# HL 10 Spintronik II

Zeit: Freitag 15:00–16:30 Raum: TU P270

HL 10.1 Fr 15:00 TU P270

**Elektrische Spininjektion über ferromagnetische Kontakte in LEDs im remanenten Zustand** — •N.C. Gerhardt[1], S. Hövel[1], M.R. Hofmann[1], F.-Y. Lo[2], D. Reuter[2], A.D. Wieck[2], E. Schuster[3] und W. Keune[3] — [1]AG Optoelektronische Bauelemente und Werkstoffe, Ruhr-Universität Bochum, Bochum — [2]Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, Bochum — [3]Laboratorium für Angewandte Physik, Universität Duisburg-Essen, Duisburg

Bei der Spininjektion in Halbleiter-LEDs wurden in den letzten Jahren beeindruckende Erfolge erzielt. Spininjektion in spinoptische Bauelemente über ferromagnetische Kontakte war bisher aber nur mit hohen externen Magnetfeldern möglich. Diese Felder von 1-2 Tesla waren erforderlich, um die Magnetisierung der Kontaktschichten für den optischen Nachweis senkrecht auszurichten.

Wir demonstrieren in diesem Vortrag Spininjektion in GaAs ohne externes Magnetfeld aus dem remanenten Zustand. Hierzu verwenden wir ein Fe/Tb-Multischichtsystem mit senkrechter magnetischer Anisotropie als Spininjektionskontakt auf einer LED-Struktur mit einem 15nm breiten (GaIn)As-QW in der aktiven Zone. Spininjektion aus Remanenz wird über eine Polarisationsanalyse der Elektrolumineszenz bis zu einer Temperatur von 260K zweifelsfrei nachgewiesen.

Wir danken der DFG für die Unterstützung im Rahmen des SFB 491.

HL 10.2 Fr 15:15 TU P270

**Dynamics of semiconductor hole systems with effective spin 3/2** — •R. Winkler — Institut für Festkörperphysik, Universität Hannover

Recently, the spin degree of freedom of the charge carriers in semiconductors has become the subject of great interest because of possible novel applications in the field of spintronics. While electrons in the conduction band have spin 1/2, the holes in the valence band of semiconductors like GaAs are characterized by an effective spin 3/2. The dynamics of these hole systems is governed by a strong spin-orbit interaction within the space of spin 3/2 states [1] which gives rise to a splitting of heavy and light hole states in 2D systems. A detailed understanding of hole systems is very important in the context of ferromagnetic semiconductors like GaMnAs where the ferromagnetism is mediated by the spin 3/2 holes in the valence band. We study the spin dynamics of hole systems at magnetic field $B = 0$ and $B > 0$. It is shown that spin 3/2 hole systems behave very different from spin 1/2 electron systems [2]. We discuss possible applications in the field of spintronics.

[1] R. Winkler, *Spin-Orbit Coupling Effects in 2D Electron and Hole Systems* (Springer, Berlin, 2003).
[2] R. Winkler, Phys. Rev. B **70**, 125301 (2004).

HL 10.3 Fr 15:30 TU P270

**Spinabhängige Polarisation eines optisch gepumpten VCSELs** — •S. Hövel[1], N.C. Gerhardt[1], M.R. Hofmann[1], J. Yang[2], D. Reuter[2] und A.D. Wieck[2] — [1]AG Optoelektronische Bauelement und Werkstoffe, Ruhr-Universität Bochum, Geb. IC 2/156, 44780 Bochum — [2]Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, Geb. NB, 44780 Bochum

Durch Injektion spinpolarisierter Elektronen in LEDs können derzeit bei Raumtemperatur nur Polarisationsgrade der Emission erreicht werden, die für spin-optoelektronische Anwendungen zu gering sind. Nichtlinearitäten an der Schwelle oberflächenemittierender Mikroresonatorlaser (VCSELs) ermöglichen dagegen eine entscheidende Verstärkung der Polarisationseffekte.

Wir zeigen, dass die Ausgangspolarisation eines optisch gepumpten VCSELs dabei nicht nur in Art und Weise der Eingangspolarisation folgt sondern auch mit einem höheren Polarisationsgrad als die Pumpstrahlung. Aus kleinen Polarisationsgraden der Pumpstrahlung resultieren somit hohe Polarisationsgrade der VCSEL-Emission. Mäßige Spin-Injektionseffizienzen lassen somit für einen elektrisch gepumpten VCSEL hohe Ausgangspolarisationen erwarten.

Wir danken der DFG für die Unterstützung im SFB 491.

