Experimental preparation and analysis of two-ion entangled states

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Quantum computers are known to perform certain computational tasks more efficiently than their classical counterparts. In 1995, Cirac and Zoller proposed a scheme for scalable quantum computing using a string of trapped ions, where each ion represents a bit of quantum information (qubit). For experimental realizations of such a scheme, it is essential to identify and characterize the most important sources of decoherence.
In our experiment, two single $^{40}Ca^{+}$ ions are held in a linear Paul trap and are individually addressed with focused laser beams. Superpositions of the $S_{1/2}$ and the $D_{5/2}$ long lived electronic states represent a qubit. A sequence of well suited laser pulses that couple the electronic and motional degrees of freedom of the ions prepare the ions in an entangled state. Further laser pulses are used to analyze the achieved quantum state.
We present experiments where the coherence time of different Bell states is investigated. The lifetime of those Bell states that are well protected against environment-induced dephasing exceeds the time needed for generating them by more than an order of magnitude.