Electrical detection of donor Rabi flops — Hans Huebel, Andre Stegner, Felix Hoehe, Christoph Bohrmann, Klaus Lips, Martin Stutzmann, and Martin Brandt — 1Walter Schottky Institute, Garching, Germany — 2University of Utah, Salt Lake City, USA — 3Hahn Meitner Institute, Berlin, Germany

Due to its potential compatibility with existing microelectronics, the proposal for a silicon based quantum computer by Kane is being pursued intensively. In this concept, the nuclear spins of single P donors serve as qubits. Exchange coupling between donor-bound electrons, whose spins experience hyperfine interaction with their nuclei enables tunable and more robust operation. An experimentally unexplored key issue is the readout of the 31P quantum state. We demonstrate the measurement of the spin state of 31P donors in silicon and the observation of Rabi flops by purely electric means, carrying out pulled electrically detected magnetic resonance experiments (pEDMR). Resonant microwave pulses are used to induce coherent manipulation of an ensemble of 31P electron spins by electric spin resonance only. The resulting change of spin-dependent charge-carrier recombination between the 31P donor and paramagnetic localized states at the silicon surface is then detected by a transient photoconductivity measurement after the coherent excitation is turned off. The electron spin information is shown to be coupled through the hyperfine interaction to the phosphorus nucleus, suggesting that recombination-based readout of nuclear spins is feasible.

Fast polarization switching in room temperature Spin-VCSEL — Stephan Hovel, Nils Gerhardt, Martin Hofmann, Fang-Yuh Lo, Dirk Reuter, and Andreas Wriedt — 1Optoelectronic Devices and Materials, Ruhr-University Bochum, IC2/133, Universitatsstr. 150, 44780 Bochum, Germany — 2Applied solid state physics, Ruhr-University Bochum, NB03/58, Universitatsstr. 150, 44780 Bochum, Germany

Spin controlled vertical-cavity surface-emitting lasers (VCSELs) are very promising devices for future spintronic applications, because of their ability to amplify electron spin information. We could show amplified polarization degrees by all optical test experiments in an InGaAs/ GaAs-VCSEL at room temperature [1, 2]. Here we present time-resolved polarization measurements of the optically pumped VCSEL showing a fast switching behaviour on a ps timescale between opposite circular polarization states in a single laser pulse. The complex polarization dynamics do not depend on carrier density, spin polarization or excitation wavelength alone, but are additionally influenced by inhomogeneities and strain of the sample structure. Understanding the polarization dynamics is therefore a key issue on the way to electrically pumped Spin-VCSELs. Taking the time-resolved polarization measurements into account, design considerations for a future electrically pumped Spin-VCSEL for both room temperature as well as highly modulated polarization switching will be discussed.

Vanishing Rashba splitting in (110)-oriented GaAs substrates is interesting for spintronics because of considerably longer spin relaxation times compared to (001)-oriented QWs. This is due to vanishing Rashba spin splitting in symmetrically grown (110)-oriented QWs. In asymmetric QWs the advantage of long spin relaxation times fades away. Here we demonstrate that the recently observed magneto-gyrotropic effect (MPGE) [1] provides a simple and direct access to symmetry properties of QWs. We show that excitation with symmetric (110)-oriented QWs with THz radiation results in the MPGE only for the magnetic field aligned parallel to growth direction while it vanishes for an in-plane magnetic field. For asymmetric QWs even the in-plane magnetic field causes an electric current whose strength increases with rising degree of asymmetry. Our measurements show that for (110)-grown QWs it is sufficient to have symmetrical doping from both sides of QWs in order to exclude Rashba spin-splitting.

AlGaInN/GaN is a very promising material system for spintronics since it is expected to become ferromagnetic with a Curie temperature above room temperature if doped with manganese and long spin relaxation times are detected in this material. Recently we observed that also a substantial Rashba spin-splitting in the electron band structure due to a large piezoelectric effect is present allowing spin manipulation by electric field [1]. Here we report on the observation of a pure spin current in AlGaN/GaN heterostructures, an effect caused by the structural inversion asymmetry. It is achieved by spin-dependent scattering of electrons due to a term in the scattering matrix elements linear in wavevector k. Experiments were carried out on hexagonal (0001)-oriented GaN heterostructures applying linear or circular polarized infrared and terahertz radiation. The effect has been detected in a wide range of temperatures from technologically important room temperature to 4.2 K.

