HL 3 Spintronik I

Zeit: Freitag 10:45–13:15 Raum: TU P164

HL 3.1 Fr 10:45 TU P164

A microscopic approach to semiconductor spin dynamics — •Christian Lechner and Ulrich Rössler — Institut für Theoretische Physik, Universität Regensburg, 93040 Regensburg, Germany

In recent years the spin degree-of-freedom of carriers in semiconductors and semiconductor heterostructures has become essential for the development of *spintronic* devices. For their realization the understanding of *spin relaxation* and *spin dephasing* is of central importance. The corresponding relaxation times have so far mostly been described by phenomenological models.

Here we present a microscopic theory of the spin dynamics with emphasis on spin-relaxation and -dephasing due to electron-phonon interaction. We use the *density matrix approach* known from the description of ultrafast carrier dynamics [1]. This scheme has been extended towards coherent spin dynamics using the Hartree-Fock truncation [2]. We go beyond this approximation by explicitly including the electron-phonon interaction on a microscopic level [3]. An extension of the equations of motion to entries of the phonon-assisted density matrix is required to account for scattering. They are treated in the Boltzmann-limit as well as beyond this limit leading to microscopic expressions for the spin relaxation times. Furthermore we give an analytical solution of the derived equations by applying the *Jaynes-Cummings model* [4].

[1] F. Rossi et al., Rev. Mod. Phys. **74** (2002).
[2] U. Rössler; phys. stat. sol. (b) **234** (2002).
[3] C. Lechneret al.; cond-mat/0407358v2 (2004).
[4] E.T Jaynes et al.; Proc. IEEE **51** (1963).

HL 3.2 Fr 11:00 TU P164

Zitterbewegung of electronic wave packets in semiconductor nanostructures — •John Schliemann[1], Daniel Loss[1], and R.M. Westervelt[2] — [1]University of Basel — [2]Havard University

We study the zitterbewegung of electronic wave packets in III-V zincblende semiconductor quantum wells due to spin-orbit coupling. Our results suggest a direct experimental proof of this fundamental effect, confirming a long-standing theoretical prediction. For electron motion in a harmonic quantum wire, we find a resonance condition maximizing the zitterbewegung. We also consider the zitterbewegung of heavy holes in quantum wells under the influence of Rashba spin-orbit coupling.

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Spin-double refraction in two-dimensional electron gas — •Vincenzo Marigliano Ramaglia[1], Dario Bercioux[1,2], Vittorio Cataudella[1], Giulio De Filippis[1], and Carmine Antonio Perroni[1] — [1]Coherentia-INFM and “Federico II” University of Naples, I-80126, Italy — [2]Institut für Theoretische Physik, Universität Regensburg, D-93040, Germany

Spin-double refraction [1] is observed in two-dimensional electron gas when electrons are injected with an angle out of normal on an interface separating a region without Rashba effect [2] from a region with it. The behavior of the electron spin in such scattering is analogous of the polarization of the light in a biaxial crystal.

This phenomenon can be used to realize a spin-field effect transistor [3] without ferromagnetic contact [4]. The source and the drain could be realized using n^+-semiconductors. The main characteristic of this device is that, fixed the injection angle, above a critical value of the Rashba effect, the transmission and the polarization behave in the same oscillating way [4].

[1] V. Marigliano Ramaglia, D. Bercioux, V. Cataudella, G. De Filippis,A.C. Perroni and F. Ventriglia, Eur. Phys. J. B **36** 365 (2003). [2] Yu A. Bychkov and E.I. Rashba, J. Phys. C: Solid State Phys. **17**, 6039 (1984). [3] S. Datta and B. Das, Appl. Phys. Lett. **56**, 665 (1990). [4] V. Marigliano Ramaglia, D. Bercioux, V. Cataudella, G. De Filippis and A.C. Perroni, cond-mat/0403534.

