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Mixed-Species Logic Gates and High-Fidelity Universal Gate Set for Trapped-Ion Qubits[1]

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Precision control over hybrid physical systems at the quantum level is important for the realization of many quantum-based technologies. For trapped-ions, a hybrid system formed of different species introduces extra degrees of freedom that can be exploited to expand and refine the control of the system. We demonstrate an entangling gate between two atomic ions of different elements that can serve as an important building block of quantum information processing (QIP), quantum networking, precision spectroscopy, metrology, and quantum simulation. An entangling geometric phase gate between a $^{9}Be^{+}$ ion and a $^{25}Mg^{+}$ ion is realized through an effective spin-spin interaction generated by state-dependent forces. A mixed-species Bell state is thereby created with a fidelity of 0.979(1). We use the gate to construct a SWAP gate that interchanges the quantum states of the two dissimilar qubits. We also report a high-fidelity universal gate set for $^{9}Be^{+}$ ion qubits, achieved through a combination of improved laser beam quality and control, improved state preparation, and reduced electric potential noise on trap electrodes.

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