arXiv:1210.3622

**Collectively Enhanced Interactions in Solid-state Spin Qubits**

Hendrik Weimer,[1,2] Norman Y. Yao,[1] Mikhail D. Lukin[1]

*(1) Physics Department, Harvard University, 17 Oxford Street, Cambridge, MA 02138, USA*

*(2) ITAMP, Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA*

We propose and analyze a technique to collectively enhance interactions between solid-state quantum registers composed from random networks of spin qubits. In such systems, disordered dipolar interactions generically result in localization. Here, we demonstrate the emergence of a single collective delocalized eigenmode as one turns on a transverse magnetic field. The interaction strength between this symmetric collective mode and a remote spin qubit is enhanced by square root of the number of spins participating in the delocalized mode. Mediated by such collective enhancement, long-range quantum logic between remote spin registers can occur at distances consistent with optical addressing. A specific implementation utilizing Nitrogen-Vacancy defects in diamond is discussed and the effects of decoherence are considered.

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**Giant Collective Spin-Orbit Field in a Quantum Well: Fine Structure of Spin Plasmons**

F. Baboux,[1] F. Perez,[1] C. A. Ullrich,[2] I. DAmico,[3] J. Gomez,[1] and M. Bernard[1]

*(1) CNRS/Universit Paris VI; (2) University of Missouri; (3) University of York.*

We employ inelastic light scattering with magnetic fields to study intersubband spin plasmons in a quantum well. We demonstrate the existence of a giant collective spin-orbit (SO) field that splits the spin-plasmon spectrum into a triplet. The effect is remarkable as each individual electron would be expected to precess in its own momentum-dependent SO field, leading to Dyakonov-Perel dephasing. Instead, many-body effects lead to a striking organization of the SO fields at the collective level. The macroscopic spin moment is quantized by a uniform collective SO field, five times higher than the individual SO field. We provide a momentum-space cartography of this field.

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**Inter-band tunneling near the merging transition of Dirac cones**

J.-N. Fuchs, [1,2,3] L.-K. Lim,[1,2] G. Montambaux[1]

*(1) Univ. Paris-Sud; (2) CNRS; (3) Univ. P. et M. Currie*

Motivated by a recent experiment in a tunable graphene analog [L. Tarruell et al., Nature 483, 302 (2012)], we consider a generalization of the Landau-Zener problem to the case of a quadratic crossing between two bands in the vicinity of the merging transition of Dirac cones. The latter is described by the so-called universal hamiltonian. In this framework, the inter-band tunneling problem depends on two dimensionless parameters: one measures the proximity to the merging transition and the other the adiabaticity of the motion. Under the influence of a constant force, the probability for a particle to tunnel from the lower to the upper band is computed numerically in the whole range of these two parameters and analytically in different limits using (i) the Stueckelberg theory for two successive linear band crossings, (ii) diabatic perturbation theory, (iii) adiabatic perturbation theory and (iv) a modified Stueckelberg formula. We obtain a complete phase diagram and explain the presence of unexpected probability oscillations in terms of interferences between two poles in the complex time plane. We also compare our results to the above mentioned experiment.

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**Majorana Single-Charge Transistor**

R. Hutzen,[1] A. Zazunov,[1] B. Braunecker,[2] A. Levy Yeyati,[2] and R. Egger[1]

*(1) Heinrich-Heine-Universität, Düsseldorf, Germany; (2) Universidad Autónoma de Madrid*

We study transport through a Coulomb blockaded topologically nontrivial superconducting wire (with Majorana end states) contacted by metallic leads. An exact formula for the current through this interacting Majorana single-charge transistor is derived in terms of wire spectral functions. A comprehensive picture follows from three different approaches. We find Coulomb oscillations with universal halving of the finite-temperature peak conductance under strong blockade conditions, where the valley conductance mainly comes from elastic cotunneling. The nonlinear conductance exhibits finite-voltage sidebands due to anomalous tunneling involving Cooper pair splitting.

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**Tuning the band gap of bilayer graphene by ion implantation: Insight from computational studies**

Shijun Zhao, Jianming Xue

*Peking University, China*

By employing molecular dynamics (MD) simulations based on empirical potentials and density functional theory, we demonstrate that the electronic properties of bilayer graphene could be tailored by means of low-energy ion irradiations. We first performed MD simulations to investigate the doping and intercalation effect in bilayer graphene induced by low-energy B and N bombardment. Our simulation shows that there are two maximal probabilities for perfect substitution of a carbon atom with incident B or N, corresponding to the two layers. The highest substitutional probability is observed for N irradiation which is 38% at 70 eV in the upper layer and 33% at 110 eV in the lower layer. We have calculated the energy bands for all the atomic configurations that appear after the bombardment of B and N and show that the band gap of bilayer graphene can be widely tuned via the incorporation of B and N into the bilayer graphene. The maximal band gap is found to be 392.1 meV when the B implants into a graphene layer with the knocked C forms a C-C dumbbell defect in another layer. We also investigate the probability of Au intercalated into the bilayer graphene and show that up to 93% of incident Au can be trapped between the two layers when the incident energy is close to 90 eV, which gives rise to the n-type doping of graphene. The present results demonstrate that ion irradiation is an effective route to manipulate the structure of bilayer graphene and thus provide a way for controllable modification of its electronic properties for a variety of future nanoelectronic applications.

