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Collective Dipole Oscillations of a Spin-Orbit Coupled Bose-Einstein Condensate

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We present an experimental study of the collective dipole oscillation of a spin-orbit coupled Bose-Einstein condensate in a harmonic trap. The dynamics of the center-of-mass dipole oscillation is studied in a broad parameter region as a function of spin-orbit coupling parameters as well as the oscillation amplitude. The anharmonic properties beyond the effective-mass approximation are revealed, such as the amplitude-dependent frequency and finite oscillation frequency at a place with a divergent effective mass. These anharmonic behaviors agree quantitatively with variational wave-function calculations. Moreover, we experimentally demonstrate a unique feature of the spin-orbit coupled system predicted by a sum-rule approach, stating that spin polarization susceptibility—a static physical quantity—can be measured via the dynamics of dipole oscillation. The divergence of polarization susceptibility is observed at the quantum phase transition that separates the magnetic nonzero-momentum condensate from the nonmagnetic zero-momentum phase. The good agreement between the experimental and theoretical results provides a benchmark for recently developed theoretical approaches.