Detecting, mapping, and manipulating a ferro-rotational order in solids

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Multipolar orders are key in addressing many outstanding questions in a wealth of quantum materials. Yet, their coupling to conventional linear probes are very weak, prohibiting the comprehensive understanding and efficient controlling of them. As the lowest rank multipolar order, the ferro-rotational order, schematically featured as a head-to-tail loop arrangement of electric dipole moments and mathematically described by the antisymmetric components of the electric quadrupolar tensor, was theoretically suggested to be widely present, but has been experimentally detected only very recently with nonlinear optics. In this talk, we will exploit the electric quadrupolar contribution to the second harmonic generation (SHG) to couple with this spatial-inversion and time-reversal symmetric ferro-rotational order. We will examine its symmetry properties with the rotational anisotropy (RA) measurements scheme of SHG, map its domain structures and domain boundaries with optical diffraction limited RA-SHG, and finally manipulate it and track its evolution on an ultrafast time scale with time-resolved RA-SHG.