## HL 15: Focussed Session: Geometry- and Topology-Controlled Nanoarchitectures I

Study of topological matter is one of the fascinating main roads of modern physics. The realm of topological matter can be conventionally subdivided in two categories. First, non-trivial topology occurs due to a special geometry of structures or fields in real space, e.g., quantum rings, Möbius rings, multi-terminal Josephson junctions, Skyrmions. Second, topologically protected surface/edge states governed by Dirac physics and/or topologically nontrivial electronic structure in the momentum space underlie Quantum Hall effect, topological insulators, superconductors, semimetals. An interplay between those two realms is the subject of the proposed Focus Session.

Organizers: Paul M. Koenraad (TU Eindhoven) and Vladimir M. Fomin (IFW Dresden)

Time: Tuesday 9:30–13:15 Location: EW 015

HL 15.1 Tue 9:30 EW 015

**Field-induced quantum rings in cone-shell GaAs quantum dots** — •Christian Heyn, Achim Küster, Michael Zocher, and Wolfgang Hansen — Center for Hybrid Nanostructures, University of Hamburg, D-22761 Hamburg, Germany

We study self-assembled GaAs quantum dots (QDs) and rings (QRs) in refilled AlGaAs nanoholes. The holes are fabricated using local droplet etching during molecular beam epitaxy. Controlled by the process conditions, QDs of varied shape can be generated in which the probability distributions of the carriers are concentrated, e.g., in the volume of a cone or on the cone shell. The optical emission of cone-shell QDs (CSQDs) is studied with single-dot photoluminescence (PL). Numerical simulations reproduce the experimental ground and excited-state emission energy of the CSQDs. Further simulations of the influence of a vertical electric field establish a field-dependent displacement of either the electron or the hole away from the tip of the cone. This displacement has several consequences. First, the Coulomb interaction is strongly reduced which compensates the single-particle Stark-shift. Accordingly, simulations as well as PL measurements indicate a non-parabolic Stark-shift with a regime of approximately constant emission energy. Second, the calculated exciton-recombination lifetime establishes a variability up to seven orders of magnitude. Third, regarding the shape of the wave-functions in CSQDs, we predict the controlled transformation of either the electron or the hole from a quasi zero-dimensional dot into a one-dimensional quantum ring by a gate-voltage. The respective other charge carrier remains as a dot.

HL 15.2 Tue 9:45 EW 015

**Magnetism in curved geometries** — •Denys Makarov — Helmholtz-Zentrum Dresden-Rossendorf e.V., Institute of Ion Beam Physics and Materials Research, Dresden, Germany

While conventionally magnetic films and structures are fabricated on flat surfaces, the topology of curved surfaces has only recently started to be explored and leads to new fundamental physics as well as applied device ideas. In particular, novel effects occur when the magnetization is modulated by curvature that has major implications on the spin statics and dynamics due to topological constraints. Advances in this novel field solely rely on the understanding of the fundamentals behind the modifications of magnetic responses of 3D-curved magnetic thin films. The lack of an inversion symmetry and the emergence of a curvature induced effective anisotropy and Dzyaloshinskii-Moriya interaction are characteristic of curved surfaces, leading to curvature-driven magnetochiral effects and topologically induced magnetization patterning [1]. In addition to these rich physics, the application potential of 3D-shaped objects is currently being explored as spin filters, magnetic field sensorics and memory devices. To this end, the initially fundamental topic of magnetism in curved geometries strongly benefited from the input of the application-oriented community, which among others explores the mechanical shapeability of curved magnetic thin films. These activities resulted in the development of shapeable magnetoelectronics [2] - spintronics on flexible, bendable and stretchable surfaces. [1] Streubel et al., J. Phys. D: Appl. Phys. (Topical Review) 49, 363001 (2016). [2] Makarov et al., Appl. Phys. Rev. (Focused Review) 3, 011101 (2016).

HL 15.3 Tue 10:00 EW 015

**Observation of Aharonov-Bohm oscillations in core-shell nanowire crystal-phase quantum rings** — Pierre Corfdir[1], •Oliver Marquardt[1,2], Ryan B. Lewis[1], Chiara Sinito[1], Manfred Ramsteiner[1], Achim Trampert[1], Uwe Jahn[1], Lutz Geelhaar[1], Oliver Brandt[1], and Vladimir M. Fomin[3] — [1]Paul-Drude-Institut für Festkörperelektronik — [2]Weierstraß-Institut für angewandte Analysis und Stochastik — [3]Leibniz-Institut für Festkörper- und Werkstoffforschung

