3rd Workshop on Nanoscale Spin and Charge Dynamics

July 8-12, 2013

City Plaza Hotel

Cluj-Napoca, Romania

The University of Iowa

3rd Workshop on Nanoscale Spin and Charge Dynamics

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Conference Organizers

Michael E. Flatté
Kimberley Hall
Paul Koenraad
Ionel Ţifrea

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3rd Workshop on Nanoscale Spin and Charge Dynamics

PROGRAM

June 8-June 12, 2013

Monday, June 8

8:45-9:00 Michael Flatté and Ionel Tifrea
Welcoming Remarks

9:00-10:00 Jay Gupta, "Tunable control over individual dopants in semiconductors via STM positioning of charged defects"

10:00-10:15 Discussion

10:15-10:45 Coffee Break

10:45-11:45 Cyrus Hirjibehedin, "Exploring the Atomic and Molecular Foundations of Nanospintronics"

11:45-12:00 Discussion

12:00-1:30 Lunch Break

1:30-2:30 Giovanni Vignale, "Spin Hall Effect in Semiconductor Quantum Wells I"

2:30-2:45 Discussion

2:45-3:15 Coffee Break

3:15-3:35 N. Stavrias, "On the electrical detection of the photoionisation of a single Er centre in an ion-implanted Si transistor"

3:35-3:55 V. R. Kortan, "Exchange Interaction of Transition Metal Spin Centers in Diamond"

3:55-4:15 L. E. Kreilkamp, "Tuning of the transverse magneto-optical Kerr effect in magnetoplasmonic crystals"

4:15-5:00 Discussion

Tuesday, June 9

9:00-10:00 Marco Polini, "Light-Matter Interactions in Graphene: From Fundamentals to Plasmonics and Quantum Optics"

10:00-10:15 Discussion

10:15-10:45 Coffee Break

10:45-11:45 Joaquin Fernandez-Rossier, "Spin relaxation mechanisms for localized spins in solids"

11:45-12:00 Discussion

12:00-1:30 Lunch Break

1:30-2:30 Kai Müller, "Ultrafast charge and spin dynamics in self-assembled quantum dots – from tunneling dynamics to coherent optical control of spin qubits"

2:30-2:45 Discussion

2:45-3:15 Coffee Break

3:15-3:35 M. Salewski, "Magnetic-field induced oscillations of spontaneous and stimulated photon echoes from the electron-trion system"

3:35-3:55 O. A. Tretiakov, "Domain-wall dynamics in ferromagnets and antiferromagnets"

3:55-4:15 N. J. Harmon, "Organic magnetoresistance and magnetoelectroluminescence in the presence of fringe fields"

4:15-4:35 M. Ţolea, "Measuring the phase of the electron in isospectral shapes: a study of disorder effects"

4:35-5:15 Discussion

6:00 Banquet

Wednesday, June 10

9:00-10:00 Ania Bleszynski Jayich, "Quantum assisted sensing with diamond spins"

10:00-10:15 Discussion

10:15-10:45 Coffee Break

10:45-11:45 Ben Murdin, "Coherent control of charge excitations in hydrogenic silicon impurities"

11:45-12:00 Discussion

Afternoon - Excursion

Thursday, June 11

9:00-10:00 Martino Poggio, "Harnessing nuclear spin polarization fluctuations in a semiconductor nanowire"

10:00-10:15 Discussion

10:15-10:45 Coffee Break

10:45-11:45 Giovanni Vignale, "Spin Hall Effect in Semiconductor Quantum Wells II"

11:45-12:00 Discussion

12:00-1:30 Lunch Break

1:30-2:45 Scheduled Discussion

2:45-3:15 Coffee Break

3:15-4:15 Scheduled Discussion

4:15-5:00 Open Discussion

Friday, June 12

9:00-10:15 Open Discussion

10:15-10:45 Coffee Break

10:45-12:00 Open Discussion

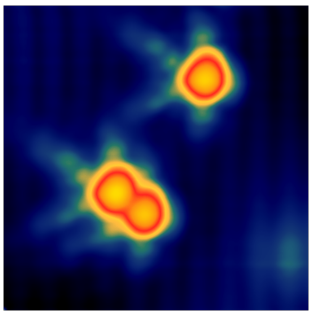
END OF PROGRAM

Tunable control over individual dopants in semiconductors via STM positioning of charged defects

