A Letters Journal Exploring the Frontiers of Physics

July 2011

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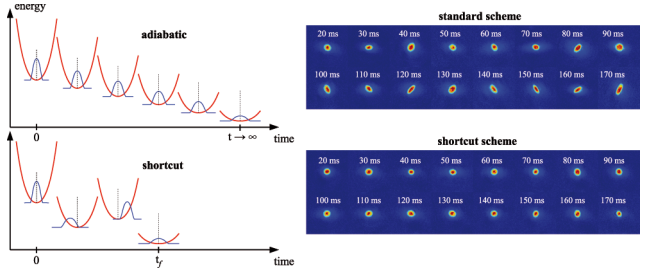
Highlights from the previous volumes

Shortcut to adiabaticity with ultracold atoms

Adiabatic transformations are widely used in physics, and, for instance, are at the heart of the manipulation of quantum states. In such transformations, the Hamiltonian should typically vary slowly with time, such that the system always remains close to equilibrium. The drawback is the long transition time, which in some situations becomes unpractical due to finite lifetime or coherence time of the state under study. Alternatively, a "shortcut to adiabaticity" is a specifically designed temporal trajectory of the Hamiltonian, which connects the initial to the final state in a shorter time. The system is out of equilibrium *during* the transition, but the final state is *identical* to that obtained via an adiabatic transition (see the left panel of the figure).

We have applied this strategy for the first time, to rapidly decompress an interacting Bose-Einstein condensate (BEC) held in a magnetic trap. Reducing the trap confinement also shifts the cloud vertically by a large amount, due to gravity. We implemented a 30 ms long trajectory designed for a 10-fold reduction of the trap frequency. Because of experimental imperfections, the final state we obtained is not an equilibrium one. However, we were able to demonstrate a large reduction of BEC excitations (dipole and breathing modes) when comparing the shortcut to other standard decompression schemes (see the right panel of the figure). This trajectory was also shown to work for a thermal cloud with negligible interactions, hinting at the broad range of application of this technique.

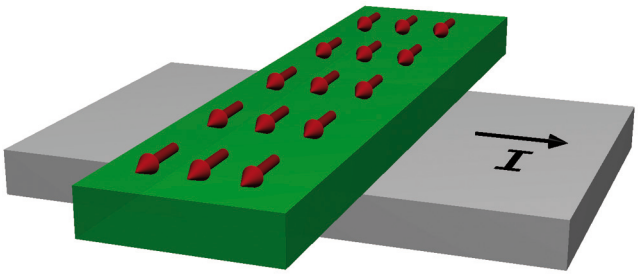


Left: principle of shortcut to adiabaticity. The blue and red curves represent the BEC wave function and trapping potential respectively. Right: comparison of BEC excitations produced by standard and shortcut decompressions.

Original article by Schaff J.-F. *et al.*
EPL, **93** (2011) 23001

Spin-charge locking and tunneling into a helical metal

Spintronics aims at exploiting the electron spin for new device functionalities. In recent years a new spintronic paradigm, based on the spin-orbit interaction, has been proposed aiming to gain spin control by electric fields. In this respect, topological insulators (TI) appear as a very promising opportunity. At the surface of a TI gapless excitations occur with extraordinarily strong spin-orbit coupling: a given surface momentum is associated with a single spin direction, such that the states on the Fermi surface have a well-defined helicity. In this paper we present a theoretical study of the dynamics of the electrons moving on the surface of a three-dimensional TI, *i.e.* in a two-dimensional helical metal (HM). When the HM is brought into contact with a ferromagnet there arises an unconventional magnetoresistance. The origin of the effect is the spin-orbit coupling: since the electron momentum is connected to a single spin state, a current flow creates a nonequilibrium spin polarization. This current-induced spin polarization increases or decreases the spin-dependent voltage difference between the helical metal and the majority or minority carriers in the FM and thus modifies the tunneling current. By reversing the flow of the current in the helical metal the two spin species exchange their role. In the ideal case the tunneling current between the FM and the HM can be switched on and off depending on the relative orientation of the magnetization of the FM with respect to the direction of the current flow in the HM.

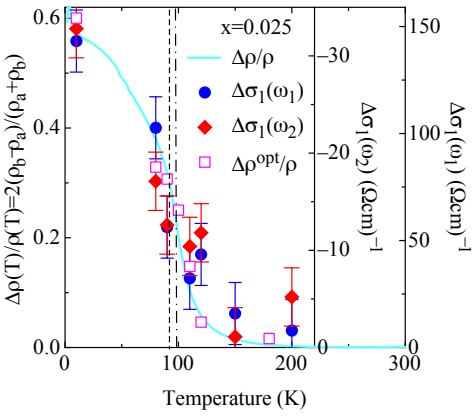


A ferromagnet (green) that is coupled to a topological insulator (grey) such that electrons can tunnel between the two materials. It is found that a current flow in the surface states of the topological insulator strongly modifies the tunneling current.

