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NEWS

In the News

Tanja Horn's PhD thesis, entitled "Exploring the Universal Glue" is currently on the Jefferson Lab home p Horn finished her PhD in April 2006. To view the article, visit www.jlab.org or www.jlab.org/news/releases/2007/glue.html

Richard Berg, Professor, was mentioned in the Washington Post article regarding homespun proverbs. E physics expertise was used to determine the reality of popular proverbs. The article appeared in the Nove 12th issue.

Robert Park, Professor, was quoted in the December 9th issue of New Scientist. Park discussed the num self-published books and articles he receives from people claiming to have discovered a breakthrou conspiracy theory in science.

IceCube is featured in Science Magazine's special Particle Astrophysics issue. Several images accompar articles written by Francis Halzen and staff writers. The issue is now available to Science subscribers at: www.sciencemag.org

Hung-Chih Kan, Assistant Research Scientist and **Raymond J. Phaneuf**, Associate Professor, have co-written and published a paper in the IOP Publishing Journal, Nanotechnology. The paper entitled, "Trar Roughening Behavior and Spontaneous Pattern Formation During Plasma Etching of Nanoporous Silica," be featured in the February 2007 print version. To read the paper online, visit: www.iop.org/EJ/abstract/-ffissn=all/0957-4

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RESEARCH SPOTLIGHT

Artificial magnetic field in spin-orbit coupled semiconductors and new devices for spin electronics
By: Victor Galitski

Conventional electronic devices are based on the transport of charged carriers (electrons or holes) in metals and semiconductors. Now, condensed matter physicists are trying to use another route to create a new generation of spintronic devices by using the quantum degree of freedom of the electron – spin – rather than its charge. Much of the recent work in this direction has concentrated on the theoretical understanding and experimental development of mechanisms to electrically manipulate the spin degree of freedom in non-magnetic systems. An important recent experimental discovery is that by applying an electric field, one can achieve electron-spin polarization near the edges of semiconductor structures with spin-orbit interactions (see Fig. 1). This remarkable phenomenon, dubbed the spin Hall effect, has a great potential for technological applications (sensing technologies, novel memory devices, quantum computing, etc.), primarily because it is compatible with existing semiconductor technologies. Apart from the purely technological interest, understanding spin transport is a very interesting problem from the theoretical point of view.

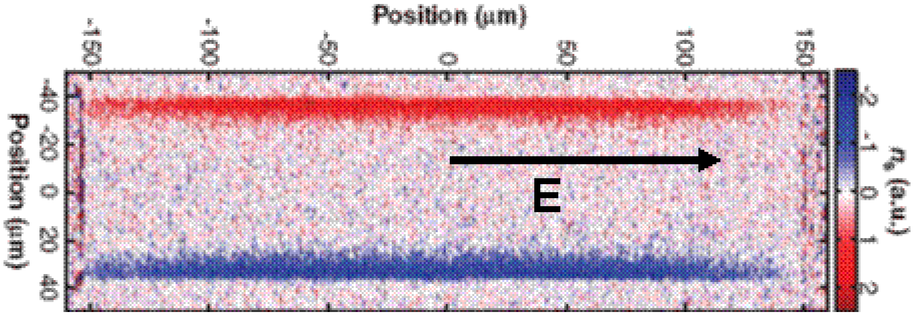

Figure 1: Electrically induced electron-spin polarization near the edges of a semiconductor channel (Kato *et al.*, Science **306**, 1910, 2004)

The key to understanding electric-field-induced spin accumulation in semiconductors is spin-orbit interaction, which couples the electron's momentum and spin. It turns out that non-trivial spin transport in clean spin-orbit coupled systems is due to so-called Berry's phase, which is a beautiful and unusual quantum-mechanical effect. To understand the latter effect, one has to recall that the properties of a quantum particle (such as the electron) are described in terms of a wave-function, which has an absolute value and a phase. In 1984, Michael Berry showed that if one very slowly (adiabatically) changes the properties of a quantum system so that in the end of the adiabatic evolution all parameters return to their initial values, the wave-function does not necessarily returns to its original value, but may acquire an additional phase (now known as the Berry's phase). This phase has a very elegant mathematical interpretation: If we imagine that the relevant parameters describing the system form a vector space (just like the coordinates x, y, and z form a three-dimensional space in which we live), the adiabatic evolution of the system would be described as a loop in this space. Remarkably, the Berry's phase can be interpreted as a flux of a fictitious magnetic field in this parameter space through the area enclosed by the loop. This strange "magnetic field" occurs due to "magnetic charges" or monopoles, which are located in the points where the spectrum is degenerate (energy of the quantum particle has special degenerate values). What does it have to do with the electron in a semiconductor? If there were no spin-orbit interactions, the electron spectrum would be the familiar parabolic dispersion, which will be the same for the electrons with up and down spins. However, once spin-orbit interaction appears, it splits the dispersion into two curves (see Fig. 2), which originate from the electrons with different projections of spin. These two bands cross at a degeneracy point, which serves a source of an artificial magnetic field in momentum space. The latter affects the motion of electrons with opposite spin projections differently. In the presence of an external electric field, electrons with opposite spin projections flow in the opposite directions and eventually lead to measurable spin polarizations near the edges of the sample.

