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P1

Berry phase and extraordinary Landau levels shift

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CgHgTe / HgTe / CdHgTe quantum wells due to large Hg mass, resulting in strong relativistic effects and thus to inverted spectrum of 3D HgTe, are rather different from other known quantum wells based on semiconductor heterostructures. Thus HgTe quantum wells have different energy spectra and so different interesting properties depending on a well width [1]. It is an ordinary insulator at width $d < 6.3$ nm; it has linear spectrum of so called Dirac fermions at $d \approx 6.3$ nm; inverted spectrum being 2D topological insulator at $d > 6.3$ nm; semimetallic spectrum with a small overlap between the conduction and vallence bands at $d \approx 20$ nm; finally at width $d > 70$ nm it is 3D topological insulator [2].

The work is devoted to the experimental investigation of Shubnikov - de Haas oscillations (ShdHO) in wide (20 - 22 nm) HgTe quantum wells. Previously for these wells it was indirectly shown by study of roughness scattering that electrons in a conduction band at large energy start to locate near well surfaces [3]. Together with calculated spin polarization of the states these wells look similar to 3D topological insulator with quantum well instead 3D volume. The present work was first directed to study more detailed obtained surface states. Experimentally we indeed obsereved appearance of beatings in oscillations with applying external gate voltage. This can be well described in model of two types of carriers (electrons on two well surfaces) which at nonzero gate voltage, due to screeneng the gate by the top surface towards the bottom one, have different electron concentrations and thus different ShdHO frequencies.

Besides observing what was expected we found an interesting Landau levels (LLs) behavior with mangnetic field increase. Landau levels degenerated at low magnetic field split at large magnetic field but instead separating also with naighbor LLs they come closer to them and degenerate causing period doubling of Shubnikov - de Haas oscillation. Such a behavior can be explained by mixing of the first conduction band states with total momentum 3/2 (due to inverted band structure) with states of second band which has momentum 1/2. This mixing causes changing of Berry phase and thus Landau levels energy.

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P2

Charge and current orders in spin-fermion model with overlapping hot spots

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Experiments carried over the last years on the underdoped cuprates suggest the presence of a variety of symmetry-breaking phenomena in the pseudogap phase. Charge-density waves, breaking of C_4 rotational symmetry as well as time-reversal symmetry breaking have all been observed in several cuprate families. In this regard, theoretical models where multiple non-superconducting orders emerge are of particular interest. We consider the spin-fermion model in the regime where adjacent hot spots on the Fermi surface overlap and merge due to the finite antiferromagnetic correlation length. Focusing on the particle-hole instabilities we obtain a rich phase diagram with the chemical potential and the Fermi surface curvature in the antinodal regions being the control parameters. We find evidence for d-wave Pomeranchuk instability, d-form factor charge density wave as well as commensurate and incommensurate staggered bond current phases. The latter are found to be promoted by the curvature. Considering the appropriate parameter range for the hole-doped cuprates, we discuss the possible relation of these results to the pseudogap phase.

P3

Density of States of Dirac Fermions in HgTe Quantum Well

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Since the discovery of the massless Dirac electrons in graphene systems with linear dispersion of carriers have been under intensive study. HgTe quantum wells with thickness of about 6.3 – 6.6 nm are the examples of such systems that have gapless single-valley 2D Dirac fermions and high quality with mobility more than 10^5 cm^2/Vs [1].

There have been done many experiments on HgTe structures that show the absence of any energy gap in the spectrum of Dirac fermions and demonstrate a number of features indicating both the linearity of the spectrum of Dirac electrons in a wide energy range and a strong effect of heavy holes valleys, which are 10 – 20 meV below the Dirac point. However, the density of states, which is the most important characteristic directly related to the energy spectrum of the system, has not yet been systematically studied. In this work, we present the Fermi energy dependences of the density of states of the system of Dirac fermions obtained by means of capacitance measurements and analyze factors affecting the density of states at the Dirac point.

