Non-linear spin dynamics, the OISTR effect, and the birth of atto-magnetism

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This lecture is about the motion of electrons in solids on the femto- and atto-second time scale; how it can be monitored, analyzed and, ultimately, controlled with ultra-short laser pulses. Real-time simulations are performed employing the ab-initio approach of time-dependent density functional theory. We shall visualize the laser-induced formation and breaking of chemical bonds in real time, and we shall highlight non-steady-state features of the electronic (charge and spin) current through nano-scale junctions. With the goal of pushing magnetic storage processes towards faster and faster time scales, we have predicted how the local magnetic moment can be manipulated with ultrashort laser pulses. The underlying mechanism is an optically induced spin transfer (OISTR) from one magnetic sub-lattice to another [1,2]. As an all-optical process, OISTR is temporally limited by the duration of the laser pulse, which may be as short as atto-seconds. OISTR was first predicted by real-time simulations and later confirmed experimentally. On longer time scales, decoherence arises from the non-adiabatic coupling of electronic and nuclear motion. A full ab-initio description of decoherence [3,4] is achieved with an algorithm deduced from the exact factorization [5].

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