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Feedback stabilization of a cavity-coupled spin oscillator

JONATHAN KOHLER, JULIAN WOLF, JOHANNES ZEIHER, DAN STAMPER-KURN, UC Berkeley — Ultracold atoms coupled to optical cavities are an ideal system for studying quantum measurement and control. Through sensitivity to the atomic state, the cavity field can apply coherent backaction, modifying the dynamics of the ensemble. In addition, photons leaking out of the cavity provide real-time information about these dynamics. In this work, we report out-of-equilibrium stabilization of the collective spin of an atomic ensemble, through continuous measurement and autonomous feedback by an optical cavity. For a magnetic field applied at an angle to the cavity axis, dispersive coupling to the cavity provides sensitivity to a combination of the longitudinal and transverse spin. Coherent backaction from this measurement, conditioned by the optical cavity susceptibility, is used to stabilize the collective spin state at an arbitrary energy. We observe real-time energy exchange between the light and spin, recorded in the Stokes and anti-Stokes sidebands of photons leaving the cavity, which reveals stabilization of the spin to an energy controlled by the frequency of the cavity drive. Our results demonstrate the intriguing interplay of measurement and feedback for ultracold atoms in optical cavities and pave the way for future studies of feedback-stabilized spin states.

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