Excitation and tuning of spin resonance by an electric current in a Si quantum well

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We investigate the Zeeman splitting of the two-dimensional electron gas in an asymmetric silicon quantum well, performing electron-spin-resonance (ESR) experiments. Applying a small dc current we observe a shift in the resonance field due to the additional current induced Bychkov-Rashba (BR) type of spin-orbit (SO) field. We also show that a high frequency current may induce electric dipole spin resonance very efficiently. We identify different contributions to this type of ESR signal.

Both the Rabi frequency and the spin relaxation rate increase with increasing SO coupling. SO coupling in III-V compounds is by up to three orders of magnitude stronger than in Si. The Rabi frequency and the current to shift ratio scale linearly with SO interaction and the line width with the square of it. Therefore materials like Si are much better suited if a big shift-to-line width ratio of the ESR is needed. On the other hand, we expect an even higher efficiency for the current induced spin manipulation for III-V compounds.

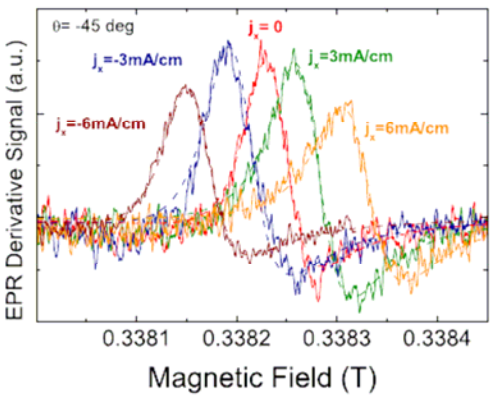

Fig. 1. ESR spectra of a 2DEG in a Si quantum well for various values of an electric current density passing a 3 mm wide sample. Measurements were performed at a microwave frequency of 9.4421 GHz.

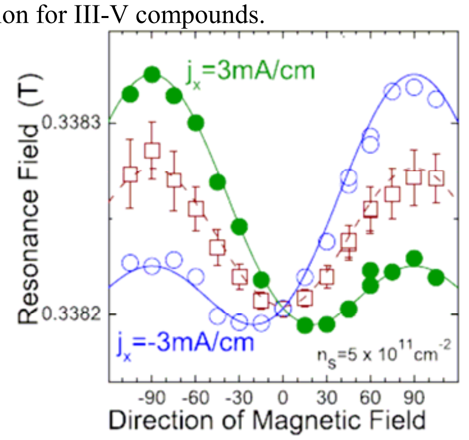

Fig. 2. Angular dependence of the ESR field for a current density j=0 (squares) and j=±3 mA/cm (open and full circles, respectively). The electron concentration is n_s=5 10^{15} m^{-2} and the sample width 3 mm.

The current induced shift of the spin resonance described in this paper is probably the most direct and conceptually simplest effect of SO interaction in solids. Moreover, the ratio of the g-shift and current density is ruled by the BR parameter and the carrier density only, but it is independent of temperature, electron mobility or details of spin relaxation.

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