Coherence in nanostructures is at the heart of a wide range of quantum effects such as Josephson oscillations between exciton-polariton condensates in microcavities, conductance quantization in one-dimensional ballistic transport, or the excitonic Aharanov-Bohm (AB) effect in quantum ring (QR) devices. However, inevitable interface roughness in self-assembled low-dimensional semiconductor heterostructures usually leads to loss of coherency and charge carrier localization. The study of AB oscillations in semiconductor QRs has thus required the fabrication of heterostructures with high interface quality, and has so far been limited to self-assembled ring structures with very limited control of shape and dimension or to nanorings that were fabricated by nanolithography. We demonstrate that core-shell GaAs/AlAs nanowires containing atomically flat polytype segments can be systematically tailored for studies of the excitonic AB effect of neutral and charged excitons. Thanks to their atomically flat interfaces and the absence of alloy disorder, phase coherence is preserved even in QRs with diameters on the order of 90 nm.

HL 15.4 Tue 10:15 EW 015

**Microwave-stimulated superconductivity in Nb thin films** — •Oleksandr V. Dobrovolskiy[1,2], Roland Sachser[1], Michael Huth[1], Antonio Lara[3], Farkhad G. Aliev[3], Valerij A. Shklovskij[2], Alexei I. Bezuglyj[2,4], and Ruslan V. Vovk[2] — [1]Goethe University, Frankfurt am Main, Germany — [2]V. Karazin National University, Kharkiv, Ukraine — [3]Universidad Autonoma de Madrid, Spain — [4]National Science Center – KIPT, Kharkiv, Ukraine

Stimulation of superconductivity due to the presence of vortices by a microwave (mw) excitation has been recently seen in increase of $T_c$ and $H_{c2}$ in type II superconducting thin films. Here we report on a mw-induced enhancement of the maximal *mixed-state* dc critical current of epitaxial Nb films. The mw-stimulated flux flow is expanded up to 10% larger dc current densities and vortex velocities $v^*$ than in the absence of mw stimulus. Here $j^*$ and $v^*$ correspond to an abrupt transition of the sample into the normal state because of the Larkin-Ovchinnikov (LO) instability. We have performed simulations of the time-dependent Ginzburg Landau (TDGL) equation, which reveal similar results to the ones observed in the experiments. These can be interpreted as a result of massless response of vortices to an external excitation, or as mw-stimulated superconductivity as vortices approach the critical velocity. We furthermore argue that the observed mw-induced enhancement of $j^*$ and $v^*$ can result in a competition between the mw-induced cooling and the dc-induced heating of quasiparticles in the vortex cores.

HL 15.5 Tue 10:30 EW 015

**Andreev levels as a quantum dissipative environment** — Artem Galaktionov[1], •Dmitry Golubev[2], and Andrei Zaikin[3] — [1]Lebedev Physical Institute, Moscow, Russia — [2]Aalto University, Espoo, Finald — [3]Karlsruhe Institute of Technology, Karlsruhe, Germany

We argue that at subgap energies quantum behavior of superconducting weak links can be exactly accounted for by an effective Hamiltonian for a Josephson particle in a quantum dissipative environment formed by Andreev levels. This environment can constitute an important source for intrinsic inelastic relaxation and dephasing in highly transparent weak links. We investigate the problem of macroscopic quantum tunneling in such weak links demonstrating that - depending on the barrier transmission - the supercurrent decay can be described by three different regimes: (i) weak intrinsic dissipation, (ii) strong intrinsic dissipation, and (iii) strong capacitance renormalization. Crossover between quantum and thermally assisted supercurrent decay regimes can also be strongly affected by the Andreev level environment.

HL 15.6 Tue 10:45 EW 015

**Non-equilibrium $\phi_0$-junction-like behavior of multi-terminal Andreev interferometers** — Pavel Dolgirev[1,2], Mikhail Kalenkov[2], and •Andrei Zaikin[3,2] — [1]Skolkovo Institute of Science and Technology, Skolkovo Innovation Center, 3 Nobel St., 143026 Moscow, Russia — [2]I.E. Tamm Department of Theoretical Physics, P.N. Lebedev Physical Institute, 119991 Moscow, Russia — [3]Institut fuer Nanotechnologie, Karlsruher Institut fuer Technologie (KIT), 76021 Karlsruhe, Germany

We predict a novel $(I_0, \phi_0)$-junction state of multi-terminal hybrid superconducting-normal nanostructures with non-trivial topology. This state emerges from an interplay between long-range quantum coherence and non-equilibrium effects. Under non-zero bias $V$ the current-phase relation $I_S(\phi)$ resembles that of a $\phi_0$-junction differing from the latter due to a non-zero average $I_0(V) = \langle I_S(\phi)\rangle_\phi$. The flux-dependent thermopower $\mathcal{S}(\Phi)$ of the system exhibits features similar to those of a $(I_0, \phi_0)$-junction and in certain limits it can reduce to either odd or even function of $\Phi$ in the agreement with a number of experimental observations.