Spin-orbit Coupling in AlGaN/GaN 2-Dimensional Electron Gases — Sergio Cabañas, Nicolas Thillois, Nicoleta Kaluza, Patrick Lehnen, Vitaliy Guzenko, Hilde Hardtdegen, and Thomas Schäpers — Institute of Bio- and Nanosystems (IBN-1) and CNI Center of Nanoelectronic Systems for Information Technology, Research Centre Jülich, 52425 Jülich, Germany

AlGaN/GaN is a very promising material system for spin electronic devices, because for GaN-based doped magnetic semiconductors Curie temperatures above room temperature have been predicted theoretically and confirmed experimentally. We have investigated weak antilocalization in AlGaN/GaN heterostructures. By fitting the experimental curves to a theoretical model we found that the decrease of the peak height in the conductivity with temperature is solely due to the decrease of the phase coherence length. Measurements on gated samples showed that the spin-orbit scattering length is constant for all carrier concentrations. This behavior is due to the fact that the spin-orbit scattering due to crystal inversion asymmetry is the dominant contribution. Although GaN is a large band gap material, the spin-orbit scattering length has a relatively small value of approximately 300 nm, which makes this material interesting for spin electron devices relying on spin precession. If a magnetic field is applied parallel to the plane of the 2-dimensional electron gas the weak antilocalization can be suppressed. We attribute the vanishing of the weak antilocalization peak to the additional contribution of the Zeeman energy competing with the characteristic spin-orbit energy.
InGaSb-based heterostructures with high indium content are promising candidates for spintronic applications because of their strong spin-orbit coupling and large $g$-factor. To investigate these properties magnetoconductance measurements around zero magnetic field (localization measurements) as well as in strong magnetic fields (coincidence method) were performed. A pronounced enhancement of magnetoconductance at $B = 0$ T due to the weak antilocalization effect was observed, which is an unambiguous indication of the spin-orbit coupling in these samples. Experimental curves measured as a function of temperature could be fitted by a theoretical model [1], and a quantitative estimation of the characteristic scattering times was done. By the coincidence method $g$-factor as large as 31 could be determined. By applying an additional constant magnetic field in the plane of 2DEG a strong suppression of the weak antilocalization peak was achieved. This is a qualitative confirmation of the result of the coincidence measurements. [1] M.M.Glazov and L.E.Golub, Semicond. 40 (2006) 1209.

Digital magneto resistance in ferromagnetic resonant tunneling diodes — Christian Ertler and Jaroslav Fabian — Institute of Theoretical Physics, University of Regensburg, Universitätsstrasse 31, D-93040 Regensburg, Germany

The development of ferromagnetic dilute magnetic semiconductors has paved the way for novel all semiconductor spintronic device concepts. For example, spin dependent resonant tunneling in magnetic double barrier heterostructures with either a ferromagnetic or a paramagnetic quantum well have already been investigated both experimentally and theoretically.

In this talk a novel spintronic device, which consists of two serial connected resonant tunneling diodes, is proposed. One diode is non-magnetic whereas the other comprises a ferromagnetic emitter and quantum well. Using a selfconsistent coherent transport model we show that the current-voltage characteristic of the ferromagnetic diode can be strongly modulated by changing the relative orientation of the magnetizations in the emitter and quantum well, respectively. By a continuous change of the relative magnetization angle the total resistance exhibits a discrete jump realizing digital magneto resistance. The interplay between the emitter's Fermi energy level and the relative magnetization orientations allows to tailor the current voltage characteristics of the ferromagnetic diode from ohmic to negative differential resistance regime at low voltages. The proposed spintronic device might be useful for a very fast detection of magnetically stored information or magnetic random access memory applications.