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Evidence for a persistent spin helix in a 2-dimensional electron gas

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Using time-resolved transient spin-grating spectroscopy we uncover strong evidence for the existence of a persistent spin helix (PSH) in a 2-dimensional electron gas. The PSH is a collective helical spin excitation that persists far beyond the lifetime of its individual constituent spins when the Rashba (α) and Dresselhaus (β) spin-orbit coupling terms are comparable. The helix is predicted to have an infinite lifetime when they are exactly equal. These effects have great potential for application to spintronics where they would allow rapid gate control of the spin lifetime over several orders of magnitude in systems with both high electron density and high mobility. The transient spin-grating technique is ideally suited for study of the PSH as it can directly measure the dynamics of optically generated spin excitations of variable spatial periodicity. This is accomplished by interfering two non-collinear, orthogonally polarized pulses from a Ti:Sapphire laser at the surface of the sample. Through the optical orientation effect in GaAs, this generates a spin excitation which varies periodically in space between up and down spins at a wavelength determined by the angle between the interfering pulses. We tune the spin-orbit coupling in our GaAs based quantum wells through asymmetric modulation doping, which has allowed us to increase α to be comparable to β. In these systems we find that spin-gratings with periodicity comparable to that of the PSH can live several orders of magnitude longer than the individual spin lifetime as measured by time-resolved Faraday rotation. We study this over a wide range of parameter space, systematically varying doping asymmetry, well width, and disorder. We find that the lifetime of the PSH in these samples is ultimately limited by the spatial disorder in the Rashba strength, and by a novel relaxation mechanism based on phonon-induced Rashba coupling. Supported by DMSE office of BES-DOE, NSF, MARCO, ASEE and CNID.

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