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Optical tweezers for trapped ion quantum simulations

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Trapped ion crystals offer a natural platform for quantum simulation. They have shown great advantages with regards to other systems, such as long coherence times (~ hours), fidelities and fully connected interactions. However, limited control over the interactions between the ions constrains the range of accessible Hamiltonians.
In our expermeint, we plan to combine trapped ions with microtraps in the form of optical tweezers.
These additional potentials will allow us to manipulate the phonon mode spectrum and thereby control the spin-spin interactions of the ions in a Paul trap. We will use a high power 1030nm laser far detuned from any transition in Yb+. The tweezers will be produced by a spatial light modulator and focused on the ions to a waist of a few μm with a high NA objective. With the right tweezer pattern [1], we can then use the system to study various Hamiltonians of interest, for example, Hamiltonians on a kagome lattice [2] in 2D ion crystals. Furthermore, in one dimensional ion chains optical tweezers can be combined with oscillating electric fields in order to realize two-qubit geometrical phase gates [3]. This has the advantage that it does not require ground state cooling of the ions and works even in very long ion chains, as the electric field couples to all ions equally. The current experimental status as well as steps taken to align the tweezers on the ions will be presented.

[1] J.D. Espinoza, M. Mazzanti, K. Fouka, R.X. Schüssler, Z. Wu, P.Corboz Phys. Rev. A 104, 013302 (2021).
[2] A. Bermudez, J. Almeida, F. Schmidt-Kaler, A. Retzker, and M. B. Plenio Phys. Rev. Lett. 107, 207209 (2011).
[3] M. Mazzanti, R.X. Schüssler, J.D. Espinoza, Z. Wu, R. Gerritsma, A. Safavi-Naini Phys. Rev. Lett. 127, 260502 (2021).

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