Program of Workshop “Spintronics Days in Bilbao 2015”

Organizers:

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Place: Sala Annexo Parainfo, Faculty of Science and Technology, Leioa

Day 1: Thursday, November 5

Chair: Roberto Raimondi (University Rome III)

10.00-10.15 Welcome remarks

10.15-11.00 Vitalii Dugaev (Rzeszow University of Technology)

Shot noise in a magnetic tunneling structure with two-level quantum dot

We consider statistical characteristics of the electron and spin transport in organic magnetic tunnel junctions by monitoring their shot noise. A super-poissonian shot noise indicating a spin dependent bunching in the electron current when it tunnels through the organic barrier is found experimentally. Theoretical model is based on full counting statistics of shot noise, including a spin-dependent tunneling through a two level (or multilevel) system. It can qualitatively explain the observed behavior.

11.00-11.45 Alberto Castro (University of Zaragoza)

Optimal control for electron dynamics: ultrafast manipulation of electronic spin and charge in quantum dots

The theory of Quantum Optimal Control (QOCT) addresses the theoretical optimization of Hamiltonian terms of a quantum system in order to control its behavior (e.g. the optimization of the shape of an external field such as a laser pulse, in order to control the reaction of a molecule irradiated by it). This theory can be applied to single or many-electron systems, in combination with some non-equilibrium electronic structure theory, such as for example time-dependent density-functional theory (TDDFT). I will review our recent progress in the development of this research program, describing the key theoretical issues and the computational solution and challenges. I will illustrate it with various examples, focusing on the manipulation of electrons and spins in semiconductor quantum dots. In particular, we have studied theoretically the possibility of ultra-fast manipulation of the electronic spin in semiconductor quantum dots, by means of high-frequency time-dependent electric fields. The electron spin degree of freedom is excited through spin-orbit coupling, and the procedure may be enhanced by the presence of a static magnetic field.

11.45-12.00 Coffee break

12.00-12.45 Mikhail Durnev (Ioffe Institute, St. Petersburg)

Magnetic field effects on topological edge states in HgTe/CdHgTe quantum wells with strong natural interface inversion asymmetry

We present a theory of the Zeeman effect for the edge states in realistic HgTe/HgCdTe quantum wells with naturally present strong interface inversion asymmetry (IIA). The IIA reflects real symmetry of quantum wells, described by D2d point group. We show that the IIA, which drastically modifies the bulk electronic spectrum, has also a great impact on the edge states. In particular, it gives rise to the following effects: (i) oscillations of the gap in the edge states dispersion as a function of orientation of magnetic field lying in the well plane, and (ii) opening of the gap in the edge states spectrum by arbitrary small out-of-plane magnetic fields. This gap, resulting from the interface mixing of ``spin-up" and ``spin-down" polarized edge states, destroys the spin-polarized quantum spin Hall (QSH) edge transport in agreement with Z2 topology arguments.

12.45 – 13.10 Pavel Pyshkin (University of the Basque Country UPV-EHU, Bilbao)

Spatial localization of electron states in a quantum dot with spin-orbit interaction

It is well known that selective measurements of a system A which is a part of system A+B can be used to control subsystem B upon the existence of coupling between A and B. In our work we study single electron 2D parabolic quantum dot (QD) in the presense of spin-orbit interaction. In such a case, we assume that mentioned above subsystem A is connected with spin and subsystem B is connected with spatial degrees of freedom of electron. We show that in the case of properly choosed time steps between selective spin measurements spatial probability density of electron in QD transforms from circle type in the case of ground or thermal states to “squeezed lines” (or “probability lattice” in case of varying of applied electric field). This effect dramatically depends on strength and type of spin-orbit interaction.

13.10 - 14.30 Lunch break

14.30-14.55 Pavel Bondarenko (University of the Basque Country UPV-EHU, Bilbao)

Dynamical properties of discrete solitons in 1D magnetic dot arrays

Magnetic dot arrays are artificial magnetic structures of submicron magnetic particles organized in one-dimensional (chain-like) or two-dimensional (planar) structures and characterized by rather high spatial regularity. The dots have no direct contact between each other; therefore the sole source of their interaction is the long-ranged dipole-dipole interaction.The kink-like nonlinear waves of magnetization in arrays are computed numerically and analytically, using the exact Gochev’s solution as first-order approximation. Long-range dipole coupling leads to the power-like interaction between soliton centre and moments on the periphery. Peierls-Nabarro barrier (i.e. pinning) is negligible in the static case and depends substantially on kink velocity and single-dot anisotropy. The conditions of pinning decay for dynamical kink in presence of the hard-axis anisotropy were obtained.

14.55-15.20 Rui Li (Beijing Computational Science Research Center)

An exactly solvable model for a strongly spin-orbit-coupled nanowire quantum dot

In the presence of spin-orbit coupling, quantum models for semiconductor materials are generally not exactly solvable. As a result, understanding of the strong spin-orbit coupling effects in these systems remains incomplete. Here we develop a method to exactly solve the one-dimensional hard- wall quantum dot problem in the presence of strong spin-orbit coupling and magnetic field, which allows us to obtain exact eigenenergies and eigenstates of a single electron. With the help of the exact solution, we demonstrate unique effects from the strong spin-orbit coupling in a semiconductor quantum dot, in particular the anisotropy of the electron g-factor and its tunability.

