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Dynamics of ultracold atoms in higher lattice orbitals

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Ultracold quantum gases in far detuned optical lattices have enabled many intriguing experiments studying a new regime of strongly correlated quantum systems. So far, such experiments have mostly concentrated on atoms in the vibrational ground state of the lattice band structure. Here, we report on the realization of a multiorbital system with ultracold atoms in the excited bands of a 3D optical lattice by selectively controlling the band population along a given lattice direction. The lifetime of the atoms in the excited band is found to be considerably longer (10-100 times) than the characteristic time scale for intersite tunneling, thus opening the path for orbital selective many-body physics with ultracold atoms in optical lattices. Upon exciting the atoms from an initial lowest band Mott-insulating state to higher lying bands, we observe the dynamical emergence of long-range coherence in 1D (and also 2D) at nonzero quasimomentum, providing a possible route for Bose-Einstein condensation to nonzero momentum.