# Advanced Ultrafast Diagnostics of Spin Dinamics in Complex Materials

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Strong correlations between spin and other (e.g. charge, lattice, orbital) degrees of freedom play an important role in an emergence of new and exotic properties of correlated electron materials (CEM). In high-temperature superconductors antiferromagnetic spin fluctuations represent the most likely mechanism of Cooper pair binding, and the strongest magneto-electric coupling in multiferroic materials arises from the symmetry breaking caused by complex spin alignment [1]. The unifying theme among all CEMs is an existence of electronic, magnetic and structural spatial inhomogeneities at sub-nanometer-to-micrometer scales and closely related nontrivial picosecond dynamics in response to transient stimuli [2]. The characteristic length and time scales of these inhomogeneities are of extreme interest because they contain information about the underpinning correlations between multiple order parameters. In this regard, ultrafast optical spectroscopy has much to offer due to its ability to temporally, and since recently, spatially resolve phenomena at the fundamental timescales of atomic and electronic motion. Here, we will review our recent results on ultrafast optical studies of spin, charge, and lattice dynamics, and more importantly, of the dynamics of the coupling between these degrees of freedom in a broad range of magnetic CEM materials [2-4]. We will also describe our new "tabletop" ultrafast time-resolved coherent x-ray capabilities [5] and give a perspective on their application to CEM studies [6].

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