HL 10.4 Fr 15:45 TU P270

**Spin-orbit coupling and anisotropy of spin splitting** — •Jens Könemann[1], D. K. Maude[2], and R. J. Haug[1] — [1]Inst. f. Festkörperphysik, Uni Hannover, Appelstrasse 2, D-30167 Hannover, Germany — [2]High Magnetic Field Laboratory, CNRS, 25 Avenue des Martyrs, BP 166, F-38042 Grenoble cedex 9, France

In our work we investigate the anisotropy of spin splitting of electrons in quantum dots with respect to different configurations of an applied magnetic field and compare it to the effective Land-factor. We explain our results by an interplay between spin-orbit coupling and quantum dot confinement of the electrons [1]. The spin splitting data for both samples display an anisotropy, i. e. the spin splitting caused by the out-of-plane field (with respect to the quantum well plane) is systematically larger than what is created by the in-plane field. In sample A (strong spatial confinement) we observe for the in-plane field orientation a smaller slope of the linear spin-splitting than for the out-of-plane-magnetic field orientation. In contrary, we find in sample B (weak confinement) the same slope of the splitting for both field orientations, but the out-of-plane field orientation of the spin-splitting dependence has a constant energy offset compared to the spin splitting in the in-plane field orientation. We will show that the anisotropy in spin splitting can be traced back to the spin-orbit coupling effects in the lateral electron motion inside the quantum well and that its values in both samples can be related to the same spin-orbit coupling characteristics.

[1] J. Könemann *et al.*, cond-mat/0409054

HL 10.5 Fr 16:00 TU P270

**Local carrier induced ferromagnetisms in a II-VI dilute magnetic semiconductor.** — •Charles Gould[1], Anatoliy Slobodskyy[1], Pawel Hawrylak[2], Fanyao Qu[2], Taras Slobodskyy[1], Peter Grabs[1], Daniel Supp[1], Georg Schmidt[1], and Laurens Molenkamp[1] — [1]Universität Würzburg (EP3), Am Hubland, D-97074, Würzburg, Germany — [2]Institute for Microstructural Sciences, National Research Council of Canada, Ottawa, Ontario K1A 0R6, Canada

We present transport measurements on an all-II-VI semiconductor tunneling structure consisting of a ZnBeMnSe barrier embedded with CdSe self assembled quantum dots. The zero magnetic field I-V characteristic exhibits many resonant peaks which are identified with tunneling through individual quantum dots. When a magnetic field is applied, the resonant peaks split following the Brillouin-like giant Zeeman splitting of the barrier. Given that there is no Mn in the dots, and the effect of the giant Zeeman splitting on the barrier height has negligible effect on peak position, this confirms that the individual electron levels in the quantum dots couple to the Mn system in the barrier.

More surprising is the observation that the splitting between pairs of states of opposite spin remains finite in the absence of magnetic field. This is explained by in a model taking into account both the antiferromagnetic direct Mn-Mn coupling and the carrier mediate ferromagnetic interaction caused by the presence of unpaired electron spins in the dot. The model confirms that the carriers in our system induce a local ferromagnetic interaction of the Mn ions in the vicinity of the current carrying dot.

HL 10.6 Fr 16:15 TU P270

**Very Large Tunneling Anisotropic Magnetoresistance in (Ga,Mn)As based tunnel structures.** — •Christian Rüster[1], Charles Gould[1], Tomas Jungwirth[2], Jairo Sinova[3], Gisela Schott[1], Karl Brunner[1], Georg Schmidt[1], and Laurens Molenkamp[1] — [1]Physikalisches Institut (EP3), Universität Würzburg, Würzburg, Germany — [2]Institute of Physics ASCR, Praha 6, Czech Republic — [3]Department of Physics, Texas A and M University, USA

We previously reported the discovery of tunneling anisotropic magnetoresistance, which manifests itself as spin-valve like behaviour in a normal-metal/insulator/ferromagnetic-semiconductor tunneling device, and results from a combination of the anisotropic density of states in the (Ga,Mn)As with respect to the magnetization direction, and a two-step magnetization reversal process in the material.

We now reports on the very large amplification of this effect in a fully epitaxial (Ga,Mn)As/GaAs/(Ga,Mn)As structure. In addition to raising questions about previous reports in the literature interpreting of spin valve behaviour in (Ga,Mn)As based structures as traditional tunneling magnetoresistance akin to that in metals, the effect reported here also exhibits several novel spintronics features: (i) Both normal and inverted spin-valve signals in a single device; (ii) a large non-hysteretic magnetoresistance for perpendicular magnetic fields; (iii) A sensitivity to the direction of the external magnetic field; (iv) Enormous amplification of the effect at low bias and temperatures to the point of behaving as a true on-off current switch.