Jay Gupta

Department of Physics, Ohio State University

The scaling of electronic devices such as transistors to nanometer dimensions requires more precise control of individual dopants in semiconductor nanostructures, as statistical fluctuations can impact device performance and functionality. Toward this end, the scanning tunneling microscope (STM) is emerging as a useful tool for its capabilities of atomic manipulation, imaging and tunneling spectroscopy. I will discuss our STM studies of acceptors (Mn, Co, Zn) within the surface layer of a *p*-doped GaAs crystal [1,2,3,4,5]. In addition to the native Zn acceptors, we introduce surface-layer acceptors (Mn, Co) by first sublimating adatoms (Co_{ad}, Mn_{ad}) onto the GaAs (110) surface, prepared by cleavage in ultrahigh vacuum. A voltage pulse applied with the STM tip allows us to replace a Ga atom in the surface with the metal atom, thus forming a single acceptor (Co_{Ga}, Mn_{Ga}) and a Ga adatom (Ga_{ad}). We find that the properties of acceptors can be tuned by control of the local electrostatic landscape. For example, the STM tip can be used to position As vacancies (V_{As}) and other adatoms (e.g. Mn, Ga), all of which are positively charged. Direct Coulomb repulsion causes a reduction in the hole-Mn binding energy as these species are moved nearby. Tunneling spectroscopy allows us to quantify this effect, through the shift of an in-gap acceptor resonance toward lower energy. In addition, we find that defect-induced band bending provides a new, indirect method for locating occupied acceptor states, (*i*) through the appearance of ionization rings in STM images and (*ii*) non-Coulombic behavior at short distances. We have extended this work to dimers of Mn acceptors, in the hopes of tuning the spin-spin interaction between them. Tunneling spectra of the dimers reveal six dimer states, representing bonding and anti-bonding combinations of Mn acceptor states. These states systematically shift in energy as charged defects are brought nearby. Comparison of these experimental results with density functional theory calculations provides further insight into the electronic states and properties of the defects. These studies show that tunable control over single dopants in semiconductors is becoming a realistic route for next-generation classical- and quantum-based information technologies, while at the same time informing the design of conventional nanoscale devices.



STM image of three Mn acceptors within the 1st layer of a GaAs (110) surface.

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[1] D H Lee and J A Gupta, "Tunable Field Control Over the Binding Energy of Single Dopants by a Charged Vacancy in GaAs," *Science* 330, no. 6012 (December 23, 2010): 1807–1810.

[2] Dong-Hun Lee and Jay A Gupta, "Tunable Control Over the Ionization State of Single Mn Acceptors in GaAs with Defect-Induced Band Bending," *Nano Letters* 11, no. 5 (May 11, 2011): 2004–2007.

[3] D H Lee, N M Santagata, and J A Gupta, "Influence of the Local Environment on Zn Acceptors in the GaAs(110) Surface," *Applied Physics Letters* 99, no. 5 (2011): 053124.

[4] David Gohlke et al., "Atomic-Scale Engineering of the Electrostatic Landscape of Semiconductor Surfaces," *Nano Letters* (May 8, 2013): 130508085235000, doi:10.1021/nl400305q.

[5] Anne L Benjamin, Donghun lee, and Jay A Gupta, "Tuning the Electronic States of Individual Co Acceptors in GaAs," *Journal of Vacuum Science & Technology B: Microelectronics and Nanometer Structures* 31, no. 4 (2013): 04D102–04D102–4, doi:10.1116/1.4803841.

How the Local Environment Affects Charge Transport Through a Single Atomic Spin

Cyrus F Hirjibehedin
London Centre for Nanotechnology
Department of Physics & Astronomy
Department of Chemistry
UCL

The drive to continue Moore's Law by shrinking electrical components down to the ultimate limit has led to a great deal of interest in atomic and molecular-scale electronics, in which individual atoms and molecules can be used as circuit elements. More recent proposals also seek to exploit the magnetic properties of these nanoscale objects in new applications in information technology and spintronics. In typical device geometries, the magnetic element is coupled to electrical leads, and these structural and electronic interactions can strongly affect the properties of the quantum system.

Because of its high spatial resolution and ability to construct nanostructures atom by atom, scanning tunneling microscopy (STM) is a powerful tool for studying magnetic atoms and molecules in prototypical device configurations. Using STM, we study charge transport through individual magnetic atoms on surfaces, allowing us to isolate the impact of the local environment. To decrease the Kondo screening that normally occurs when magnetic atoms are in close proximity to metals, we separate the magnetic atoms and the metallic surface with a thin insulating layer of copper nitride (Cu_2N). For Mn and Fe, the low bias charge transport through the atom contains significant contributions from inelastic tunneling. This can be used to directly measure the low energy spin excitation spectrum of these atoms, which allows us to quantify directly their magnetic anisotropy, the property that determines the stability of the spin orientation.

For Co atoms on Cu_2N, we find that exchange coupling of the spin to the metallic bath can result in Kondo screening that exists even in the presence of strong magnetic anisotropy. Remarkably, we find that this coupling changes as a function of position on the island, resulting in a dramatic shifting of the spin excitations that modifies the effective magnetic anisotropy. By controlling the exchange coupling, we can tune both the Kondo screening of the atomic spin as well as the anisotropy energy over a sizeable range of values. This constitutes one of the few cases in which an open quantum system's energy levels, rather than just its excited-state lifetimes, can be controllably and observably renormalized.