HL 3.4 Fr 11:30 TU P164

Spinrelaxation bei Anwesenheit eines elektrischen Feldes — •Olaf Bleibaum — Institut für Theoretische Physik, Otto-von-Guericke Universität Magdeburg, PF 4120, 39016 Magdeburg

Der Einfluss eines elektrischen Feldes auf die Spinrelaxation in einem Halbleiter mit Rashba-Wechselwirkung wird im Rahmen einer feldtheoretischen Formulierung studiert. Die Untersuchung zeigt, dass ein elektrisches Feld direkten Einfluss auf die Relaxationsrate und den Charakter der Relaxation hat. Überschreitet das Feld ein kritisches Feld, so führt es zu einer zusätzlichen Drehung der Magnetisierung, die mit Hilfe optischer Techniken leicht beobachtet werden könnte. In dem Beitrag untersuchen wir die Abhängigkeit der Rotationsfrequenz und des kritischen Feldes von den Materialparametern und der Stärke des elektrischen Feldes und studieren den Einfluss von Quantenkorrekturen auf die Relaxation.

HL 3.5 Fr 11:45 TU P164

First-principles studies of $Mg_xZn_{1-x}O$ alloys — M. Bouhassoune[1], A. Ernst[1], •J. Henk[1], P. Bruno[1], M. Däne[2], D. Ködderitzsch[2], and W. Hergert[2] — [1]MPI für Mikrostrukturphysik, Halle/S., Germany — [2]Martin-Luther-Universität Halle-Wittenberg, Halle/S., Germany

Recent research on O-based semiconductors (e. g., ZnO, MgO) suggested an enormous potential for applications in optics and electronics. One important parameter in device design is the width of the fundamental bandgap which, for example, determines the conductance of tunneling devices. One method to modify the band gap is alloying (‘bandgap engineering’). We report on a first-principles study of $Mg_xZn_{1-x}O$ for various concentrations x and crystal structures. The phase transition from the wurtzite (ZnO) to the rock-salt structure (MgO) was found at $x = 0.36$, i. e., close to the experimental value of $x_{\mathrm{exp}} = 0.4$. The fundamental band gap increases upon alloying of ZnO with Mg. Although its size is underestimated due to the local-density approximation, the trends in experiment are fully reproduced.

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Properties of a nondispersive Mn-3d band in $(Ga_xMn_{1-x})As$ — A. Ernst, L. M. Sandratskii, M. Bouhassoune, •J. Henk, and P. Bruno — MPI für Mikrostrukturphysik, Halle/S., Germany

The magnetic properties of Mn-based diluted magnetic semiconductors (DMS) depend significantly on the energy position of the Mn-3d levels. Recent photoemission experiments [1] reported on a nondispersive band at 0.3 eV binding energy in $(Ga_xMn_{1-x})As$ which was attributed to Mn impurities. The combination of low dispersion and small Mn-3d contribution makes the nature of this band puzzling. Hence, first-principles KKR-CPA calculations were performed for both Mn substituting Ga and for Mn in the interstitial in various magnetic configurations. A nondispersive band with the experimental binding energy shows up in the Mn-interstitial case, but does not in the pure substitutional alloy. It has Mn-3d character, and its low experimental intensity is explained by its low spectral weight. Further, its occurrence is robust against various magnetic configurations of the substitutional and the interstitial Mn atoms.

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HL 3.7 Fr 12:15 TU P164

Spin Transport and Manipulation by Dynamic Quantum Dots — •James A. H. Stotz, Rudolph Hey, Paulo V. Santos, and Klaus H. Ploog — Paul-Drude-Institut für Festkörperelektronik, Hausvogteiplatz 5-7, 10117 Berlin, Germany

We present a spatially resolved photoluminescence (PL) study of spin transport in confined geometries via a new form of quantum dots – denoted as dynamic quantum dots (DQDs). The DQDs are produced by the superposition of piezoelectric fields from surface acoustic waves (SAWs) propagating along orthogonal directions on a GaAs/(Al,Ga)As quantum well sample. Within the DQD array, spin polarized carriers are excited by circularly polarized laser light and captured by the DQDs. The carriers are then transported at a velocity determined by the SAWs, and the spin transport is detected by the circular polarization of the resulting PL. The photogenerated electrons and holes are spatially separated by the piezoelectric potential of the DQDs resulting in a dramatic increase of the spin-polarized PL signal and, conseqently, of the electron-spin lifetime. In addition, we demonstrate that the electron spins can be transported over distances exceeding 70 μm, which corresponds to a further increase in their spin lifetimes of more than an order of magnitude. These long spin lifetimes are attributed to the reduction of the D’yakonov-Perel’ spin scattering mechanism within the confinement potential of the DQDs. Futhermore, application of an external magnetic field enables the electron spin state to be manipulated during transport.