Day 2: Friday, November 6

Chair: Mikhail Durnev (Ioffe Institute, St. Petersburg)

10.15-11.00 Roberto Raimondi (University Rome III)

Spin current swapping and spin Hall effect in a 2DEG

In this talk I will present some of the results obtained over the last year about spin-orbit induced effects in a two-dimensional electron gas. At first I will discuss the spin current swapping effect according to which a spin current flowing in the i direction with spin polarization along the j axis is converted into a spin current flowing in the j direction with spin polarization along the i axis. I will analyze the circumstances under which to observe the effect and its connection with the spin Hall effect. As a second topic I will focus on the spin Hall effect due to the skew-scattering mechanism induced by phonon scattering. A comparison will be made with the standard skew-scattering due to impurities and the consequences for the temperature dependence of the spin Hall angle will be analyzed. Finally, I will present a model with a striped Rashba spin-orbit coupling, which could possibly be realized in LAO/STO interfaces. Such a non homogeneous spin-orbit coupling may give rise to a spin Hall effect robust with respect to impurity scattering.

11.00-11.45 Vladimr Stephanovich (University of Opole)

Fermion condensation quantum phase transition

The common approaches to describe the non-Fermi-liquid (NFL) behaviour in the strongly correlated fermion systems can be summarized by the phrase, that Landau quasiparticles become heavy and die. We propose other approach, in which the Landau quasiparticles also acquire very high (actually infinite) effective mass, but then survive changing their properties drastically. The essence of the approach is that Pomeranchuk conditions of LFL stability do not encompass all possible types of instability. This channel corresponds to the situation (related to the properties of Landau interaction amplitudes) when quasiparticle effective mass diverges. In this case, to avoid the unphysical situation with negative effective mass, the Fermi surface alters its topology so that the substance undergoes so - called fermion condensation quantum phase transition (FCQPT), leading to possibility of "fermion condensation" (FC), i.e. to the situation, where the fermions can occupy the same quantum state very similar to Bose-Einstein condensation. In contrast to the standard Landau Fermi liquid (LFL) result that the quasiparticle effective mass is independent of external parameters like temperature, external magnetic field, pressure etc, the quasiparticle in FC state have their mass dependent on the above parameters. This dependence permits to explain theoretically many NFL peculiarities, inaccessible to other approaches, which do not utilise our extended quasiparticle picture.

11.45-12.00 Coffee break

12.00-12.45 Elena Gomonay (University of Mainz)

Spintronics as spinning of spins: from ferro- to antiferromagnets

Spintronics of antiferromagnets is a new emerging field which opens new perspectives for the element base of information technologies. Practical application of AFM materials however encounters the problems of deterministic switching (writing), measuring (reading) and stabilization (storage) of AFM state in the presence of spin current. This talk gives some fundamental principles of AFM magnetic dynamics and overviews our recent results on manipulation the state of AFM nanoparticle by spin current. Starting from general principles we demonstrate that spin current pumped into AFM particle induces nontrivial magnetic dynamics and present simple analytical tool for its description. We also compare the peculiar features of ferro-and antiferromagnetic dynamics for the typical spintronic materials and highlight the problems of the predictable switching between different AFM states.

12.45 – 13.10 Anna Dyrdal (A. Mickiewicz University, Poznan)

Current-induced spin polarization and spin-orbit torque in graphene

Electric current flowing in a system with spin-orbit interaction can induce spin polarization of conduction electrons. Such a nonequilibrium spin polarization in magnetic structures can generate a spin-orbit torque exerted on localized magnetic moments, and may lead to magnetization switching in the system. Spin-orbit torque is a new interesting alternative to the spin-transfer torque observed in spin valves. We have calculated current-induced spin polarization in graphene deposited on nonmagnetic and ferromagnetic substrates. In the later case the substrate ensures not only the Rashba spin-orbit interaction but also a ferromagnetic moment in the graphene layer. Using the zero-temperature Green functions formalism and linear response theory, we have derived analytical formulas for the spin polarization. We have also compared analytical results with those obtained numerically. In a general case, all components of the current-induced spin polarization are nonzero, contrary to the nonmagnetic limit, where the only nonvanishing component of spin polarization is that in the graphene plane and normal to electric field. We have also determined the corresponding spin-orbit torque that contains two components. The first term is proportional to the component of spin polarization that survives in nonmagnetic limit (therefore is proportional to the momentum relaxation time) and the second one that is independent of the relaxation time.

13.10-13.35 Da-Wei Luo (Beijing Computational Science Research Center and UPV-EHU, Bilbao)

Dynamical invariants in non-Markovian quantum state diffusion equations

We find dynamical invariants for open quantum systems described by the non-Markovian quantum state diffusion (QSD) equation. In stark contrast to closed systems where the dynamical invariant can be identical to the system density operator, these dynamical invariants no longer share the equation of motion for the density operator. Moreover, the invariants obtained with from bi-orthonormal basis can be used to render an exact solution to the QSD equation and the corresponding non-Markovian dynamics without using master equations or numerical simulations. Significantly we show that we can apply these dynamic invariants to reverse-engineering a Hamiltonian that is capable of driving the system to the target state, providing a novel way to design control strategy for open quantum systems.