It is found that the density of states of Dirac electrons is a linear function of the Fermi energy at $E_F > 30$ meV with the corresponding velocity $v = 8.2 \cdot 10^5$ m/s. At lower energies this dependence deviates from the linear law, indicating a strong effect of disorder, which is associated with fluctuations of a built-in charge, on the density of states of the studied system near the Dirac point. At negative energies, a sharp increase in the density of states is observed, which is associated with the tail of the density of states of valleys of heavy holes. The described behavior is in agreement with the proposed model, which includes both the features of the real spectrum of Dirac fermions and the effect of the fluctuation potential.

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Dimensional crossover as the origin of reentrant resistive behavior in superconducting films

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A reentrant temperature dependence of the normal state resistance often referred to as the N-shaped temperature dependence, is omnipresent in disordered superconductors – ranging from high-temperature cuprates to ultrathin superconducting films – that experience superconductor-to-insulator transition. We investigate strongly disordered superconducting TiN films and demonstrate universality of the reentrant behavior. We offer a quantitative description of the N-shaped resistance. We show that upon cooling down the resistance first decreases linearly with temperature and then passes through the minimum that marks the 3D - 2D crossover in the system. We show that the shift from the downturn to upturn of the resistance occurs once the thermal coherence length L_T matches the thickness of the film d. In the 2D temperature range the resistance first grows with decreasing temperature due to quantum contributions and eventually drops to zero as the system falls into a superconducting state. Our findings demonstrate the prime importance of disorder in dimensional crossover effects [1].

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P5

Dipolar quantum phase transition in the Dicke model with infinitely coordinated frustrating interaction

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We consider a system of Josephson junctions coupled to a single mode electromagnetic resonant cavity. In a CPB approximation this system can be described by a Dicke Hamiltonian with frustrating term:

$$H = \frac{1}{2}(p^2 + \omega^2 q^2) - E_J \sum_{i=1}^{N} \sigma_i^x - gp \sum_{i=1}^{N} \sigma_i^z + \frac{g^2}{2} \sum_{i,j=1}^{N} \sigma_i \sigma_j. \tag{1}$$

To obtain its eigenvalues and eigenstates we calculate and diagonalize the Hamiltonian matrix in basis of Hamiltonian

$$H_0 = \frac{1}{2}(p^2 + \omega^2 q^2) - gp \sum_{i=1}^{N} \sigma_i^z + \frac{g^2}{2} \sum_{i,j=1}^{N} \sigma_i \sigma_j \tag{2}$$

which are eigenstates of the harmonic oscillator displaced by $\frac{ig_m}{\sqrt{2\omega}}$ in phase space. Numerical calculations for case three Josephson junctions were performed. As a result, were obtained Hamiltonians energy spectrum, spin projections time-dependence and dependence of squares of spin projections on the coupling constant. For the thermodynamic limit, when the number of junctions is infinite, the problem could be solved analytically. It is shown, that in this case the phase transition is present and system switches to a superradiant state.

Disorder-tuned superconductor-insulator transition in thin NbTiN films

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The superconductor-insulator transition (SIT) has been the subject of numerous studies for several decades [1–3]. Nevertheless, the SIT nature still remains elusive and the experimental data can be explained by the various models. Thus, the question about SIT specific mechanism is open.

We investigated the superconductor-insulator transition in NbTiN films with thicknesses $d < 18\,\mathrm{nm}$. The films were grown by atomic layer deposition onto Si/SiO_2 substrates. The samples for transport measurements were patterned into Hall bridges. The low frequency ($f = 3\,\mathrm{Hz}$) resistance measurements were carried out by using standard four-probe technique.

The experimental results indicate a direct superconductor-insulator transition in disordered thin NbTiN films. The critical temperature of the superconducting transition T_c is suppressed due to increasing the resistance per square in the normal state, that is in agreement with a fermionic approach for the demise of superconductivity in the 2D limit. At the same time, the insulating ground state of the system was observed. Furthermore, the Berezinskii-Kosterlitz-Thouless transition temperature is completely suppressed at nonzero T_c. These features are typical for a bosonic suppression superconductivity scenario. It was demonstrated that the resistance temperature dependencies of the insulating films follow the Arrhenius activation behavior.

