BRIEF RESEARCH SUMMARY

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Our research investigates driven quantum systems from nanoscale to strongly correlated electron materials. Our studies both provide a fundamental understanding of light driven quantum systems and make progress towards achieving coherent control of quantum phenomena from "simplicity" to complexity. This also involves the development and applications of ultrafast laser spectroscopy and nano-imaging techniques over a wide frequency spectrum, spanning from terahertz to ultraviolet to study quantum non-equilibrium processes and many-body correlation effects.

Selective contributions

1. THz-driven superconductivity: we demonstrate light tuning of a metastable quasi-particle phase with vanishing scattering hidden by superconductivity by a single-cycle terahertz (THz) quench (*Nature Materials*, 2018).
2. THz-driven forbidden Anderson pseudo—spin precessions: we show light--induced subcycle symmetry breaking to drive long-lived gapless superfluidity, quantum beats forbidden by the equilibrium symmetry and strong high harmonic peaks assisted by the pairing interaction (*Nature Photonics*, 2019, cover article).
3. Discovery of new collective modes in iron pnictides: we show the buildup of excitonic interpocket correlation between electron-hole (e-h) quasiparticles (QP) in FeAs superconductors after fs photoexcitation leading to a long-lived excitonic state (*Phys. Rev. Lett.*, 2018); Using non-adiabatic THz quench we recently discover a new hybrid Higgs mode driven by interband pairing fluctuations controlled by light and measure its coherent dynamics (2019).
4. Manipulating coherent transport in topologically protected states: We observe frequency-dependent carrier cooling times of THz conductivity after ultrabroadband pumping from THz, mid-IR to visible regions that clearly differentiate topological surface from bulk contributions (*Nature Communications*, 2019). Recently we also report that coherent lattice vibrations periodically driven by a single-cycle terahertz (THz) pulse can significantly suppress surface-bulk coupling channel (*npj-Quantum Materials*, and *PRX* 2020).
5. Quantum coherence and collective modes in metal halide perovskites: we use coherent time-frequency visualization methods to reveals symmetry-selective quantum beats from excitons (*Nature Communications*, 2017), polarons and Rashba excitons (*PRB and PRL, 2020*).
6. Dark excitons in single-walled carbon nanotubes: we accesses the dark excitonic ground state in resonantly-excited (6,5) SWNTs via internal, direct dipole-allowed transitions between lowest lying dark-bright pair state (*Phys. Rev. Lett*. 2015). This follows our discovery of ultrafast mid-infrared intra-excitonic resonances in single-walled carbon nanotubes (*Phys. Rev. Lett*. 2010).
7. Study ultrafast dynamics of the Ising-Nematic phase: we pioneered in femtosecond-resolved polarimetry approach to quantum materials. One example is to distinguish macroscopic critical fluctuations associate with the Ising symmetry breaking from microscopic softening of magnetic order in the normal state of iron pnictide superconductors (*Nature Communications,* 2014).
8. Broadband terahertz generation in metamaterials: We showed single-cycle, broadband terahertz (THz) emission up to 4 THz from deep subwavelength structures of split ring resonator metamaterials of a few tens of nanometers (*Nature Communications*, 2014).
9. Ultrafast quantum spin switching: we demonstrate fs quantum coherence of quasi-particles in a colossal magento-resistive manganite to manipulate magnetic orders (*Nature*, 2013).

10. Discovery of femtosecond population inversion of extremely dense Dirac fermions in graphene monolayer (Phys. Rev Lett, 2012)

11. Ultrafast demagnetization in ferromagnetic semiconductors (Phys. Rev Lett, 2005, 2008, 2010)

12. Tools development: we develop and apply extensive in-house ultrafast laser spectroscopy, magneto-topical spectroscopy and microscopy techniques, spanning from far-infrared to ultraviolet, that allow for the simultaneous space, energy and time visualization of coherent effects and correlation phenomena. Recently we also focus on pushing the state-of-art terahertz instruments at space-time limits of nanometer and femtosecond using customer-build laser-coupled scanning probe microscopies (SPMs) under extreme environments of high magnetic field and cryogenic temperature.