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Spin-motion coupling for sensitive amplitude detection with large ion crystals JUSTIN G. BOHNET, National Institute of Standards and Technology, KEVIN A. GILMORE[1], Dept. Physics, U. Colorado, BRIAN C. SAWYER[2], JOSEPH W. BRITTON[3], JOHN J. BOLLINGER, National Institute of Standards and Technology — During the past decade, optomechanical systems have shown increasingly sensitive techniques for measuring a mechanical oscillator's amplitude, using the coupling of the oscillator to an optical field. Here we present experimental measurements of the amplitude of a center-of-mass (COM) drumhead motion of a 2D ion crystal composed of 100 ions in a Penning trap using a spin-dependent, optical-dipole force to couple the oscillator to the electron spin of the trapped ions. For motion off-resonant with the trap axial frequency we demonstrate measurements of amplitudes as small as 50 pm, 40 times below the ground state zero-point fluctuations. We show the sensitivity of our technique is limited by the quantum projection noise of the trapped ions. In the future, we expect to achieve a sensitivity of (20 pm)/$\sqrt{\text{Hz}}$, which can be useful for detecting extremely weak forces (< 1 yN) and electric fields, as well as exploring protocols for sensing beyond the standard quantum limit for force detection.

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