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Edge states and spin-valley edge photocurrent in transition metal dichalcogenide monolayers

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We develop an analytical theory for edge states in monolayers of transition metal dichalcogenides based on a general boundary condition for a two-band **kp**-Hamiltonian in case of uncoupled valleys. Taking into account *edge* spin-orbit interaction we reveal that edge states, in general, have linear dispersion that is determined by three real phenomenological parameters in the boundary condition. In absence of the spin-orbit interaction, edge states are described by a single real parameter whose sign determines whether their spectra intersect the gap or not. In the former case we show that illumination by circularly polarised light results in spin and valley polarised photocurrent along the edge. Flow direction, spin and valley polarisation of the edge photocurrent are determined by the direction of circular polarisation of the illuminated light [1].

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Electronic properties and the persistent current of one-dimensional mesoscopic rings with inhomogeneitiest

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Since the discovery of the Aaronov-Bohm effect and its first observation, ring structures continue to attract the attention of the scientific community. This is due not only to the fact that they exhibit many new physical phenomena associated with quantum interference effects, but also with the possibilities of using them in various optoelectronic devices. The ring graphene nanostructures were widely studied both theoretically and experimentally [1, 2].

In this paper, we consider the electronic properties of gapped graphene and silicene quantum rings in the presence of a magnetic field. The one-dimensional model used allows to obtain most of the results in an analytical form. It is shown, in particular, that the presence of a transverse electric field leads to the appearance of two groups of levels for the silicene ring, periodically dependent on the magnetic flux, but characterized by different spin-valley indices. The persistent current as a function of the magnetic flux in such a ring exhibits an abrupt behavior for a nonzero , which is associated with the spin-valley symmetry breaking. The joint effect of the gap parameter and local perturbation (inhomogeneity) on the energy levels structure of the ring is considered. The conditions for crossing the levels are found depending on the magnitude of the perturbation (analogue of extra Dirac points (see, for example, [3])). A dispersion equation is also obtained for finding the energy spectrum of an inhomogeneous ring with an arbitrary number of local defects periodically distributed along it (i.e., forming a superlattice). Such a superlattice can be formed, for example, by adsorbed atoms or impurities [4], or a local potential can be created using control electrodes [5].

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Fluctuation superconductivity: from the dirty to the clean case

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We study the effect of superconducting fluctuations on the conductivity of metal films at arbitrary temperatures and impurity scattering rates. Using the standard diagrammatic technique in the Keldysh representation, we obtain the general expression for fluctuation conductivity applicable both for dirty and clean superconductors. We observe that the usual classification in terms of the Aslamazov-Larkin, Maki-Thompson and density-of-states diagrams is to some extent artificial since these contributions produce similar terms, which partially cancel each other. In the diffusive limit, the results are compared with known predictions of early approaches [1],[2]. In the clean case [3], we demonstrate that the correction does not contain a divergent term $(T\tau)^2$ attributed previously to the DOS-type contribution. The crossover between the diffusive and ballistic regimes is also studied.

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Helical edge transport in the presence of a magnetic impurity: influence of a local anisotropy

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We study transport along the helical edge of a two-dimensional topological insulator in the presence of a Kondo magnetic impurity. We take into account the local magnetic anisotropy, which is inherently present in the structure for the impurities with spin $S > 1/2$. By analyzing the transport both at low and high energies, we show that the anisotropy has a profound influence on the differential conductance along the edge in the wide region of voltage and temperature, which is significantly larger than the typical sclae of anisotropy. Importantly, the results differ for the impurities with integer and half-integer spin.