Spin Hall effect in semiconductor quantum wells

G. Vignale
University of Missouri-Columbia

The spin Hall effect, i.e., the generation of a transverse spin current from a charge current and viceversa, has attracted much attention in the past decade: it has now become one of the standard tools for the generation and detection of spin currents in magnetoelectronic devices. In the first part I present a pedagogical review of our current understanding of the theory of the spin Hall effect in semiconductor quantum wells and the experiments that support it. In particular, I explain the distinction between "intrinsic" and "extrinsic" spin Hall effect, and the interplay between the two. An interesting many-body effect – the spin Hall drag – involving the Coulomb interaction between two parallel quantum wells will also be discussed.

In the second part I address the question of how the spin Hall effect manifests itself in the dynamics of collective states, e.g. an electron-hole density wave induced by optical excitation on the surface of n-doped GaAs. It has recently been predicted[†] that an electric field parallel to the wavefronts of an electron-hole grating in a GaAs quantum well generates, via the electronic spin Hall effect, a spin grating of the same wave vector and with an amplitude that can exceed 1% of the amplitude of the initial density grating – an observable effect. I refer to this phenomenon as "collective spin Hall effect". A detailed study of the coupled-spin charge dynamics for quantum wells grown in different directions reveals rich features in the time evolution of the induced spin density, including the possibility of generating a helical spin grating from a density grating.

[†]Ka Shen and G. Vignale, arXiv:1306.0889

On the electrical detection of the photoionisation of a single Er centre in an ion-implanted Si transistor

Nikolas Stavrias[1,4], Chunming Yin[2], Milos Rancic[3], Gabriele G. de Boo[2], Jeffrey C. McCallum[1], Matthew J. Sellars[3] and Sven Rogge[2]

[1] Centre of Excellence for Quantum Computation and Communication Technology, School of Physics, University of Melbourne, Melbourne, Victoria 3010, Australia
[2] Centre of Excellence for Quantum Computation and Communication Technology, School of Physics, University of New South Wales, Sydney, New South Wales 2052, Australia
[3] Centre of Excellence for Quantum Computation and Communication Technology, RSPE, Australian National University, Canberra, Australian Capital Territory 0200, Australia
[4] Current address: Radboud University, Institute for Molecules and Materials, FELIX Facility, Toernooiveld 7, 6525 ED Nijmegen, The Netherlands

A goal for solid state quantum information processing is the measurement of a single charge or spin state. Here we present recently published results [1] on the detection of an electron spin associated with a single erbium defect in silicon. Devices were produced by ion-implanting Er into a pre-formed Fin-FET channel and annealing to activate the ions. By applying light resonant to an Er^{3+} transition, photoionisation of single Er centres were detected electrically using the transistor channel as a charge sensor. Optical excitation offers a high resolution probe and electrical detection is extremely sensitive to changes in the charge state of the centre making this hybrid approach an ideal method to study such systems. The Zeeman and hyperfine splitting of single Er centres were also measured. This work could lead to the development of interconnects between optical based and Si quantum technologies.

[1] Yin C. *et al*. Optical addressing of an individual erbium ion in silicon. *Nature*, **497**, 91-94, (2013).

Exchange Interaction of Transition Metal Spin Centers in Diamond

Victoria R. Kortan, Cuneyt Sahin, and Michael E. Flatté
Department of Physics and Astronomy, University of Iowa
Iowa City, IA, USA

Advances in single-ion implantation as well as electronic and optical spectroscopy have permitted direct observation of the exchange interaction between two dopant spins in a semiconductor[1,2], which is accurately described by tight-binding models of the semiconducting host[2,3]. These advances suggest controllable fabrication and utilization of few-dopant structures to explore fundamental properties and for applications[4]. Transition metal substitutional dopants in tetrahedrally-bonded semiconductors are good candidates for controllable spin manipulation and spin-spin interaction because they offer both highly-localized and more extended spin-polarized states. For example, both the Ni and Cr dopants have spin-1 ground states in diamond, but the extent of wavefunction localization is very different[5]. We calculate the exchange interaction between pairs of transition metal spin centers and between two NV centers in diamond as a function of pair separation using the technique of Ref. 3, but with an spds* tight-binding model. We find strong exchange interactions between pairs of transition metal dopants as well as between two NV centers. Table 1 shows the exchange interaction for different pairs of dopant spins along the (001) direction. This work was supported by an AFOSR MURI.

[1] Semiconductor Spintronics and Quantum Computation, ed D.D. Awschalom, N. Samarth & D. Loss (Springer Verlag, Heidelberg, 2002). [2] D. Kitchen et al., Nature 442, 436 (2006). [3] J.-M. Tang & M.E. Flatté, Phys. Rev. Lett. 92, 047201 (2004). [4] P. Koenraad & M.E. Flatté, Nat. Mat. 10, 91 (2011). [5] T. Chanier, et. al., Phys. Rev. B 86, 085203 (2012).

