University of Fribourg / Faculty of Science and Medicine / Department of Physics

Non-linear optical processes in condensed matter systems

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In this thesis, we study different manifestations of light-matter coupling in condensed matter systems. Emphasis is put on non-linear responses and their role as spectroscopic tools of the underlying materials. In particular, we study the phenomenon of high harmonic generation (HHG) in paradigmatic models of strong electron correlation. Extending previous results on HHG in the Hubbard model, we identify new mechanisms of HHG in the Hubbard-Holstein model as well as in a two-orbital Hubbard model. As another application of HHG, we will investigate HHG in systems with spin-orbit coupling (SOC). A central finding is the identification of HHG selection rules which reflect the underlying symmetries of the material including its spin degrees of freedom. Beyond low energy tight-binding models of systems with SOC, we also present realistic ab-initio simulations of third harmonic responses of transition metals and compare our results with recent experiments.

While the first part of the thesis is concerned with semiclassical light-matter coupling, the second part of the thesis work explores the light-matter responses where light is treated quantum mechanically. In particular, we explore the resulting relationships between topology, quantum geometry and (non-linear) light-matter responses in a fully quantum mechanical framework. We find signatures of quantum geometry, such as the shift vector, in the photon up-conversion processes in optical cavities. Lastly, we devise a novel quantum optical measurement scheme based on heterodyne detection capable of measuring quantum geometry as well as topological invariants. On top of these, we derive inequalities that provide sharper bounds relating quantum geometric quantities and topological invariants and show how these can be accessed by our method.

Jury

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