MAR12-2011-004167

Abstract for an Invited Paper
for the MAR12 Meeting of
the American Physical Society

Doppler velocimetry of a current driven spin helix

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We present direct observation of the translational motion of spin helices in GaAs quantum wells under the influence of applied electric fields. Previously, the lifetime of such helices was observed by time-resolving the amplitude of light diffracted from the periodic spin polarization [1]. This technique cannot be applied to tracking the motion of current-driven spin helices because diffraction amplitude is insensitive to translation of the center of mass of a periodic structure. In this talk, we describe a new experimental technique, Doppler spin velocimetry, capable of resolving displacements of spin polarization at the level of 1 nm on a picosecond time scale [2]. This is accomplished through the use of heterodyne detection to measure the optical phase of the diffracted light. We discuss experiments in which this technique is used to measure the motion of spin helices as a function of temperature, in-plane electric field, and photoinduced spin polarization amplitude. Several striking observations will be reported – for example, the spin helix velocity changes sign as a function of wavevector and is zero at the wavevector that yields the largest spin lifetime. Another important observation is that the velocity of spin polarization packets becomes equal to the drift velocity of the high-mobility electron gas in the limit of small spin helix amplitude. Finally, we show that spin helices continue propagate at the same speed as the Fermi sea even when the electron drift velocity exceeds the Fermi velocity of 10^7 cm-s^{-1}. In collaboration with J. D. Koralek and J. Orenstein, UC Berkeley and LBNL, D. R. Tibbetts, J. L. Reno, and M. P. Lilly, SNL. Supported by DOE under Contract No. DE-AC02-05CH11231 and DE-AC04-94AL85000.

[1] J. D. Koralek et al., "Emergency of the persistent spin helix in semiconductor quantum wells," Nature 458, 610-613 (2009).

[2] L. Yang et al, "Doppler velocimetry of spin propagation in a two-dimensional electron gas," to appear in Nature Physics.