Coherent dynamics of macroscopic electronic order through symmetry-breaking transitions: superconductors and charge-density waves.

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The study of system trajectories undergoing symmetry breaking phase transitions (SBTs) - whether in condensed matter physics, cosmology or finance - is difficult because they are hard to repeat, or they occur very rapidly. Here we report for the first time on a high-time-resolution study of the nonergodic evolution of bosonic and fermionic excitations through an electronic charge-ordering SBT in charge-density-wave systems[1,2] and $La_{1.9}Sr_{0.1}CuO_4$ superconductors[3] using a novel multi-pulse femtosecond laser spectroscopy technique. Quenching our system with intense optical pulses, we subsequently detect hitherto unrecorded coherent aperiodic undulations of the order parameter, critical slowing down of the collective (Higgs) mode, and evolution of the particle-hole gap as the system evolves through the transition (see figure for a summary of observed events). Modeling based on Ginzburg-Landau theory is used to reproduce the aftermath of the transition without free parameters[1,2]. However, in both systems the behavior departs from TDGL predictions in the close vicinity of the transition, and preceding it. Of particular interest is the observation of spectro-temporal distortions arising from spontaneous annihilation of topological defects, analogous to those discussed by the Kibble-Zurek cosmological model and the incoherent annihilation at long times.

[1] R.Yusupov et al., Nature Physics **6**, 681 (2010)
[2] R.Yusupov et al, J.Supercond Nov Magn **24**, 1191 (2011)
[3] P.Kusar et al. (unpublished, 2011)