

1.2 Semiconductor Spectroscopy

The research activities of the Semiconductor Spectroscopy group focus on controlling elementary excitations (photons, electrons, and spins) using surface acoustic waves (SAWs), the optical properties of wide-gap group-III-nitride films, hetero-, and nanostructures, the electrical and optical properties of quantum-cascade lasers in the THz regime, the magnetotransport in curved two-dimensional electron gases, the transport and magnetic properties of MnAs films and dots, as well as the quantum transport theory for carriers and spins.

Mobile piezoelectric potentials produced by SAWs have been used to coherently transport electron spins in GaAs(110) quantum wells (QWs) over distances exceeding $60 \mu\text{m}$ [O. D. D. Couto, Jr., *et al.*, Phys. Rev. Lett. **98**, 036603 (2007)]. The dynamics of mobile spins under external magnetic fields depends on the direction of motion in the QW plane. This transport anisotropy is an intrinsic property of the moving spins associated with the bulk inversion asymmetry of the underlying GaAs lattice. Furthermore, a novel approach for the microscopic confinement and transport of excitons in GaAs QWs using the moving strain field of a SAW has been demonstrated [J. Rudolph *et al.*, Phys. Rev. Lett. **99**, 047602 (2007)]. The band-gap modulation induced by the SAW strain field traps long-living indirect excitons in a double QW structure within sub- μm -wide stripes parallel to the acoustic wave fronts and transports them over several hundreds of μm .

Using spatially resolved cathodoluminescence spectroscopy, the spectral and spatial distribution of the luminescence intensity of GaN/(Al,Ga)N nanocolumns containing quantum disks has been investigated [U. Jahn *et al.*, Appl. Phys. Lett. **90**, 161117 (2007)]. The optical emission of the quantum disk and of the thick (Al,Ga)N layer in the columns have been clearly identified. A significant contribution to the broadening of the quantum disk emission is probably due to the laterally inhomogeneous strain distribution within the disks. With regard to nonpolar GaN films, it has been demonstrated that the *A* exciton in unstrained *A*-plane GaN films becomes completely linearly polarized [P. Misra *et al.*, Appl. Phys. Lett. **91**, 141903 (2007)]. The combination of a polarization-sensitive photodetector with a polarization filter made from two identical *M*-plane GaN films on a γ -LiAlO₂(100) substrate can be used for very narrow-band ultraviolet photodetection with a band width limited to a few nanometers [S. Ghosh *et al.*, Appl. Phys. Lett. **90**, 091110 (2007)]. A polarization-dependent beam switch based on an *M*-plane GaN/AlN distributed Bragg reflector has also been demonstrated [D. Schaadt *et al.*, Appl. Phys. Lett. **90**, 231117 (2007)].

With regard to quantum-cascade lasers, the spectra of two-sectioned, coupled-cavity (TSCC) terahertz quantum-cascade lasers have been investigated [M. Giehler *et al.*, Appl. Phys. Lett. **91**, 161102 (2007)]. They exhibit a number of longitudinal modes, which are periodically suppressed due to interference effects. The number of suppressed modes is equal to the ratio of the lengths of the two subcavities. At maximum laser output, the mode suppression disappears

due to optical saturation, and a switching between TSCC and single-cavity-like mode features appears for certain delays between the current pulses through the individual subcavities. In addition, a super-superlattice structure containing a conventional superlattice, a graded-gap superlattice, and a wide quantum well in its unit cell has been analyzed for intra-miniband gain [L. Schrottke *et al.*, J. Appl. Phys. **101**, 036101 (2007)]. It is designed in such a way that alternating high- and low-electric-field domains appear due to the presence of positive and negative space charges. Such structures may be useful for terahertz lasers, since the large dipole matrix element of the intra-miniband transitions allow for a rather low doping density and hence a reduction of scattering processes.

The free-electron trajectories in a high-mobility, two-dimensional electron gas, which is rolled up as a tube with an electron mean free path as large as the radius of the tube, have been shown to bend in space, while being confined in the curved quantum well [K.-J. Friedland *et al.*, Phys. Rev. B **75**, 045347 (2007)]. In cross junctions, negative bend resistances have been observed at zero magnetic field. Furthermore, the bend resistance becomes strongly asymmetric with respect to the orientation of the magnetic field due to varying magnetic field along the junction. A giant asymmetry in the magnetoresistance has been revealed in high-mobility, two-dimensional electron gas on a cylindrical surface [A. B. Vorob'ev *et al.*, Phys. Rev. B **75**, 205309 (2007)]. The longitudinal resistance along the magnetic-field gradient impressed by the surface curvature was found to vanish if measured along one of the edges of the curved Hall bar. If the external magnetic field is reversed, then the longitudinal resistance vanishes at the opposite edge of the Hall bar.

The scattering processes of carriers, which are responsible for charge conduction, in MnAs channels prepared on GaAs(001) and GaAs(111)B substrates have been investigated through the temperature dependence of the resistivity in the regime where MnAs undergoes two phase transitions [Y. Takagaki *et al.*, Phys. Rev. B **75**, 035213 (2007)]. The temperature coefficient changes discontinuously at the phase transitions and is negative for the β phase, indicating that a certain magnetic order exists in β -MnAs. Magnetic-force microscopy on MnAs dots fabricated from an epitaxial film on GaAs(001) reveals that the magnetic moment in about 6% of the MnAs dots is tilted from the magnetic easy axis [Y. Takagaki *et al.*, J. Appl. Phys. **101**, 123914 (2007)]. The amount is consistent with the ratio of the type-A and type-B crystallographic directions of MnAs estimated from the magnetization curve of the film.

Based on a rigorous quantum-kinetic approach, spin-charge-coupled drift-diffusion equations are derived for a strongly confined two-dimensional hole gas [P. Kleinert *et al.*, Phys. Rev. B **76**, 073314 (2007)]. An electric field leads to a coupling between the spin and charge degrees of freedom. For weak spin-orbit interaction, this coupling gives rise to a spin accumulation at the edges of a stripe.