MAX PLANCK INSTITUTE
FOR THE STRUCTURE AND DYNAMICS OF MATTER

ANNOUNCEMENT - TALK

Title: Optical coherent control of quantum materials

Abstract:
A major research effort in the area of condensed matter physics aims to optically manipulate the macroscopic properties of quantum materials [1]. Remarkable critical phenomena have been reported, such as the laser-induced metal-insulator transition [2], metamagnetic phase transitions [3], and even superconductivity [4]. The dynamical control of the order parameter has been achieved in magnetic materials [5], even via coherent processes, which rely on the optical generation of coherent collective eigenmodes [6,7]. In my talk, I will introduce the main light-matter interaction mechanisms enabling the optical activation of coherent quasiparticles, with a particular focus on magnetic excitations. I will discuss in details two aspects. First, the generation of collective spin excitations, namely spin waves or magnons, both at the center and at the edges of the Brillouin zone, while avoiding the absorption of light by the lattice and the electrons [8-9]. The regime of quantum spin dynamics triggered by the activation of high-energy magnons will be discussed as well [9-10]. Second, I will address the coupling between spins and electrons at the ultrashort timescale. Mechanisms allowing to drive spin waves both at the center and at the edges of the Brillouin zone, via mixed electronic and magnonic transitions, will be the topic of discussion [11-12]. I will then report on our very recent successful attempts to couple coherent THz magnons to charges at the picosecond timescale and our ongoing efforts to establish a manipulation of the spin-orbit coupling, via the excitation of coherent THz phonons [13]. In the final part of my talk, I will then present novel concepts to manipulate quantum materials, i.e. the dynamical modification of the spectrum and dispersion relation. I will show an unprecedented scheme to couple zone-edge and zone-centre modes [14], which results in the renormalization of the frequency and amplitude of the zone-centre magnons [15]. The observed regime of strongly nonlinear coherent spin dynamics is elusive of the conventional picture provided by linear spin wave theory. The development of a quantitative theoretical understanding of the observations, in collaboration with theorists, will be presented as well. In conclusion, I will briefly show extremely novel results concerning an alternative route to modify the magnon spectrum, which does not involve zone-edge magnons at all. The concepts discussed in my talk provide basic tools for a dynamical engineering of macroscopic coherent states of quantum materials, operating at the intrinsic characteristic time scales of

the collective eigenmodes. The approaches presented here can be applied to a wide variety of systems and can be generalized to lattice excitations.

[1] Advances in Physics 65, 58–238 (2016). [2] Nature 449, 72–74 (2007). [3] Physical Review Letters 116, 097401 (2016). [4] Science 331, 189–191 (2011). [5] Physical Review Letters 99, 047601 (2007). [6] Nature 435, 655 (2005). [7] Nature Photonics 5, 31–34 (2010). [8] Physical Review B 89, 060405(R) (2014). [9] Nature Communications 7, 10645 (2016). [10] Physical Review B 100, 024428 (2019). [11] Physical Review Letters 127, 077202 (2021). [12] Nature Physics 14, 370–374 (2018). [13] ArXiv (2023) doi:10.48550/arxiv.2310.08411. [14] Laser Photonics Rev. 2301152, (2024). [15] ArXiv (2023) doi: 10.48550/arXiv:2310.19667v1

Date/Time: **TUESDAY, OCTOBER 8 at 11:00**
Location: **MPSD Building 900, EG 136**
Speaker: **PROF. DR. DAVIDE BOSSINI** (Department of Physics University of Konstanz)