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Nonlinear interferometric scaling from spinor atom density measurements[1] KHAN MAHMUD, Joint Quantum Institute, NIST and University of Maryland, PHILIP JOHNSON, American University, EITE TIESINGA, Joint Quantum Institute, NIST and University of Maryland — Quantum effects can improve the measurement precision beyond the shot noise limit to reach the Heisenberg limit. The effects of nonlinearity due to multi-particle interactions can further boost the precision beyond the Heisenberg limit. We show that the spin-dependent atom-atom interactions for spin-1 atoms in an optical lattice can be measured with super-Heisenberg scaling $n^{-5/4}$, where n is the mean number of atoms per lattice site. In our proposal, we start from a superfluid ground state in a shallow lattice and suddenly raise the lattice depth, thus creating a nonequilibrium state where the populations of different spin components oscillate. These oscillations have nonlinear characteristics arising from atom-atom spin-exchange collisions. We show that an in-situ measurement of the population density dynamics and its variance can reveal the nonlinear scaling. We further explore the improvement and degradation of the precision limit for different compositions of the initial state. Since spin-mixing density oscillations have already been observed with spin-1 atoms in a harmonic trap, we argue that the attainment of nonlinear precision scaling is within reach of current ultra-cold atom experiments.

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