単一自己形成量子ドットにおける光検出電子スピン共鳴の解析

Analysis on Optically-detected Electron Spin Resonance in Single Self-Assembled Quantum Dots

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An electron spin trapped in a self-assembled quantum dot (QD) can form a robust qubit. Electron spin resonance (ESR) induced by radiation of microwave field has been utilized for coherent control and detailed analysis of the QD spin [1].Optically detected ESR in single QDs has been reported [2], in which the electron spin rotation is detected from the intensity of the resonance fluorescence signal. While this novel method provides an a faster alternative to electrical detection of electron spin, there were aspects of the results which were not fully understood in the previously-reported optical QD ESR models [3]. In this work, we attempt to perform a more comprehensive physical modeling of the optically-detected QD ESR by using a 4-level system expressing a negatively charge trion, X^-. In our numerical simulations, we reproduced the basic features of the optically detected ESR, together with the observation of possible effects of optical and microwave co-excitation, giving an additional peak in the ESR spectra.

Our model is developed in accordance to the experiments in ref. [2] which includes a coherent laser pump and a microwave excitation on a 4 level system, as shown in Fig 1(a). Numerically solving this model in the steady state, we managed to reproduce the basic features of an ESR experiment: the sharp resonant peak at zero microwave field detuning to the electron Zeeman splitting (Fig. 1(b)). We also find another peak with a broader resonance, at which the microwave field frequency corresponds to the sum of the electron and hole Zeeman splitting. As such it is suspected that the combined optical and microwave excitation could give rise to a multi-step excitation process leading to this additional ESR peak. Further simulations and experimental verification is required to understanding the peak properties and underlying mechanisms.

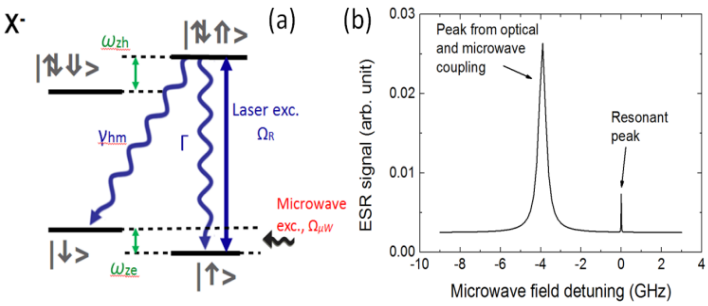

Fig. 1 (a) Schematic showing the 4-level system of an X^- (b) An exemplary ESR spectrum showing the resonant peak and peak from optical and microwave coupling (microwave field detuning is relative to the electron Zeeman splitting).

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