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Spin Transport by Surface Acoustic Waves in (110) GaAs Quantum Wells — •Yang Guang, Fernando Iikawa, Rudolph Hey, and Paulo V. Santos — Paul-Drude-Institut für Festkörperelektronik, Hausvogteiplatz 5-7, 10117 Berlin, Germany

The manipulation and transport of spins are critical steps towards the realization of novel, functional devices for information processing, quantum computing, and quantum cryptography. Recently, we have demonstrated that the piezoelectric field induced by a surface acoustic wave (SAW) can be applied to increase the lifetime of photogenerated spins and transport them in semiconductor quantum wells (QWs) [1]. One of the limitation of the SAW-induced spin transport is the rather slow acoustic propagation velocity, which requires very long spin lifetimes for large (i.e., several tens of μm) transport lengths. In this work, we demonstrate spin transport lengths approaching 20 μm in GaAs/(Al,Ga)As QWs grown along the [110] direction. The longer lifetimes and transport lengths under the SAW fields are attributed to the simultaneous quenching of the excitonic [2] and D'yakonov-Perel (DP) spin relaxation mechanisms in (110) QWs [3]. We further show that the spins can be manipulated during transport by applying a magnetic field perpendicular to the carrier propagation direction, thus opening the way for applications in quantum information processing.

[1] T. Sogawa *et al.*, Phys. Rev. Lett. **87**, 276601 (2001)
[2] M. Z. Maialle *et al.*, Phys. Rev. **B47**, 15776 (1993)
[3] Y. Ohno *et al.*, Phys. Rev. Lett. **83**, 4196 (1999)

HL 3.9 Fr 12:45 TU P164

Hybrid ferromagnet/semiconductor nanostructures on a cleaved (110) InAs surface: spin-valve effect and extraordinary magnetoresistance — •Andreas Wittmann and Dirk Grundler — Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg, Jungiusstrasse 11, D-20355 Hamburg, Germany

We present a novel design for a ferromagnet/semiconductor hybrid transistor. For this, a ferromagnetic film is deposited on a cleaved InAs/InGaAs heterostructure incorporating a two dimensional electron system (2DES). As no Shottky barrier is present we obtain an excellent Ohmic interface contact with a measured resistance close to the Sharvin resistance.

To separate the FM layer on the cleaved edge into a source and a drain electrode we have used a shadow evaporation technique. This allowed us to tailor the separation length down to about 0.2 μm which was shorter than the mean free path in the 2DES. We have performed magnetotransport experiments and observe hysteretic spin–valve–like effects and a large positive magnetorestistance. We attribute the latter to the extraordinary magnetoresistance effect.

Currently we perform experiments on samples which are cleaved in situ right before evaporation. Source and drain are nanostructured by scratching the film with the tip of an atomic force microscope. This results in smaller separation lengths of the contacts. We present our latest results in this direction.

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Magneto-transport in MnAs/GaAs:Mn paramagnetic-ferromagnetic hybrids grown by MOVPE and obtained by annealing of MBE-grown (Ga,Mn)As — •Shuangli Ye, Peter J. Klar, Wolfram Heimbrodt, Michael Lampalzer, Kerstin Volz, and Wolfgang Stolz — Department of Physics and Material Sciences Center, Philipps-University of Marburg, Germany

The MnAs/GaAs:Mn granular material consists of MnAs nanoclusters embedded in a GaAs:Mn matrix. The clusters are ferromagnetic or superparamagnetic (depending on size) at room temperature and compatibile with III-V heterostructures which makes them suitable for possible applications in magneto-optic or spintronic semiconductor devices. Here, we compare the physical properties of the two kinds of (Ga,Mn)As:MnAs paramagnetic-ferromagnetic hybrids prepared either by MOVPE directly or by annealing of (Ga,Mn)As alloys grown by low-temperature MBE. The size and the density of MnAs clusters and the distance between them depends strongly on the growth and annealing parameters. The magnetic properties of clusters determined by ferromagnetic resonance measurements as well as the magneto-transport properties measured in the temperature range from 2 to 300 K in fields up to 10 T will be compared for hybrids fabricated by the two methods. The correlation between the magnetic properties of the ferromagnetic clusters and the paramagnetic matrix with the transport mechanisms will be discussed.