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Spectroscopy and Thermometry of Drumhead Modes in a Mesoscopic 2D Coulomb Crystal of $^9Be^{+1}$ BRIAN SAWYER, JOSEPH BRITTON, CARSON TEALE, NIST - Boulder, ADAM KEITH, CU - Boulder, JOSEPH WANG, JAMES FREERICKS, Georgetown University, JOHN BOLLINGER, NIST - Boulder — We demonstrate spectroscopy and thermometry of individual motional modes in a mesoscopic 2D ion array using entanglement between ion valence electron spins and collective motion. Our system is a $\sim$400 μm-diameter planar crystal of several hundred $^9Be^+$ ions exhibiting complex drumhead modes in the confining potential of a Penning trap. Exploiting precise control over the $^9Be^+$ valence electron spins, we apply a homogeneous spin-dependent optical dipole force to excite arbitrary transverse modes with wavelengths ranging from the array diameter to the interparticle spacing of $\sim$20 μm. In addition to temperature measurements, this spin-motion entanglement induced by the spin-dependent optical dipole force allows for extremely sensitive detection of external forces ($\sim$100 yN) acting on the ion crystal. Characterization of mode frequencies and temperatures is critical for quantum simulation experiments that make use of the ion spins.

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