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arXiv:1210.4338

**Spontaneous time-reversal symmetry breaking for spinless fermions on a triangular lattice**

Olivier Tieleman,[1] Omjyoti Dutta,[1] Maciej Lewenstein,[1,2] Andr Eckardt[1,3]

*(1) Parc Mediterrani de la Tecnologia, Castelldefels, Spain;*

*(2) Institució Catalana de Recerca i Estudis Avançats, Barcelona, Spain; (3) MPI, Dresden*

As a minimal fermionic model with kinetic frustration, we study a system of spinless fermions in the lowest band of a triangular lattice with long-range repulsion. We find that the combination of interactions and kinetic frustration leads to spontaneous symmetry breaking in various ways. Time-reversal symmetry can be broken by two types of loop current patterns, a chiral one and one that breaks the translational lattice symmetry. Moreover, the translational symmetry can also be broken by a density wave forming a kagome pattern or by a Peierls-type trimerization characterized by enhanced correlations among the sites of certain triangular plaquettes (giving a plaquette-centered density wave). We map out the phase diagram as it results from leading order Ginzburg-Landau mean-field theory. Several experimental realizations of the type of system under study are possible with ultracold atoms in optical lattices.

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arXiv:1210.4320

**Induced superconductivity in the three-dimensional topological insulator HgTe**

L. Maier, J. B. Oostinga, D. Knott, C. Bruene, P. Virtanen, G. Tkachov, E. M. Hankiewicz, C. Gould, H. Buhmann, L. W. Molenkamp

*University of Würzburg*

A strained and undoped HgTe layer is a three-dimensional topological insulator, in which electronic transport occurs dominantly through its surface states. In this Letter, we present transport measurements on HgTe-based Josephson junctions with Nb as superconductor. Although the Nb-HgTe interfaces have a low transparency, we observe a strong zero-bias anomaly in the differential resistance measurements. This anomaly originates from proximity-induced superconductivity in the HgTe surface states. In the most transparent junction, we observe periodic oscillations of the differential resistance as function of an applied magnetic field, which correspond to a Fraunhofer-like pattern. This unambiguously shows that a precursor of the Josephson effect occurs in the topological surface states of HgTe.

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**Quantum oscillations and Berry's phase in topological insulator surface states with broken particle-hole symmetry**

Anthony R. Wright, Ross H. McKenzie

*University of Queensland, Australia*

Quantum oscillations can be used to determine properties of the Fermi surface of metals by varying the magnitude and orientation of an external magnetic field. Topological insulator surface states are an unusual mix of normal and Dirac fermions. Unlike in graphene and simple metals, Berry's geometric phase in topological insulator surface states is not necessarily quantised. We show that reliably extracting this geometric phase from the phase offset associated with the quantum oscillations is subtle. This is especially so in the presence of a Dirac gap such as that associated with the Zeeman splitting or interlayer tunneling. We develop a semiclassical theory for general mixed normal-Dirac systems in the presence of a gap, and in doing so clarify the role of topology and broken particle-hole symmetry. We propose a systematic procedure of fitting Landau level index plots at large filling factors to reliably extract the phase offset associated with Berry's phase.

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**A proposal to probe quantum non-locality of Majorana fermions in tunneling experiments**

Jay D. Sau,[1] Brian Swingle,[1] Sumanta Tewari[2]

*(1) Harvard University; (2) Clemson University*

Topological Majorana fermion (MF) quasiparticles have been recently shown to exist in semiconductor quantum wires with proximity induced superconductivity and a Zeeman field. Although the experimentally observed zero bias tunneling peak and a fractional ac-Josephson effect can be taken as necessary signatures of MFs, neither of them constitutes a sufficient "smoking gun" experiment. Since one pair of Majorana fermions share a single conventional fermionic degree of freedom, MFs are in a sense fractionalized excitations. Based on this fractionalization we propose a tunneling experiment that furnishes a nearly unique signature of end state MFs in semiconductor quantum wires. In particular, we show that a "teleportation"-like experiment is not enough to distinguish MFs from accidental conventional zero energy states, but our proposed tunneling experiment, in principle, can make this distinction.

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**Finite-difference method for transport of two-dimensional massless Dirac fermions in a ribbon geometry**

Alexis R. Hernández,[1,2] Caio H. Lewenkopf[3]

*(1) Univ. Federal do Rio de Janeiro; (2) PUC Rio de Janeiro, (3) Universidade Federal Fluminense*

We present a numerical method to compute the Landauer conductance of noninteracting two-dimensional massless Dirac fermions in disordered systems. The method allows for the introduction of boundary conditions at the ribbon edges and accounts for an external magnetic field. By construction, the proposed discretization scheme avoids the fermion doubling problem. The method does not rely on an atomistic basis and is particularly useful to deal with long-range disorder, the correlation length of which largely exceeds the underlying material crystal lattice spacing. As an application, we study the case of monolayer graphene sheets with zigzag edges subjected to long-range disorder, which can be modeled by a single-cone Dirac equation.

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**First-Matsubara-frequency rule in a Fermi liquid. I. Fermionic self-energy; II. Optical conductivity and comparison to experiment**

Andrey V. Chubukov, Dmitrii L. Maslov

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Phys. Rev. Lett. 109, 160503 (2012)

**High Threshold Error Correction for the Surface Code**

James R. Wootton, Daniel Loss

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arXiv:1210.4057

**Majorana fermions from Landau quantization in a superconductor–topological-insulator hybrid structure**

Rakesh P. Tiwari, U. Zlicke, C. Bruder