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Ion-photon coupling with phase Fresnel lenses for large-scale quantum computing ERIK STREED, BENJAMIN NORTON, JUSTIN CHAPMAN, DAVID KIELPINSKI, Griffith University — Efficient ion-photon coupling is an important component for large-scale ion-trap quantum computing. We propose that arrays of phase Fresnel lenses (PFLs) are a favorable optical coupling technology to match with multi-zone ion traps. Both are scalable technologies based on conventional micro-fabrication techniques. The large numerical apertures (NAs) possible with PFLs can reduce the readout time for ion qubits. PFLs also provide good coherent ion-photon coupling by matching a large fraction of an ion's emission pattern to a single optical propagation mode (TEM_{00}). To this end we have optically characterized a large numerical aperture phase Fresnel lens (NA=0.64) designed for use at 369.5 nm, the principal fluorescence detection transition for Yb^+ ions. A diffraction-limited spot w_0=350+/-15 nm ($1/e^2$ waist) with mode quality M^2= 1.08+/-0.05 was measured with this PFL. From this we estimate the minimum expected free space coherent ion-photon coupling to be 0.64%, which is twice the best previous experimental measurement using a conventional multi-element lens. We also evaluate two techniques for improving the entanglement fidelity between the ion state and photon polarization with large numerical aperture lenses.

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