P11

Intrinsic Magnetic Moments in the Topological Insulators

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The presence of magnetic moments in topological insulators (TI) in the case of their ordering via indirect RKKY coupling may give rise to the time-reversal symmetry (TRS) breaking and to appearance of different topological states corresponding to new quantum materials. One of the most promising ways to develop long rang magnetism in TI is the doping with magnetic ions. However, quite recently [1] it was found that local moments may emerge from the intrinsic nonmagnetic defects of anti-site type (e.g. Bi on the Te site for 3-dimensional TI Bi_2Te_3) . The corresponding local magnetic moments value is about 0.6 μB and originates from the p-orbital of the guest Bi atom.

We report the results of the comprehensive investigations of the intrinsic magnetism of TI on the example of popular bismuthates family. The main part of our investigations of the intrinsic magnetic moments in TI was carried out using the isostructural version of Bi telluride compound $Bi_{1.08}Sn_{0.02}Sb_{0.9}$ Te_2S, which is known to be one of the best 3D topological insulators [2]. The resistivity measured using the standard four-probe method revealed the typical for the TI behavior with the activated character down to T$\sim$100 K followed by the decrease below T$<$100 K which may be considered as the manifestation of the surface conductivity. The magnetization measurements were carried out using the SQUID magnetometer. Our SQUID data reveal the distinction in behavior of the field cooled magnetization and the zero field cooled one due to correlations of magnetic moments.

Using the calculated value for the magnetic moments typical for anti-site defect makes it possible to estimate the relative fraction of these defects as $\sim$ 0.1-0.3%. The SQUID data obtained are in agreement with our electron spin resonance results which indicate that at temperatures below 80-90 K the underlying magnetic state may be considered as an array of small of easy plane ferromagnets with the magnetizations randomly oriented in the hexagonal (easy) plane. Therefore in the absence of external field the TRS is not violated. Nevertheless it is worth noting that there exist possibilities to generate intrinsic ferromagnetism without introducing any magnetic dopants.

The whole set of our experimental data gives evidence in favor of the possibility of intrinsic magnetism of the topological insulators.

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P12

Inverse proximity effect in Majorana nanowires

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We apply the tunneling Hamiltonian approach to study the superconducting proximity effect in semiconducting nanowires fully covered by a thin superconducting shell. In the framework of the microscopic Gor'kov theory we calculate the superconducting critical temperature of the shell as a function of the chemical potential, Zeeman field, and the energy of spin-orbit coupling. We show that, depending of the values of the quasiparticle relaxation rates, the superconductivity in the shell can be fully suppressed near the van Hove singularities in the electronic density of states in the wire.

Josephson coupling across a long single-crystalline Cu nanowire

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We report on a fabrication method and the electron-transport measurements for submicron Josephson junctions formed by Cu nanowires coupling superconducting planar Nb electrodes for 2-probe and 4-probe measurements. Copper nanowires were prepared by metal electrodeposition inside the cylindrical channels of porous template aluminum oxide. Transmission electron microscopy image and selected area electron diffraction pattern image reveal that copper nanowires have single crystal structure. By taking advantage of Nb as a superconducting electrode and a singlecrystalline Cu nanowire as a barrier, we demonstrate measurable Josephson supercurrent up to relatively high temperature of 3.5 K. The resistivity of Copper nanowires $\rho_{Cu} \simeq 1\ \mu\Omega$ cm is comparable to the values of ρ experimentally achieved earlier for Cu nanowire systems at the liquid helium temperature [1]. The measurements of I_c as a function of magnetic field show that the Josephson supercurrent can be detectable up to a field of 800 Oe. The observed monotonic decrease in I_c with magnetic field and temperature is quantitatively explained on the framework of the quasiclassial theory of superconductivity. As a model for the junctions investigated using 2-probe geometry, we consider an SINIS type structure where I is the interface barrier between the Nb electrode and the Cu nanowire described by the parameter $\gamma_B = R_B/\rho\xi_N$.

