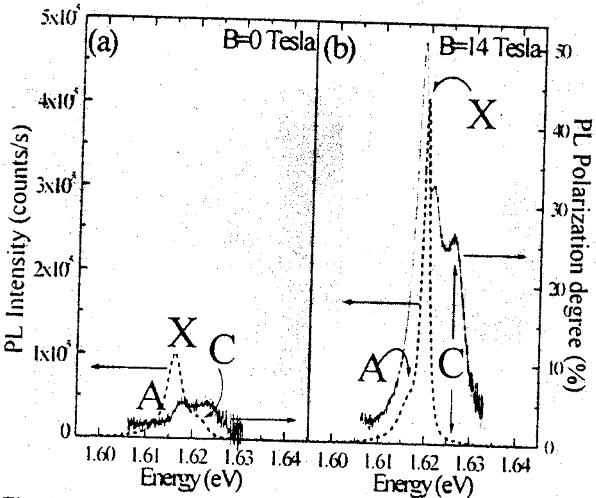

Fig. 2 Microcavity PL (dashed line) and polarization spectra (solid line) at (a) zero Tesla and (b) 14 Tesla. The magnetic field was applied in the Faraday configuration.

The magnetic field enhances the polarization of the PL, making the σ^- emission intensity much larger than that of the σ^+. The effect is observed for the three lines but it is noticeably larger for line A, whose polarization degree increases from <5% for zero Tesla to ~50% at 14 Tesla. This increase for the two polaritonic lines, X and C, is considerably smaller than that of line A: it changes from ~5% to ~35% and from ~5% to ~25% for lines X and C, respectively.

Conclusions

We have studied the influence of an external magnetic field on the optical properties of cavity polaritons. The PL spectrum has revealed the normal mode splitting between the exciton-like and the cavity-like polariton branches, and a third peak, attributed to excitons confined inside a thicker QW, due to a monolayer fluctuation.

The magnetic field in the Voigt configuration has only a little influence on the PL spectrum: a diamagnetic shift of ~2 meV is observed in the two excitonic peaks. The decrease of the polarization degree of the PL is so small that no accurate value for the spin relaxation time can be extracted. However, this fact confirms the stiffness of the spin orientation in microcavities.

In the Faraday configuration, the diamagnetic shift amounts to ~4 meV. The exciton is tuned into resonance with the cavity. The polarization degree of the PL increases considerably with increasing magnetic field, reaching values as high as 50%.

Acknowledgments

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