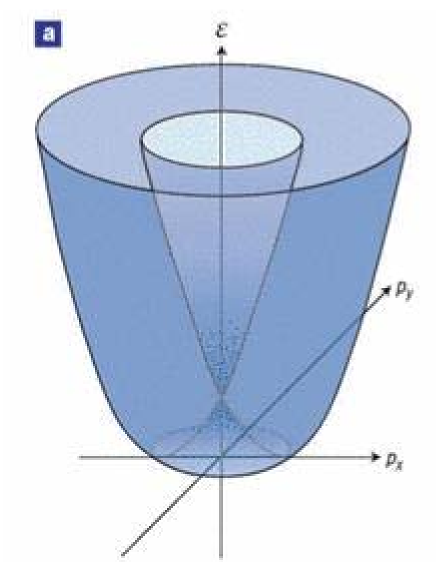

Figure 2: Electron spectrum in the presence of spin-orbit interactions. The coupling between the momentum and spin splits the conventional parabolic dispersion into two bands, which cross at a degeneracy point. This degeneracy point serves as a source of an artificial magnetic field in momentum space.

We, at the University of Maryland, have been trying to understand spin transport and electric-field-induced spin accumulation in realistic disordered spin-orbit coupled systems. All real materials contain impurities and other defects, which strongly affect the above-mentioned picture of spin transport based on the Berry's phase. Electrons scatter off of the impurities and each scattering sharply changes the momentum. Due to the spin-orbit interaction, this also leads to a sharp and random change in the spin precession axis. Thus, in the presence of disorder, the electron spin precesses in a random fashion. This spin dynamics can be visualized as diffusion or random walk of the spin on a sphere. For example, if we start with the state in which the electron's spin points in the up direction (toward the North pole of the sphere), after a few scatterings, the spin will deviate from its original direction. Eventually, spin diffusion will lead to complete spin relaxation. In our research, we have been studying different mechanisms of spin relaxation and in particular looking for ways to minimize its negative effects. It has been shown that by considering different types of spin-orbit interactions and boundary structures, one can find optimal conditions, which would enhance the desired effect of spin accumulation. This opens a new exciting opportunity for engineering of new spintronic devices.

Dr. Galitski is an Assistant Professor of Physics at the University of Maryland. He is a member of the Condensed Matter Theory group. If you would like to contact him, please send any questions or comments to the Editor .

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ALUMNI SPOTLIGHT

Physics Alumnus' Journey Leads to Familiar Grounds

When Rich Barber Jr. gives advice, he’s speaking from experience. Through years of trials and errors, he’s found a position that’s rewarding and familiar. As the Physics Chair at Santa Clara University in California’s Silicon Valley, Barber enjoys the environment of his institution, which is very similar to the place where he received his undergraduate degree.

Barber grew up in Mooresville, NC. He earned his bachelor’s degree, in Physics, from Davidson College; a small liberal arts college near Charlotte, NC. After graduating, he searched for an institution with a broad range of possibilities to obtain a doctoral research degree.

“Maryland had just about everything,” said Barber.

In 1990, Barber received his Ph.D. His research work was under Professor Rolfe E. Glover, III. His dissertation was entitled, “The Onset of Conduction and Superconductivity in this Pb films.” At Maryland, he always felt appereciated.

"I think the graduate students were respected as a vital resource in the department, " said Barber. "For such a big department it seemed small because of the feeling of community...

There were certainly the 'big university' red tape issues, but there always seemed to be an Earlene Bradley/ Jane Hessing or Lorraine DeSalvo to help fix them."

After Maryland, Barber was a post-doc at UC San Diego, with Bob Dynes. There, he helped set up a lab and studied the superconductor-insulator transition in disordered films. Then, he decided to take a different path.

“In 1993, the job market was pretty bad,” said Barber. “I tried a second post-doc position in physical oceanography. That was a good experience, because I learned that I did not want to do oceanography.”

As Barber began his search for yet another faculty position, he was hired at Santa Clara University. Here, he has continued work on disordered superconductors and also some new research on polymer photovoltaics. Since starting with the University in 1995, Barber built a laboratory where he studies superconductivity and other low-temperature phenomena. Recently, he completed a sabbatical at Laboratory for Physical Sciences in College Park. This current position often reminds Barber of his past.

“Santa Clara is a liberal arts university (no physics graduate students), “Said Barber. “This fact presents both challenges and opportunities. The undergraduates are very good and very motivated. They can do significant research, and they are a delight to teach in the lab and the classroom. It is an environment not unlike my own undergraduate experience.”

Now, Barber finds himself in a great position as Physics Chair at Santa Clara University. He offers this advice to current students:

” Don’t be afraid to try things that might not work out, you’ll probably learn more from the failures anyway. When you are looking for a job, be yourself. When we hire faculty we look for the best match, not simply the ‘best’ scientist.”

Betsy Beise, professor, and Maryland alumna, **Kristin Kiriluk**, participated in an experiment at NIST whic resulted in the first experimental observation of a rare neutron decay process in which quanta of light are emitted along with the other, more well-known decay products (a proton, electron and anti-neutrino). A key element of the experiment was the development of a photon detector that could operate well at low temperatures inside the bore of the superconducting magnet that was part of the apparatus. While Kristin an undergraduate physics major, she worked with the NIST group to help develop the photon detector. He work culminated in a senior thesis project, for which she was a co-recipient of both the best honor's thesis award and IPST's Monroe Martin Undergraduate thesis prize for outstanding research in 2005. Kristin is r graduate school in experimental nuclear physics at Colorado University in Boulder. The results of the NIST experiment are reported in the December 21 issue of Nature. Additional background information and the p release by NIST can be found at www.nist.gov/public_affairs/releases/neutron_light.html.