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Demonstrating single-ion addressing of dynamic 2D ion crystals for quantum simulation

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Coherently manipulated large ion crystals in a Penning trap are a promising candidate for near-term quantum simulation of complex many-body phenomena [1]. At the University of Sydney, we have developed a Penning trap to perform such experiments with crystals containing hundreds of beryllium ions [2]. The system has recently demonstrated efficient site-resolved imaging, enabling single-shot experiments to investigate dynamics in correlated systems [3]. To further advance the quantum simulation capabilities to tackle more exotic many-body systems [4], we have developed a technique to address individual ions in these fast-rotating crystals. To this end, an acousto-optic modulator (AOM) with variable driving frequency deflects a 313nm optical pumping laser beam to address different radii in the ion crystal. A second AOM is used to rapidly modulate the laser power, thereby addressing individual ions at a certain radius. An optical system has been built which generates a laser beam displacement large enough to cover ion crystals with more than 300um diameter and, at the same time, achieves a focus size small enough to hit only a single ion at a time (˜30um). The system design, characterisation as well as a first application to create an exotic collective spin state [4] will be presented.

References
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