Table 1: NV center and transition metal exchange along (001)

nearest neighbor	pair spacing (Å)	NV–NV (meV)	Cr–Cr (meV)	Ni–Ni (meV)	Cr–Ni (meV)
1	3.56	39	76	87	6
2	7.13	64	0	15	0
3	10.69	7	0	0	0
4	14.26	0	0	0	0

Tuning of the transverse magneto-optical Kerr effect in magnetoplasmonic crystals

L.E. Kreilkamp [1], M. Pohl [1], V.I. Belotelov [2,3] ,I.A. Akimov [1,4], A.N. Kalish [2,3], N.E. Khokhlov [2], V.J. Yallapragada [5], A.V. Gopal [5], M. Nur-E-Alam [6], M. Vasiliev [6], D.R. Yakovlev [1,4], K. Alameh [6], A.K. Zvezdin [3,7] and M. Bayer [1]

[1] Experimentelle Physik 2, Technische Universität Dortmund, 44221 Dortmund, Germany
[2] Lomonosov Moscow State University, 119991 Moscow, Russia
[3] Prokhorov General Physics Institute, Russian Academy of Sciences, 119992 Moscow, Russia
[4] Ioffe Physical-Technical Institute, Russian Academy of Sciences, 194021 St. Petersburg, Russia
[5] Tata Institute of Fundamental Research, 400005, Mumbai, India
[6] Electron Science Research Institute, Edith Cowan University, 6027 Joondalup, WA, Australia
[7] Moscow Institute of Physics and Technology (State University), 141700, Dolgoprudny, Russia

Magneto-optical effects in ferri- or ferromagnetic materials are usually too weak for potential applications. The transverse magneto-optical Kerr effect (TMOKE) in ferromagnetic films, for example, is typically on the order of 0.1%. A viable route to enhance those effects is to capitalize on the electromagnetic field concentration induced by exciting surface plasmon polaritons, collective motions of the electron gas at the interface between a metal and a dielectric. While enhancement schemes based on the use of ferromagnetic metals are hampered by the high optical losses in those materials, nanopatterning of a noble metal gold grating on top of a magnetic dielectric allows to create hybrid magnetoplasmonic structures that can even be studied in transmission geometry.[1]

In this work the spectral properties of the TMOKE in such one-dimensional magnetoplasmonic crystals are studied, in particular with respect to the achievable magnitude. It is shown that the TMOKE is sensitive to the magneto-optical activity of the bismuth-substituted rare-earth iron garnet, which is used as dielectric material in the investigated structures. For samples with larger Bi substitution level and, consequently, larger gyration constant the magnitude of the TMOKE increases and reaches 13% in case of a $Bi_{1.8}Lu_{1.2}Fe_{3.6}Al_{1.4}O_{12}$ magnetic film. Further, it is demonstrated that the TMOKE vanishes at the high symmetry points of the Brillouin zone (at the Γ and X points). The main enhancement of the TMOKE takes place near the resonances of the surface plasmon-polaritons (SPPs) at the metal/magnetic-dielectric interface. However, near the degenerate resonances of the SPPs at the air/metal and metal/magnetic-dielectric interfaces the TMOKE is increased by the air/metal SPPs as well. This phenomenon is explained in terms of a coupled oscillator model.

Literature:

[1] V. I. Belotelov et al., Enhanced magneto-optical effects in magnetoplasmonic crystals. Nat. Nanotechnol., 6(6):370–376, 2011.

Light-Matter Interactions in Graphene: From Fundamentals to Plasmonics and Quantum Optics

Marco Polini
Scuola Normale Superiore di Pisa

In my lecture I will review recent progress in the rapidly evolving field of `graphene plasmonics' [1]. In particular, I will focus on the fundamental properties of Dirac plasmons [2,3] in a doped graphene sheet, highlighting the subtle differences with plasmons in ordinary two-dimensional electron liquids. In the last part of my lecture I will argue that the unique optoelectronic properties of graphene make this two-dimensional material an ideal platform for fundamental studies of cavity quantum electrodynamics in the strong-coupling regime. I will demonstrate [4] that the celebrated Dicke model of cavity quantum electrodynamics can be approximately realized in this material when the cyclotron transition of its 2D massless Dirac fermion carriers is nearly resonant with a cavity photon mode. I will present a theory of strong matter-photon coupling in this circumstance, emphasizing the essential role of a dynamically generated matter energy term that is quadratic in the photon field and absent in graphene's low-energy Dirac model.

References

[1] A.N. Grigorenko, M. Polini, and K.S. Novoselov, Nature Photon. **6**, 749 (2012).
[2] S.H. Abedinpour, G. Vignale, A. Principi, M. Polini, W.-K. Tse, and A.H. MacDonald, Phys. Rev. B **84**, 045429 (2011).
[3] A. Principi, G. Vignale, M. Carrega, and M. Polini, arXiv:1305.4666v1.
[4] L. Chirolli, M. Polini, V. Giovannetti, and A.H. MacDonald, Phys. Rev. Lett. **109**, 267404 (2012).

