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Barium Qubit State Detection and Ba Ion-Photon Entanglement[1]

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A modular ion-trap network is a promising framework for scalable quantum-computational devices. In this architecture, different ion-trap modules are connected via photonic buses while within one module ions interact locally via phonons. To eliminate cross-talk between photonic-link qubits and memory qubits, we use different atomic species for quantum information storage ($^{171}Yb^{+}$) and intermodular communication ($^{138}Ba^{+}$). Conventional deterministic Zeeman-qubit state detection schemes require additional stabilized narrow-linewidth lasers. Instead, we perform fast probabilistic state detection utilizing efficient detectors and high-NA lenses to detect emitted photons from circularly polarized 493 nm laser excitation. Our method is not susceptible to intensity and frequency noise, and we show single-shot detection efficiency of $\sim$2%, meaning that we can discriminate between the two qubits states with 99% confidence after as little as 50 ms of averaging. Using this measurement technique, we report entanglement between a single $^{138}Ba^{+}$ ion and its emitted photon with 86% fidelity.

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