PHYSICS DEPARTMENT COLLOQUIUM

"THE ELECTRICAL DETECTION OF SPIN COHERENCE - APPLICATIONS FOR SEMICONDUCTOR SPECTROSCOPY AND IMPLICATIONS FOR QUANTUM INFORMATION CONCEPTS"

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Traditional spin measurement techniques such as electron spin resonance (ESR) and nuclear magnetic resonance require spin ensembles consisting of about 1010 and 1015 spins, respectively. This poses a fundamental challenge for the coherent spin spectroscopy of low dimensional semiconductor systems and also for spin based quantum information (QI) concepts which demand the sensitive measurement of coherent electron or nuclear spin states.

Different approaches for the solution of this problem have been pursued in the past which commonly take advantage of spin-selection rules that govern electronic transitions. For optically detected transitions it has been proven that both, the detection of coherent spin motion as well as the spectroscopy of a single spin is possible [1]. For the spin-measurement in low band gap materials like silicon, such optically detected spin techniques are oftentimes not feasible since either the spin-dependent transitions are non-radiative or radiative at wavelengths too long to be detected at very low intensities and high time resolution. Hence, alternative concepts based on spin-controlled charge currents are currently investigated which show that single spins can be detected electrically [2,3] and that the coherent spin propagation can be observed for spin ensembles consisting of 100 to 1000 spins [4,5].

In this talk, the experimental principles of coherent (pulsed) electrically detected magnetic resonance (pEDMR) are presented. The difficulties and challenges of the electrical detection of coherent spin motion during a pulsed ESR excitation are outlined and the potentials and limitations of an electrical spin spectroscopy are discussed based on different experimental examples that are presented. Beyond its application for semiconductor spectroscopy, the time dependent detection scheme used for pEDMR may also be applied for the readout of small spin ensembles or even single spins in QI systems. This idea is discussed for the example of the readout of 31P nuclear spins in a crystalline 28Si host matrix.

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