Spin relaxation mechanisms for localized spins in solids

Joaquin Fernandez-Rossier
INL Portugal

In this talk I will discuss the problem of spin relaxation of a localized spin in a solid state environment. The systems include magnetic dopants in semiconductor nanostructures, NV centers in diamond, magnetic adatoms on surfaces, nuclear spins in a variety of hosts, etc. I will discuss 3 things:

1) The definition of two different time scales, T1, and T2, and their physical meaning, in the context of the theory of system plus reservoir dissipative dynamics
2) The different physical mechanisms that lead to spin relaxation, such as exchange coupling to nearby electrons, hyperfine interactions and spin-phonon coupling
3) The technical details to calculate the spin relaxation lifetimes, and how the scaling of these lifetimes with different energy scales in the problem sheds information on the dominant type of mechanism.

Ultrafast charge and spin dynamics in self-assembled quantum dots - from tunneling dynamics to coherent optical control of spin qubits

Kai Müller
Walter-Schottky-Institut
TU-München

Due to their discrete optical spectrum and strong interaction with light, self-assembled semiconductor quantum dots (QDs) have strong potential for quantum information processing applications. The properties listed above allow them to profit from the established toolbox of quantum optical techniques, while in contrast to real atoms they can be easily integrated into opto-electronic devices. Vertically stacking of quantum dots produces more sophisticated nanostructures so-called quantum dot molecules.

In this presentation, I give a review of the basic properties of self-assembled quantum dots such as growth, optical properties and the main optical spectroscopy techniques that are commonly used such as photoluminescence emission, photocurrent absorption, photoluminescence-excitation or resonance fluorescence. In addition, I discuss an ultrafast multicolor pump-probe spectroscopy technique that allows probing charge and spinning dynamics on picosecond timescales. This technique provides exquisite sensitivity to probe charge and spin dynamics as well as coherence properties of individual quantum dot nanostructures [1-3] or even perform coherent optical control of single spins [4].

We present several recent results obtained with this technique. The investigated charge dynamics include the tunneling of charge carriers from single quantum dots [1] and intra-molecular tunneling dynamics in quantum dot molecules [2]. While tunneling from single quantum dots is well described by WKB formalism, inter-dot tunneling plays an important role for quantum dot molecules. In particular, the comparative roles of ultrafast resonant elastic and phonon-mediated inelastic tunneling are discussed.

We discuss the ultrafast initialization, coherent optical control and projection readout of single exciton spins and single hole spins with fidelities exceeding 96% [3-4]. By applying a third laser pulse we obtain high-fidelity coherent optical control of the single spin state.

[1] K. Müller et al. Ann. Phys., 525: 49–58 (2013)
[2] K. Müller et al. Phys. Rev. Lett. 108, 197402 (2012)
[3] K. Müller et al. Phys. Rev. B 85, 241306(R) (2012)
[4] K. Müller et al. Scientific Reports 3, 1906 (2013)

Magnetic-Field induced oscillations of Spontaneous and Stimulated Photon Echoes from the Electron-Trion System

M. Salewski,[1] L. Langer,[1] S.V. Poltavtsev,[1,2] I. A. Yugova,[1,2] D. R. Yakovlev,[1,3] G. Karczewski,[4] T. Wojtowicz,[4] J. Kossut,[4] I. A. Akimov,[1,3] and M. Bayer[1]

[1] *Experimentelle Physik 2, Technische Universität Dortmund, 44221 Dortmund, Germany*
[2] *Spin Optics Laboratory, St. Petersburg State University, 198504 St. Petersburg, Russia*
[3] *A.F. Ioffe Physical-Technical Institute, 194021 St. Petersburg, Russia*
[4] *Institute of Physics, Polish Academy of Sciences, PL-02668 Warsaw, Poland*

Coherent optical phenomena in atomic ensembles and other systems with discrete energy level structure attract a lot of attention for realization of optical quantum memories. One of these phenomena is the photon echo where in the classical picture an intense optical pulse results in rephasing and retrieval of the macroscopic medium's polarization, which was created by a preceding optical pulse. The extension by a third pulse allows to stimulate the photon echo such that the retrieval occurs on demand.

Our concept relies on the photon echo in an electron-trion system in n-type CdTe semiconductor quantum wells subject to transverse magnetic field. The ground (electron) and the excited (trion) states are the doublets characterized by the electron ($S = +1/2, -1/2$) and hole ($J = +3/2, -3/2$) spin projections, respectively. The selection rules for optical transitions allow the coupling of the $\pm 1/2$ and $\pm 3/2$ states, respectively. Optical transitions can be well accessed due to a spectral separation of neutral and charged (trion) exciton resonances. As shown in Fig. 1, three pulses were used for excitation and an additional reference pulse enabled the use of heterodyne detection of the emitted photon echo amplitude.

