



Ultrafast optics and the emergent properties of solids

Jake D. Koralek

Lawrence Berkeley National Laboratory

Just as a body in motion through a vacuum tends to stay in motion, the axis of a spinning electron tends to remain fixed in direction. Both phenomena are conservation laws that ultimately derive from the uniformity of empty space. By contrast, an electron moving through a solid crystal flies past a lattice of charged atoms at $\sim 1\%$ of light speed, causing its spin direction to fluctuate wildly. This interaction, called spin-orbit coupling, leads to the non-conservation of spin, which has severely limited our ability to make use of spin in technological applications. In the first part of this talk I will discuss experiments in which femtosecond pulses of light are used to manipulate spins in a 2D Fermi gas in Gallium Arsenide. In this model system we have been able to tune the spin-orbit interaction such that the symmetry of the Hamiltonian is increased, and spin conservation is restored. This new form of spin conservation is unique in that it is no longer simply the total spin polarization which is conserved, but rather a collective helical spin density wave which we call the persistent spin helix. We have recently been able to detect the velocity of moving spin helices in a current carrying Fermi gas, revealing a new picture of spin & charge transport in spin-orbit coupled systems.

In the second part of my talk I will focus on Cuprate superconductivity. Unlike Gallium Arsenide, which is so well understood that we can engineer whatever Hamiltonian we desire, the physics of the high T_c Cuprates remains a mystery. One key to solving this mystery lies in understanding the pseudogap which exists at intermediate temperatures between the superconducting and normal metallic phases. I will discuss our observation of a transient optical reflectivity signal which emerges rapidly with the opening of the pseudogap in Cuprates. This is complemented by angle-resolved photoemission, polar-Kerr effect, and transport measurements on the same samples, all showing an abrupt transition upon cooling below the pseudogap temperature. I will also discuss a new technique we have developed to distinguish coexisting phases of matter by resolving the phase of their optical response.