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Laser pulse probe of the chirality of Cooper pairs

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The internal chirality of Cooper pairs is shown to modify strongly the response of a superconductor to the local heating by a laser beam. The suppression of the chiral order parameter inside the hot spot appears to induce the supercurrents flowing around the spot region. The chirality affects also the sequential stage of thermal quench developing according to the Kibble-Zurek scenario: besides the generation of vortex–antivortex pairs the quench facilitates the formation of superconducting domains with different chirality. These fingerprints of the chiral superconducting state can be probed by any experimental techniques sensitive to the local magnetic field. The supercurrents encircling the hot spot originate from the inhomogeneity of the state with the broken time reversal symmetry and their detection would provide a convenient alternative to the search of the spontaneous edge currents sensitive to the boundary properties. Thus, the suggested setup can help to resolve the long-standing problem of unambiguous detection of type of pairing in Sr_2RuO_4 considered as a good candidate for chiral superconductivity.

P15

Modeling of networks and globules of charged domain walls observed in pump and pulse induced states.

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Experiments on optical and STM injection of carriers in layered tantalum disulfide $1T-TaS_2$ revealed the formation of nanoscale patterns with networks and globules of domain walls [1–3]. This is thought to be responsible for the metallization transition of the Mott insulator and for stabilization of a "hidden" state [3]. In response, here we present studies of the classical charged lattice gas model emulating the superlattice of polarons ubiquitous to the material of choice [4]. The injection pulse was simulated by introducing a small random concentration of voids which subsequent evolution was followed by means of Monte Carlo cooling. Below the detected phase transition, the voids gradually coalesce into domain walls forming locally connected globules and then the global network leading to a mosaic fragmentation into domains with different degenerate ground states. The obtained patterns closely resemble the experimental STM visualizations. The surprising aggregation of charged voids is understood by fractionalization of their charges across the walls' lines.

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P16

Multiferroicity of $CuCrO_2$ tested by ESR

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CuCrO2 is an example of quasi-two-dimensional antiferromagnet (S = 3/2) with triangular lattice structure. The neutron scattering experiments below $T_N \approx 24\ K$ detected a three dimensional coplanar magnetic order with incommensurate wave vector q_{ic} = (0.329, 0.329, 0) that slightly differs from the wave vector of a commensurate 120° -structure. Spins form the spin planes, which are further described by normal vector **n**. According to ESR and NMR investigations the orientation of the spin plane of magnetic structure is defined by strong easy axis anisotropy perpendicular to trigonal plane (along z-axis) and weak anisotropy perpendicular to one side of the triangle (along y-axis). The magnetic ordering is accompanied by the appearance of an electric polarization **P** (Ref. [1]). The electric polarization is perpendicular to spin plane and is defined by its orientation in space. According to Ref. [2], the main magnetic and multiferroic properties of antiferromagnetic $CuCrO_2$ have explanation in frame of Dzyaloshinski-Landau theory of magnetic phase transitions. Following [2], the potential energy of $CuCrO_2$ dependent on the spin plane orientation in both external magnetic field **H** and electric field **E** in respect to crystallographic axes can be written as:

$$U = \frac{\beta_1}{2} n_z^2 + \frac{\beta_2}{2} n_y^2 - \frac{\chi_\parallel - \chi_\perp}{2} (\mathbf{nH})^2 - P(n_x E_x + n_y E_y) \qquad (1)$$

The first two terms describe the anisotropy energy. One hard axis for the normal vector **n** is parallel to the z-axis and the second axis is parallel to y-axis ($\beta_1,\ \beta_2 > 0, \beta_1 >> \beta_2$). The next term describes the anisotropy of magnetic susceptibility. The last two terms describe the interaction of spontaneous electric polarization **P** with applied electric field **E**.

In the studied case when applied **H** was directed along y-axis and applied **E** was directed along x-axis, the low-frequency branch of spin plane oscillations can be described as:

$$\frac{\omega^2}{\gamma^2} = H^2 + \frac{\beta_2}{\chi_\perp} + \frac{E}{\chi_\perp} \qquad (2)$$

As it can be seen from (2), applied **E** leads to the shift of ESR-spectra.