The first pulse at $t = 0$ induces a coherent superposition of optically accessible electron and trion states (e.g. $S = +1/2$, $J = +3/2$ - called *optical coherence*). A magnetic field in Voigt-geometry leads to Larmor precession of the electron spin in the ground state. Hence the *optical coherence* is continuously transferred into a superposition of a pair of states that is optically inaccessible (e.g. $S = -1/2$, $J = +3/2$ - called *dark coherence*) and back with Larmor precession frequency. This results in an oscillatory behavior of the photon echo, which depends sensitively on the polarization configuration of the exciting and refocusing pulses [1].

The second pulse at $t = \tau_{12}$ can also lead to transfer of the *optical coherence* into a long-lived, dark electron spin coherence. Using a third pulse we can convert it again into an optical coherence which is selected by the stimulated echo appearing at $t = 2\tau_{12} + \tau_{23}$. Fig. 2 shows that the application of a transverse magnetic field allows storing optical coherence for a long period of time. The results are explained in terms of the optical Bloch equations accounting for the spin level structure of electrons and trions.

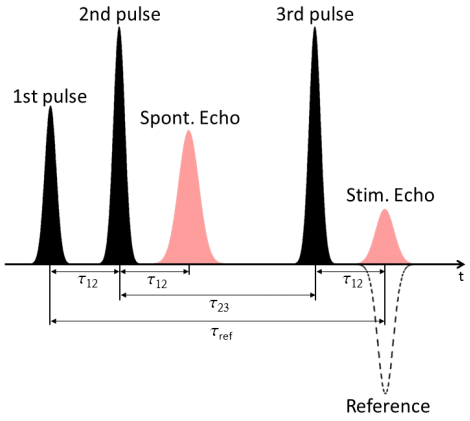

Fig. 1: Scheme of pulses and delay times.

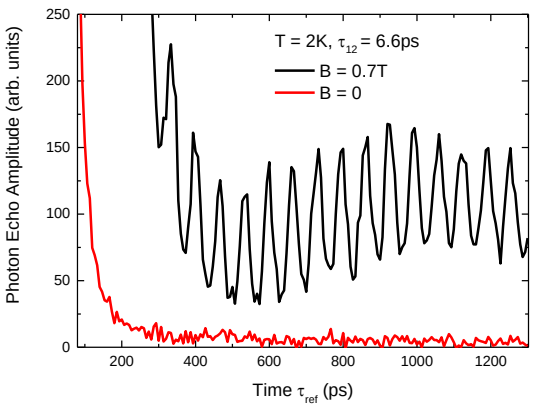

Fig. 2: Amplitude of Stimulated Photon Echo.

[1] L. Langer *et al.*, Phys. Rev. Lett. **109**, 157403 (2012).

DOMAIN-WALL DYNAMICS IN FERROMAGNETS AND ANTIFERROMAGNETS

O. A. Tretiakov
Institute for Material Research, Tohoku University, Sendai 980-8577, Japan
olegt@imr.tohoku.ac.jp

Ferromagnets (FMs) and antiferromagnets (AFMs) can be used to store and manipulate spin information, and new developments have created opportunities to use them as active components in spintronic devices. We study current-induced domain-wall (DW) dynamics in thin FM and AFM nanowires. We derive effective equations of motion describing the dynamics of the DW soft modes associated with topological defects. Because the DWs are topological objects with a rigid spin structure, these equations are rather universal. The DW rigidity makes the microscopic details irrelevant and allows us to solve the DW dynamics for a very general class of spin Hamiltonians. We show that the DW dynamics in FMs is described by simple equations with only four parameters. Based on these equations, we study DW dynamics in a ferromagnetic wire with Dzyaloshinskii-Moriya interaction (DMI) [1]. We obtain spin spiral DW structure and how the critical current required to move the domain wall depends on the strength of DMI. We also investigate the DW dynamics driven by time-dependent currents. We find the most efficient (with the lowest Ohmic losses) way to move the DWs by resonant current pulses [2]. In addition, we propose a procedure to unambiguously determine the DW dynamics parameters by all-electric measurements of the time-dependent voltage induced by moving DW [3]. Furthermore, based on the derived DW dynamics equations for the translationally non-invariant nanowires, we show how to make prospective magnetic memory nanodevices much more energy efficient [4].

In AFMs, the dynamics is described by coupled equations of the staggered field and the magnetization. These equations are very complex and have many degrees of freedom. We present a theory which is conceptually much simpler and which uses collective coordinates to describe staggered field dynamics in antiferromagnetic textures [5]. The theory includes effects of dissipation, external magnetic field, as well as reactive and dissipative current-induced torques. We derive the equations of motion for the collective modes, equivalent to the classical motion of a massive particle subjected to dissipation-induced friction and external forces. We conclude that, at low frequencies and amplitudes, currents induce collective motion in AFMs by means of dissipative rather than reactive torques.