**15 min. break.**

HL 15.7 Tue 11:30 EW 015

**Voltage tuning of exciton topology and g-factor in type-II InAs/GaAsSb quantum dots** — •Benito Alén[1], José M. Llorens[1], Edson R. Cardozo de Oliveira[2], Lukasz Wevior[1], Vivaldo Lopes-Oliveira[3], Victor López-Richard[2], José M. Ulloa[4], Marcio D. Teodoro[2], Gilmar E. Marques[2], Alberto García-Cristóbal[5], and Guo-Quiang Hai[3] — [1]IMN-Instituto de Micro y Nanotecnología (CNM-CSIC), Spain. — [2]Dept. de Física, Universidade Federal de Sao Carlos, Brazil. — [3]Instituto de Física, Universidade de Sao Paulo, Brazil. — [4]ISOM, Universidad Politécnica de Madrid, Spain. — [5]ICMUV, Universidad de Valencia, Spain.

We will report experimental and theoretical work done in the InAs/GaAsSb QD system. For Sb molar fractions beyond 16 %, the band alignment becomes type II, with the electron confined inside the InAs and the hole delocalized in the GaAsSb overlayer. Voltage control of the exciton dipole moment in the vertical direction thus allows large tuning of the radiative lifetime. [1] It also brings a topological change in the hole ground state wavefunction from singly to doubly connected. [1,2] The latter causes Aharonov-Bohm oscillations and a change of the exciton g-factor, as observed in the QD ensemble magneto-photoluminescence. Both effects are modulated by external bias in a device and can be explained in the frame of k.p and effective Hamiltonian models. This result could open a venue for new quantum memories beyond the InAs/GaAs realm.

[1] J. M. Llorens et al. Appl. Phys. Lett., 107, 183101 (2015) [2] J. M. Llorens et al. arXiv:1710.08828 [cond-mat.mes-hall]

HL 15.8 Tue 11:45 EW 015

**Cleavage Energies of Layered Materials: $Bi_{14}Rh_3I_9$, $Bi_2TeI$, $\beta$-$Bi_4I_4$ and 2H-$MX_2$** — •Madhav Prasad Ghimire[1,2], Jeroen van den Brink[1], and Manuel Richter[1,3] — [1]IFW Dresden e. V., Helmholtzstr. 20, D-01069 Dresden, Germany — [2]CMPRC, Butwal-11, Rupandehi, Lumbini, Nepal — [3]DCMS, TU Dresden, D-01062 Dresden, Germany

In recent years weakly bonded layered systems have become important for the manufacturing of two-dimensional materials. Precise knowledge of the interlayer bonding allows to understand in detail the exfoliation process in these compounds. Cleavage energies are crucial in this respect. Here we report the cleavage energies and electronic properties of the weak topological insulators (TIs) $Bi_{14}Rh_3I_9$, $Bi_2TeI$ and $\beta$-$Bi_4I_4$, as well as of 2H-transition metal dichalcogenides ($MX_2$ where M=Mo, W and X=S, Se, Te) determined by means of density functional theory calculations. Our calculations reproduce the experimentally measured value of cleavage energy of graphite, $E_c$ (graphite) = 0.37 $Jm^{-2}$, which we use as a benchmark. Based on this, we calculate the cleavage energies of the three weak TIs and 2H-$MX_2$ systems. We find that all energies are smaller than $2\times E_c$ of graphite. The obtained values suggest the possibility of exfoliation of individual layers in these materials.

HL 15.9 Tue 12:00 EW 015

**Topologically Distinct Semiconductor Nanostructures by Droplet Epitaxy** — •Stefano Sanguinetti[1,2], Francesco Biccari[3], Sergio Bietti[1], Anna Vinattieri[3], Alexey Fedorov[2], and Massimo Gurioli[3] — [1]L-NESS and University of Milano Bicocca, Via Cozzi 55, 20126 Milano, Italy — [2]IFN-CNR, Via Anzani 42, 22100 Como, Italy — [3]University of Florence and LENS, Via Sansone 1, 50019 Sesto Fiorentino (FI), Italy

Extremely complex semiconductor quantum nanostructures, constituted by multiple concentric rings, disks and dots can be designed and realized by Droplet Epitaxy. Topology induced effects determines the electronic and optical properties of these nanostructures. In particular, carrier dynamics appears to be related to topology induced selection rules. We present in detail the droplet epitaxy growth procedure and the analysis of the emission of individual GaAs/AlGaAs complex nanosystems composed by concentric and topologically distinct quantum nanostructures. Time resolved, temperature and excitation power density dependence of the photoluminescence from single and ensemble nanostructures have been used in order to determine the carrier dynamics. Despite the small spatial separation between the dot and the ring, the exciton dynamics in the nanostructures is completely decoupled at low temperatures. At higher temperatures it is possible observe a clear change in the carrier dynamics, which shows the onset of the coupling between the nanostructures. Electronic structure calculations show that the interaction takes place via a delocalized common excited energy state.

