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Coherent spin dynamics in organic electronic devices

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Organic semiconductors, such as pi-conjugated polymers, offer exciting opportunities for the development of novel device architectures. While much of the earlier work has focused on exploiting the unique processing conditions of these materials – solution-based, flexible plastics – organic electronics also provides access to a range of physical parameters not found in many inorganic systems. The spin-degree of freedom is particularly intriguing in organic semiconductors, which are characterized by weak spin-orbit coupling and medium to strong hyperfine interactions. Primary photoexcitations exhibit strong ($\sim$0.7 eV) exchange interactions, leading to phosphorescent triplet states shifted to lower energy with respect to the singlets [1]. Organic semiconductors exhibit strong magnetic field dependencies in charge carrier recombination and transport, and concomitantly in conductivity [2,3], which generally indicate extremely weak spin-lattice relaxation [2]. Spin dephasing is also very slow, so that spin excitations maintain phase coherence over timescales in excess of microseconds. This phenomenon allows the observation of time-domain spin Rabi flopping in the device current, by exploiting the technique of electrically-detected magnetic resonance [4]. Most recently, spin beating due to the coherently-coupled nutation of electron and hole spins has been observed, providing a direct visualization of hyperfine coupling. Coherent organic spin electronics may ultimately lead to new device concepts besides providing a deeper understanding of fundamental material properties, which are crucial to minimizing degradation.

[1] PRL 89, 167401 (2002).
[2] Nature Mat. 4, 340 (2005).
[3] Nature Mat. 7, 598 (2008).
[4] Nature Mat. 7, 723 (2008).