Single ion addressing and read out of dynamic 2D ion crystals for quantum simulations in a Penning trap

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Trapped-ion spins are a strong contender for performing analogue simulations of complex many-body systems that are otherwise computationally intractable [1]. These quantum simulators are a promising tool for feasibly studying condensed-matter phenomena such as quantum magnetism and two-dimensional superconductor behaviour [2]. The Penning trap at the University of Sydney has been specially designed for engineering Ising-type spin-spin interactions with large, two-dimensional Beryllium ion crystals [3]. We propose a setup for targeting single-ion spins using a focussed laser beam to either optically pump to a different spin state or generate an AC Stark shift. The beam position will be controlled using acousto-optic deflectors and strobed with nanosecond precision to achieve selective ion addressing. This will enable more sophisticated quantum states to be initialised and, thus, more complex quantum simulations. Furthermore, we utilise a time-correlated single-photon-counting camera to detect and read out individual ion states efficiently. A neural-network-based object detection algorithm is used to evaluate camera images, allowing for efficient single-site ion detection [4].

References

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