We report the results of ESR experiments on single crystals of $CuCrO_2$ at the applied electric field. Because of it smallness, the shift of ESR absorption lines was observed with use of modulation technique. The alternating low frequency electric field E_{al} was applied to the sample together with magnetic field. The response on the frequency of applied electric field E_{al} is proportional to derivative of absorption line. The theoretical expectation satisfactory agrees with experimental response.

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Quantitative determination of the the heat conductance for niobium-nitride single photon detectors

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A new generation of niobium-nitride single photon detectors with an internal detection efficiency equal to one is used to determine very accurately the absorbed power. By measuring the electron temperature from the resistive transition of the superconductor, we determine the heat conductance to the substrate, which is a direct measure of the electron-phonon thermal conductance (G_{eph}) and the thermal conductance between phonons and substrate (G_k). We measure the temperature behaviours of G_{eph} and G_k over a temperature range of 5 to 7 Kelvin. This result allows a more accurate modelling of the response of single photon detectors.

Simulating quantum dynamical phenomena using classical oscillators

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Classical oscillators are ubiquitous in nature. With some modifications, they provide analogues of systems from other fields of physics. An important example here is a basic system of quantum mechanics and quantum technologies, a two-level system, or qubit. A qubit is described by its tuned energy levels. Being driven, such system experiences resonant transitions, which is important for both system characterization and control. However, in a number of works in different contexts, it was argued that diverse classical systems can behave like qubits. Such systems include mechanical, opto-mechanical, electrical, and optical realizations.

A quantum system can be driven by either sinusoidal, rectangular or noisy signals. In the literature, these regimes are referred to as Landau-Zener-Stückelberg-Majorana interferometry [1-4], latching modulation [5], and motional averaging [6], respectively. We demonstrate that these pronounced and useful effects are also inherent in the dynamics of classical two-state systems. We discuss how such classical systems are realized using mechanical, electrical, or optical resonators.

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Spin-polarized-current switching mediated by Majorana bound states

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In solid-state systems Majorana bound states (MBSs) are implemented as quasiparticle excitations which are characterized by exponentially small or zero energy and delocalized. The last circumstance makes them attractive for topological quantum computations since an MBS-based qubit is persistent against local perturbation [1]. Semiconducting wires with strong spin-orbit coupling on superconducting substrates [2, 3] seem to be one of the most perspective for this purpose since the experimental proofs of the presence of MBSs in these systems have been already proposed [4, 5]. Today different features related to the MBSs are being actively studied, such as fractional Josephson effect, electronic teleportation, Andreev reflection and the MBS spin polarization. In the last case an important stimulating factor is the prospect to detect MBSs in the spin-polarized tunnel spectroscopy and microscopy experiments. A number of devices using the properties of MBS and the transition between topologically trivial and nontrivial phases have been suggested, for example, memory cells, switches, current rectifiers, Cooper pair splitters [6].

We present the study of transport properties of a superconducting wire with strong Rashba spin-orbit coupling for different orientations of an external magnetic field. Using the nonequilibrium Greens functions in the tight-binding approach the crucial impact of the relative alignment of lead magnetization and the Majorana bound state (MBS) spin polarization on the low-bias conductance and shot noise is presented. Depending on this factor the transport regime can effectively vary from symmetric to extremely asymmetric. In the last situation the current-symmetry breaking, the suppression of the MBS- assisted conductance and specific Fano factor behavior lead to current-switch effect. The persistence of these features under the presence of diagonal disorder and phenomenologically modeled g-factor anisotropy is demonstrated [7].

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Charge and current orders in spin-fermion model with overlapping hot spots

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Authors of this work fabricated hybrid planar Josephson junctions (Al-Cu/Fe-Al) and investigated the electron transport in the structures in the presence (and not) of spin-polarized electrons injector. As well as control current, variable parameters were temperature and the thickness of Cu layer . As a result, one can observe strong suppression of induced superconductivity and oscillating dependence of critical current on spin-injecting current.