Theoretical Study of Polariton Dynamics in Semiconductor Microcavities

Abstract
This study is a small part of a larger research project with theory groups at the Chinese University of Hong Kong and the University of Paderborn, Germany, and an experimental group in Paris. The larger project aims to further our understanding of polariton pattern formation and control in semiconductor microcavities in the hopes that it will lead to the development of optical transistors and useful applications of the optical spin Hall effect. When light is pumped into a semiconductor microcavity and creates polaritons, their polarization changes due to the energy difference between the transverse magnetic(TM) and transverse electric(TE) energy states of a polariton. The polariton’s polarization can be expressed in terms of the polariton’s pseudospin. The steady state solution of the pseudospin was studied using two models. It was found that as $\gamma$, a decay factor for the polariton, increased, the polarization of TM polaritons and TE polaritons mixed, ruining the optical spin Hall effect.

Methods

Equation 1 A model for the pseudospin of a polariton

$\frac{d}{dt} S_k = -\hbar (B_k^0 × S_k) - \gamma (S_k + R × S_{ph})$

Figure 1 Experiment Setup (ref. 1)

Figure 2 A schematic of an exciton

Figure 3 A dispersion plot showing polariton scattering

Plots of equation 1 were made using the fourth-order Runge-Kutta method. The steady state solutions to the equation were calculated. The plots of equation 1 were analyzed to make sure it converged to these values. The steady state solutions of equation 1 were studied for the pumping of both left and right circularly polarized light. The polarization of TM and TE polaritons was calculated using equations from reference 2. These polarizations were studied as a decay factor of polaritons, $\gamma$, was varied.

Results

Figure 4 Contour plots of the steady state solutions of $S_y$ for the pumping of right circularly polarized(RCP) and left circularly polarized(LCP) light

Figure 5 A diagram showing the physical meaning of $\theta_y$ and $\theta_x$

Figure 6 Plots showing how $\theta_y$ and $\theta_x$ change with $\gamma$

Conclusion

The $S_y$ component of equation 2 of the pseudospin was studied in particular because it had the most physical meaning by showing if the light was primarily linearly polarized in the $x$-direction or $y$-direction. It was found from the plots in figure 4 that the maximums and minimums of $S_y$ rotated as the intensity of the pumping increased and that the maximums and minimums were in opposite locations for the pumping of RCP and LCP light. These results show the polarization distribution for different pumping magnitudes. It was also found from the plots in figure 6 that as a decay factor of the polariton, $\gamma$, increased the polarization of TM and TE polaritons mixed and their ellipticities increased, ruining the optical spin Hall effect.

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References

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