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Ultrafast many-body interferometry of impurities coupled to a Fermi sea[1]

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The fastest possible collective response of a quantum many-body system is related to its excitations at the highest possible energy. In condensed matter systems, the time scale for such ultrafast processes is typically set by the Fermi energy. Taking advantage of fast and precise control of interactions between ultracold atoms, we observed nonequilibrium dynamics of ^{40}K impurities coupled to a Fermi sea of ^{6}Li atoms [Cetina *et al.*, Science **354**, 96 (2016)]. Our interferometric measurements track the nonperturbative quantum evolution of a fermionic many-body system, revealing in real time the formation dynamics of quasi-particles and the quantum interference between attractive and repulsive states throughout the full depth of the Fermi sea. Ultrafast time-domain methods applied to strongly interacting quantum gases enable the study of the dynamics of quantum matter under extreme nonequilibrium conditions. We also report on new results, where we replace the fermionic ^{40}K impurities with bosonic ^{41}K atoms. In this case, a small BEC is formed in the center of the large Fermi sea. Close to an interspecies Feshbach resonance we observe striking nonequilibrium dynamics in the collective behavior of the BEC.

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