Direct Observation of Optically Injected Spin-Polarized Currents in Semiconductors

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Abstract: Direct experimental evidence for the spin-polarization of optically injected ballistic spin currents by coherent one and two photon excitation in unbiased semiconductors is provided via the detection of a phase-dependent movement of the circularly polarized photoluminescence in ZnSe.

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The manipulation of carrier spins in semiconductors currently attracts great attention since it is a prerequisite to spintronics [1]. One of the main obstacles to the development of spintronics is the efficient and controlled injection of carrier spin currents. We present here experiments on the injection of fast, ballistic, spin-polarized electrons in an unbiased semiconductor. The generation of directed currents due to the preferential occupation of carriers in specific k-directions via quantum interference of one- and two-photon absorption has been theoretically and experimentally demonstrated [2]. Bhat and Sipe predicted [3] that the quantum interference of one- and two-photon absorption can, under suitable polarization and phase conditions, also lead to injection of *ballistic, spin-polarized* currents. We provide direct experimental evidence that indeed current directions as well as carrier spin orientations of optically excited electrons in unbiased semiconductors can be directly controlled via the relative phase and polarization of the excitation by two-color light fields of femtosecond laser pulses. We measure the phase dependent shift of the circularly analyzed photoluminescence (PL) of cubic ZnSe after cross-linearly polarized, coherent one- and two-photon excitation. ZnSe was chosen for practical reasons: a Ti:Sapphire laser can be used for two-photon excitation and its frequency-doubled mode for one-photon excitation, respectively. The sample is a 290 nm thick cubic ZnSe layer grown by molecular beam epitaxy on a GaAs. A differential technique with high spatial resolution is applied, since the movement of the spot for a given circular polarization in dependence of the phase relation is much smaller than the optical resolution. The results are shown in Fig. 1. The measured data are fitted with a sine function with the phase and amplitude as fit parameters. The period of the sine is fixed by the simultaneously recorded relative phase of the two laser fields (lower curve). The displacement of ± 6 nm is in reasonable agreement with the theoretically expected displacement of ± 9.5 nm, calculated for optimally balanced and aligned incident fields.

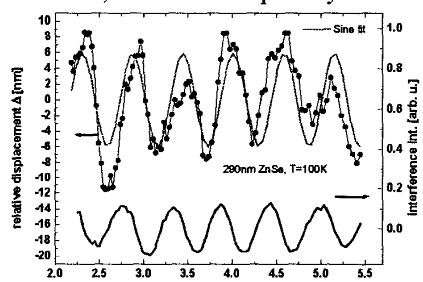

Fig. 2. Relative displacement Δ of the σ^+ and σ^- polarized PL spots (upper part) and the intensity coded relative phase dependence (lower part) as a function of the applied delay. The phase offset with respect to the lower curve is caused by dispersion of the ω and 2ω beam after passing the sample.

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