[1] O. A. Tretiakov and Ar. Abanov, Phys. Rev. Lett. 105, 157201 (2010).
[2] O. A. Tretiakov, Y. Liu, and Ar. Abanov, Phys. Rev. Lett. 105, 217203 (2010).
[3] Y. Liu, O. A. Tretiakov, and Ar. Abanov, Phys. Rev. B 84, 052403 (2011).
[4] O. A. Tretiakov, Y. Liu, and Ar. Abanov, Phys. Rev. Lett. 108, 247201 (2012).
[5] E. G. Tveten, A. Qaiumzadeh, O. A. Tretiakov, and A. Brataas, Phys. Rev. Lett. 110, 127208 (2013).

Organic Magneto-resistance and Magneto-electroluminescence in the Presence of Fringe Fields

N. J. Harmon[1], F. Macià[2], F. Wang[1], M. Wohlgennant[1], A. Kent[2], and M. E. Flatté[1]

[1] *Department of Physics and Astronomy and Optical Science and Technology Center, U. of Iowa, Iowa City, Iowa 52242, USA*

[2]*Department of Physics, New York University, New York, New York 10003, USA*

Recently it was discovered that the spatially varying fringe fields emanating from an unsaturated ferromagnet layer produce large effects on the magneto-conductive (FIG 1) and magneto-electroluminescent properties of organic semiconductors [1]. Unlike the normal magnetic field effect observed in organic semiconductors [2], which is caused by the hyperfine fields varying roughly at the hopping length scale [3], the fringe fields vary on a length scale much larger than the hopping length. We have incorporated fringe fields into our recent theory [4] of organic magneto-resistance to explain the transport phenomena [5]. Solutions to the stochastic Liouville equation are found to explain the magneto-electroluminescence properties. In both cases, analysis of the fringe field distributions and their gradients shows that the spatial variation of the fringe fields across a typical hopping distance can be comparable to that of the hyperfine fields. Our theory and calculations yield several results in general agreement with the experiments such as how the fringe fields change the magneto-resistance and magneto-electroluminescence line shape, and the dependence of the magneto-resistance on the distance, z_i, between the organic semiconductor and the ferromagnetic layer (FIG 2). We acknowledge support from an ARO MURI and stimulating discussions with P. A. Bobbert.

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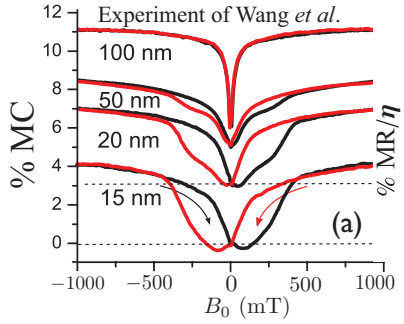

FIG 1

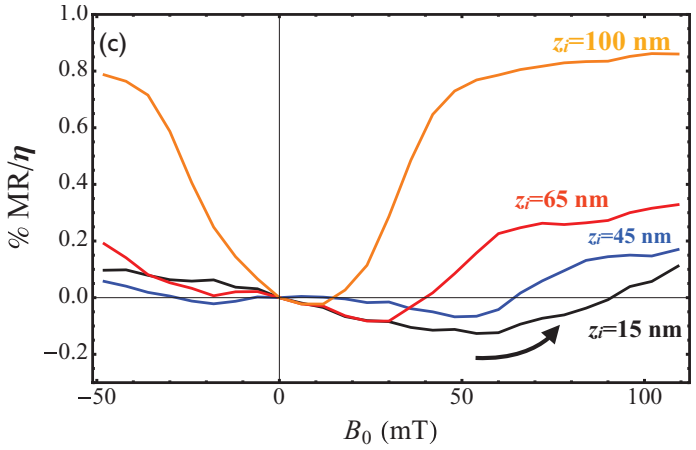

FIG 2

Measuring the phase of the electron in isospectral shapes: A study of disorder effects

M. Ţolea, B. Ostahie, M. Niţă, F. Ţolea, and A. Aldea
National Institute of Materials Physics, Bucharest-Magurele, Romania

The phase of a wave function is not a direct observable, unlike the amplitude, however the phase distribution is essential in interference experiments, bonding of molecular orbitals, etc. When one thinks about measuring the electron phase, the interference is the first word coming to mind - as initially realized by Schuster et al. [Nature 385, 417 (1997)]. However, C.R. Moon et.al. [Science 319, 782 (2008)] -in a remarkable recent experiment- demonstrated that isospectrality can also be used to extract phase distributions. The existence itself of isospectral shapes (i.e. non-congruent polygons which have the same spectrum for the Laplace operator) was a long-debated mathematical challenge, the first such pairs being found by Gordon et al. [Inventiones Math. 110, 1 (1992)]. The eigenfunctions of the isospectral pairs have a particular property, called transplantation, which allows to build one function by using combination of parts from the other. In principle, this brings a supplementary information, allowing one to extract the phase distributions of the eigenfunctions, if the amplitude distributions are known. In our theoretical study [M. Tolea et. al Phys.Rev.E 85, 036604 (2012)], we numerically simulate such a phase extraction procedure in the presence of disorder. With disorder, the transplantation can no longer lead to a perfect fit of the wave functions, however we show that a phase can still be extracted - defined as the phase that minimizes the misfit. Interestingly, this extracted phase coincides with (or differs negligibly from) the phase of the disorder-free system, up to a certain disorder amplitude, and a misfit of the wave functions as high as 5%, proving a robustness of the phase extraction method against disorder. A discrete model is used, which is the natural approach for disorder analysis.