Original article by Schwab P. *et al.*
EPL, **93** (2011) 67004

Optical evidence of nematicity in iron-based superconductors

A nematic order recently arose as a robust electronic state describing the nature of the pseudogap phase in the high-temperature superconducting cuprates. In the field of liquid crystals, a nematic state derives from a transition breaking the rotational symmetry of the high-temperature phase but preserving the translational one. Besides the cuprates, the novel iron-based superconductors in their parent and underdoped phase recently emerged as an alternative playground for studying an electron nematicity in a correlated system. The iron-arsenide superconductors harbor indeed an antiferromagnetic ground state, which is either preceded or accompanied by a structural tetragonal-orthorhombic phase transition at T_s. This structural transition breaks the fourfold symmetry of the high-temperature lattice and leads to an anisotropic conducting state. This broken rotational symmetry has thus a direct impact in the optical properties. We investigate the optical conductivity $\sigma_1(\omega)$ with light polarized along the in-plane orthorhombic a- and b-axes of $Ba(Fe_{1-x}Co_x)_2As_2$ for $x = 0$ and 2.5% under uniaxial pressure across their phase transitions. The charge dynamics on these detwinned, single-domain samples reveals an in-plane optical anisotropy (*i.e.*, linear dichroism) which extends to relatively high frequencies and at $T > T_s$. This reveals substantial nematic susceptibility as well as the electronic nature of the structural transition. Another key result consists in the opportunity to disentangle the distinct behaviors of the Drude weights and scattering rates of the itinerant charge carriers, which are both enhanced along the a-axis with respect to the b-axis. Our findings allow us to clarify the long-standing striking anisotropy ($\rho_b > \rho_a$) of the dc resistivity.

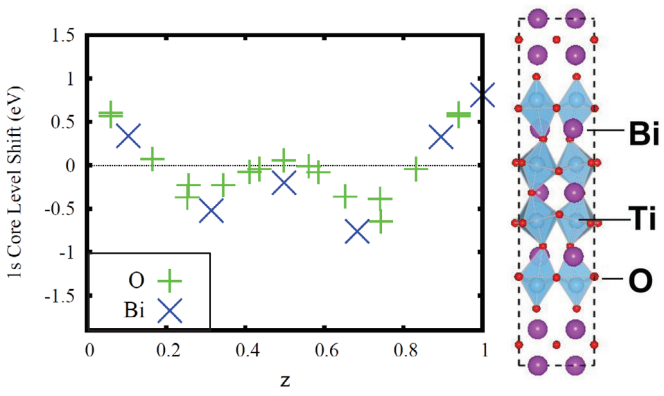


Temperature dependence of the dichroism $\Delta\sigma_1(\omega) = \sigma_1(\omega, E \parallel a) - \sigma_1(\omega, E \parallel b)$ for $x = 0.025$ at selected frequencies compared to the dc anisotropy ratio ($\Delta\rho/\rho$). The anisotropy in the dc limit of the optical conductivity ($\Delta\rho^{opt}/\rho$) is reported, as well. The vertical dashed and dash-dotted lines mark the magnetic and structural phase transitions, respectively.

Original article by Dusza A. *et al.*
EPL, **93** (2011) 37002

Design of a low band gap oxide ferroelectric: $Bi_6Ti_4O_{17}$

The manipulation of band gaps in oxides while retaining function is a long-standing problem. Xu and co-workers discuss a strategy based on manipulation of the Coulomb potential by artificial layering and illustrate its use to produce a titanate ferroelectric with a band gap below 2 eV. This is 1 eV below the lowest band gap of a titanate ferroelectric compound and is in a range that is potentially useful for solar and other optical applications. They start with the known ferroelectric $Bi_4Ti_3O_12$, which has a band gap of approximately 3 eV. This compound may be regarded as a layered system consisting of stacks of alternating perovskite and fluorite structure blocks. Importantly, the ferroelectric polarization is substantial and close to the plane of the layers. The authors used a combination of first-principles relaxations and electronic-structure calculations to show that they could alter the Coulomb potential enough to shift the relative positions of the cation derived conduction bands relative to the O $2p$ valence bands by 1 eV, while nonetheless retaining a sizable ferroelectric polarization. This manipulation of the Coulomb potential is illustrated in the figure, which shows the calculated shifts in the $1s$ core levels of the Bi and O atoms as a function of position along the layer stacking direction in the unit cell. The mechanism that the authors use is general and could be applied to other layered oxide systems including other ferroelectrics. The ability to shift bands in engineered oxide structure on the eV scale may also be important for other applications such as oxide electronics and photo-catalysis.



$1s$ core level variation for O and Bi along the long axis of the unit cell as shown on the right. This represents the variation in the Coulomb potential that is induced by the layer stacking in this material.

Original article by Xu Bo *et al.*
EPL, **94** (2011) 37006