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POS-E28 – Holographic optical manipulation of trapped ions for quantum simulation

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Trapped ions can offer a functional platform for quantum simulation of many-body Hamiltonians modeled by spin-systems. Programmable, arbitrary and precise control over each ion is required in order to tune ion-ion interactions, which translate to diverse parameters of the system under study. Current technologies suffer from scalability issues to large ion chains, and from "cross-talk" due to micron-level inter-ion separation. Here, we report our development of a holographic optical ion-addressing setup for Yb^+ ions ($\lambda = 369.5$ nm) using a Digital Micromirror Device (DMD). This technique uses a reprogrammable hologram to modulate the wavefront of the addressing beam and thus engineer the amplitude and phase profile of light across the ion ensemble to better than $\lambda/20$. We implement a novel Iterative Fourier Transform Algorithm (IFTA) to compute the desired hologram. This algorithm efficiently compensates for optical aberrations and produces $< 10^{-4}$ intensity cross-talk error in arbitrary pair-wise addressing profiles, suitable for over fifty ions. This scheme relies on standard commercial hardware, can be readily extended to over a hundred ions, and adapted to other ion-species and quantum platforms. Such high-precision optical control will enable the simulation of arbitrary and dynamic lattice geometries of spins to be realized in a 1D chain of ions. This technique will also allow us to investigate problems in quantum quench, quantum phase transitions, and physics of higher dimensional systems such as the creation of topological states.

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