Quantum assisted sensing with diamond spins

Ania Bleszynski Jayich
University of California, Santa Barbara

Nitrogen-vacancy (NV) centers in diamond are single spin systems with remarkable quantum properties. They are easy to initialize, read out, and manipulate on the individual spin level and they maintain exceptionally long (many ms) coherence times at room temperature. Motivated by their enticing properties, there has been a significant amount of research on NV centers in recent years spanning disciplines from quantum information processing to nanoscale magnetic sensing. In this talk, I will review recent advances in understanding, forming, and using NV centers in quantum applications. I will focus primarily on quantum assisted sensing of fields (e.g. magnetic, electric, and strain) as well on the different approaches aimed at integrating NVs into quantum networks.

Coherent control of charge excitations in hydrogenic silicon impurities

BN Murdin[1], K Litvinenko[1], Juerong Li[1], E. Bowyer[1], M. Pang[1], PT Greenland[2], B Villis[2], G Aeppli[2], AFG van der Meer[3], B Redlich[3] H. Engelkamp[3], and CR Pidgeon[4]

[1]Advanced Technology Institute, University of Surrey, Guildford GU2 7XH, UK
[2]London Centre for Nanotechnology, University College London, London WC1H 0AH, UK
[3] Institute for Molecules and Materials, Radboud University Nijmegen, Toernooiveld 7, NL-6525 ED Nijmegen, The Netherlands
[4]Department of Physics, Heriot-Watt University, Edinburgh EH14 4AS, UK
E-mail: b.murdin@surrey.ac.uk

Shallow donor impurities in silicon, once frozen out at low temperature, share many properties in common with free hydrogen atoms [1]. They have long been the subject of spectroscopic investigation, but it is only very recently [2,3] that it has been possible to investigate the time-domain dynamics of orbital excitations such as the 1s to 2p, due to the difficulty of obtaining short, intense pulses in the relevant wavelength range. These new techniques make shallow donors (and also acceptors [4]) attractive for studying atomic physics effects, and for applications in quantum information. We have measured the population dynamics [2] of electrons orbiting around phosphorus impurities in commercially-available silicon, and shown that the lattice relaxation lifetime is about 200ps, only 1 order of magnitude shorter than the radiative lifetime of free hydrogen.

Coherent oscillation, where many particles cycle in phase, is responsible for classical phenomena like the emission of strong radio waves by many individual electrons in an antenna. At the quantum scale, coherent superposition of spin polarisations is central to Magnetic Resonance Imaging and its family, in which coherence is excited and then reappears later producing a delayed radio pulse (the spin “echo”). Quantum computer logic will also rely on coherence, and spins are often chosen as “qubits” because they are only weakly connected to, and disturbed by, the environment. Paradoxically, connection with the outside world is crucial for control, making charge (i.e. orbital) oscillations in semiconductors attractive. We have shown that silicon donor electrons can be put into a coherent superposition of orbital states that lasts for nearly as long as the lattice relaxation time [3]. Our results pave the way for new devices where information is stored in single electron orbits (“coherent orbitronics”) in the material that has dominated the classical computing industry for half a century.

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Harnessing nuclear spin polarization fluctuations in a semiconductor nanowire

Martino Poggio
University of Basel

Soon after the first measurements of nuclear magnetic resonance (NMR) in a condensed matter system, Bloch [1] predicted the presence of statistical fluctuations proportional to N^(-1/2) in the polarization of an ensemble of N spins. First observed by Sleator et al. [2], so-called "spin noise" has recently emerged as a critical ingredient in nanometer-scale magnetic resonance imaging (nanoMRI) [3-5]. This prominence is a direct result of MRI resolution improving to better than (100 nm)^3, a size-scale in which statistical spin fluctuations begin to dominate the polarization dynamics. We demonstrate a technique that creates spin order in nanometer-scale ensembles of nuclear spins by harnessing these fluctuations to produce polarizations both larger and narrower than the natural thermal distribution. We focus on ensembles containing ~10^6 phosphorus and hydrogen spins associated with single InP and GaP nanowires (NWs) and their hydrogen-containing adsorbate layers. We monitor, control, and capture fluctuations in the ensemble's spin polarization in real-time and store them for extended periods. This selective capture of large polarization fluctuations may provide a route for enhancing the weak magnetic signals produced by nanometer-scale volumes of nuclear spins. The scheme may also prove useful for initializing the nuclear hyperfine field of electron spin qubits in the solid-state.

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