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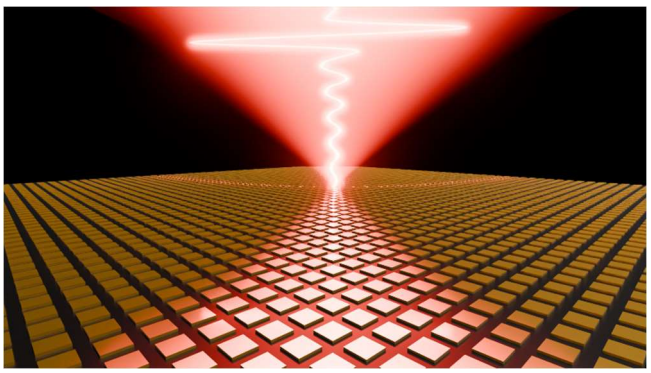
Terahertz Cavity Electrodynamics of Superconducting Collective Modes

Context: Light control of a material's properties is an emerging field with potentially far-reaching applications. Within this field enhancing or modifying superconductivity (SC) holds a special place ever since the discovery of a superconducting-like state in several materials well above their equilibrium SC temperature [1]. The dynamics of superconductors driven out-of-equilibrium is governed by their collective mode spectrum, and in particular the SC amplitude mode which is an analog of the Higgs mode in high-energy physics [2]. These SC collective modes not only give fingerprints of the nature of the ground state, but also a path to dynamically drive or even control SC order.
Light control of SC may be achieved through two main routes. The first involves driving the collective modes with light pulses tuned to their energy, typically in the THz frequency range, which may dynamically modify SC properties such as the pairing potential and explore new regions of the free energy landscape inaccessible via static means. The second route involves dressing the SC collective modes with vacuum fluctuations through strong light-matter coupling in THz cavities [3,4,5] aiming to harness hybrid light-matter states to engineer novel equilibrium phases of matter without external driving.
Research program: In this master project, we propose to address the first of these two routes with $NbSe_2$, an exotic SC hosting simultaneously SC and a charge-density-wave (CDW) state. With pump-probe THz time domain spectroscopy, the student will investigate the dynamics and interaction of the Higgs and CDW modes when driven far away from equilibrium and the possibility to induce long-lived metastable SC states in this system. The master project may be followed by a PhD which will aim at dressing the SC collective modes via integration of this SC inside THz cavities in order to create hybrid light-SC matter states and to explore their impact on SC properties.



[1] Fausti et al. Science 331, 6014 (2011): 189 91.
[2] Pekker and Varma, Annual Review of Condensed Matter Physics 6, (2015): 269 97.
[3] Garcia-Vidal et al. Science 373, 6551 (2021).
[4] Raines et al. Physical Review Research 2, n(2020): 013143.
[5] I. Aupiais et al. Nature Comm. 14, 7645 (2023)