HL 15.10 Tue 12:15 EW 015

**Optical geometric phase in Möbius ring and asymmetric microtube cavities** — •Libo Ma — Institute for Integrative Nanosciences, IFW Dresden, Helmholtzstr. 20, 01069 Dresden, Germany

Optical whispering gallery modes (WGMs) in micro-ring cavities are formed by self-interferences of optical waves with integer numbers of $2\pi$ phase differences along a ring trajectory. This kind of phase is usually called as dynamical phase since an extra phase, Berry phase (also known as geometrical phase), was discovered for general physical wave systems in nontrivial evolutions. Optical Berry phase was excluded from conventional WGM cavities because of trivial topology therein. Here, we talk about the generations of Berry phase in optical ring microcavities formed by twisted nano-strip (i.e. Möbius ring) and cone-shaped microtube structures. A Berry phase $\pi$ is generated in Möbius ring, which leads to the formation of half-integer number of resonant modes and anomalous plasmon modes. More interestingly, the generations of Berry phase together with basis conversion was observed in the cone-shaped microtube cavities due to optical spin-orbit coupling in an anisotropic medium. Berry phase theory and quantum mechanical diagonalization procedure were applied to explain our observations. Our work paves a way for generating and manipulating optical Berry phase for both fundamental and applied studies in the platform of on-chip quantum devices.

HL 15.11 Tue 12:30 EW 015

**Artificial magnetoelectric materials with curvilinear helimagnets** — •Oleksii Volkov, Jürgen Fassbender, and Denys Makarov — Helmholtz-Zentrum Dresden - Rossendorf e.V., Institute of Ion Beam Physics and Materials Research, Dresden, Germany.

Magnetoelectric (ME) materials are technologically relevant, e.g. as prospective non-volatile memory devices [1]. The ME effect in single-phase bulk materials is weak and observed in rather special crystals. Therefore, artificial ME materials have been proposed and are typically realized as heterostructures of magnetostrictive and piezoelectric layers. Thus, magnetic and electrical subsystems are coupled via strain. However, substrate clamping effect do not allow to achieve full change in the magnetization from zero to remanent value.

Here we propose a novel approach towards artificial ME materials with helimagnetic nanohelices embedded in a piezoelectric matrix. By applying an electric field, geometrical properties of a helical wire (i.e. pitch and radius) could be changed deterministically. In this system not relying on magnetostriction in a magnetic subsystem, pure geometrical change results in a strong modification of a magnetic state of a curvilinear helimagnet [2]. We analyse phase diagrams of magnetic and geometrical parameters, which allow us to realize switching of a magnetic state from a homogeneous (full average magnetic moment) into a periodical one (zero average magnetic moment).

[1] M. Fiebig et. al., Nature Reviews 1, 1-14 (2016).

[2] R. Streubel et. al., J. Phys. D: Appl. Phys. 49, 363001 (2016).

HL 15.12 Tue 12:45 EW 015

**Nano-SQUIDs with controllable weak links via electromigration** — Wout Keijers[1], Xavier D.A. Baumans[2], Ritika Panghotra[1], Jospeh Lombardo[2], Vyacheslav S. Zharinov[1], Alejandro V. Silhanek[2], and •Joris Van de Vondel[1] — [1]INPAC-Institute for Nanoscale Physics and Chemistry, KU Leuven, Celestijnenlaan 200D, B-3001 Leuven, Belgium — [2]Experimental Physics of Nanostructured Materials, Q-MAT, CESAM, Université de Liège, B-4000 Sart Tilman, Belgium

This work deals with modifying the weak links of a thin film aluminum nano-SQUID beyond the limit of current lithography techniques using controlled electromigration (EM). In order to achieve this goal, a nano-SQUID is designed and fabricated using e-beam lithography (EBL) and molecular beam epitaxy (MBE) techniques. Since the design of the SQUID consists of two weak links in parallel, the next step was to experimentally verify that this design is indeed compatible with parallel EM. This is achieved by the, direct and in-situ, observation of the parallel EM process using scanning electron microscopy. Hereafter, we investigated the evolution of the superconducting properties of the SQUID using low temperature measurements as function of the cross section of the weak links. The behavior of the SQUID's critical current perfectly matches the numerical calculations based on a SQUID model which takes into account the kinetic inductance and asymmetry of the device. Moreover, it is observed that when EM has sufficiently reduced the junction cross section, the SQUID can be operated in the dissipative state, where magnetic flux readout from voltage is possible.