Seeing Quantum Matter with Nonlinear Optics

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Abstract: In modern physics, emergence describes the collective behavior of the whole that is different from that of its individual parts because of interactions. In the research of materials, it corresponds to the spontaneous organization of ~10^{23} electrons into novel phases that differ in the orchestration of their individual degrees of freedom: lattice, charge, spin, and orbital. While some of these phases, such as ferroelectricity and ferromagnetism, can be directly measured and controlled, others are much more hidden to many existing probes and controls due to their complex organizational textures. Nonlinear optical spectroscopy offers a potential venue to approach these “hidden” phases, because it involves multiple copies of the electromagnetic fields that can combine to couple with the complex electronic textures. In this talk, we will show our recent progress in developing and utilizing nonlinear optics to reveal “hidden” phases [1,2]. In particular, we will use the example of a layered antiferromagnetic van der Waals magnet, CrSBr, to illustrate a previously hidden and counter-intuitive magnetic phenomenon that the surface magnetic order onsets at a higher temperature than the bulk one does [3]. We will further provide an outlook for the prospects of nonlinear optics in future material research.

References:

[1] "Observation of a ferro-rotational order coupled with second-order nonlinear optical fields" Nature Physics, 16, 42 (2020) [2] "Electric quadrupole second harmonic generation revealing dual magnetic orders in a magnetic Weyl semimetal" Nature Photonics 18, 26 (2024) [3] "Extraordinary Phase Transition Revealed in a van der Waals Antiferromagnet" arXiv 2309.01047 (2024)