Orbital Selective Charge Quadrupole Density Wave in FeSe$_{1-x}$S$_x$

Charge Fluctuations in Iron Pnictides and Selenides

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Iron based superconductors present a new paradigm of multi-orbital superconductivity in proximity to nematic transition and spin density wave (SDW) order. Most compounds share a common phase diagram which in the underdoped region is marked by a tetragonal to orthorhombic phase structural transition at temperature $T_S$ followed by a SDW transition at $T_{SDW}$, slightly below $T_S$. The orthorhombic distortion at $T_S$ breaks $C_4$ rotational symmetry while the translational symmetry is broken due to doubling of the unit cell either at or above $T_{SDW}$. The systems provide exceptional setting to study coexistence and/or competition between charge quadrupole fluctuations, superconductivity, and density-wave phases.

We employ polarization-resolved resonant Raman spectroscopy to study phononic, electronic, inter-band and magnetic excitations in numerous families of the oxypnictide compounds. The Raman susceptibility shows critical quadrupole charge fluctuations across the entire phase diagram which we interpreted in terms of inter-orbital quadrupole excitations. We demonstrate that above the structural phase transition the quadrupolar fluctuations with long correlation times are precursor to the discrete four-fold symmetry breaking transition. This is manifested in the $XY$-symmetry collective fluctuations observed in dynamical Raman susceptibility and enhancement of the static Raman susceptibility. Below superconducting transition, these collective excitations undergo a metamorphosis into a coherent in-gap collective mode of extraordinary strength and at the same time serve as glue for non-conventional superconducting pairing [1-4].

In the most recent studies of FeSe$_{1-x}$S$_x$, the system which does not show long range magnetic order, we have discovered that a gap reminiscent to a mean-field order parameter opens in the spectra of $XY$ symmetry below $T_S$. The data is interpreted as formation of the stripe-type quadrupole order. The interpretation provides explanation for the recently reported anisotropic electronic properties in the nematic phase as well as for the puzzling orbital selective superconductivity.

Work was done in collaboration with P. Dai, Y. Matsuda, A. Sefat, T. Shibauchi, V.K. Thorsmølle, S.F. Wu, and W.-L. Zhang. Research at Rutgers was supported by U.S. DOE, Office of BES, Award DE-SC0005463 and by NSF award DMR-1709161.

References