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Controlling trapped-ion qubits with microwave near-fields and a stimulated-Raman laser system

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Trapped-ion qubits are a promising hardware platform for quantum computing and quantum simulation. In our experiment, the qubits are encoded in two hyperfine levels of $^9Be^+$ ions confined in a cryogenic surface-electrode Paul trap. By integrating microwave conductors into the trap, we can generate an oscillating magnetic field and gradient at the ion's position which can drive carrier and sideband transitions between the qubit states, respectively. In this way, motional ground state cooling, single qubit gates and entangling interactions can be implemented.
An alternative method to control the ion's internal and motional states is the use of a stimulated-Raman laser system. For that, we generate two beams of 313 nm laser light via sum-frequency generation and subsequent second harmonic generation. To enable precise control of the frequency difference between the two beams, each beam path features a double-pass acousto-optic modulator setup with a geometry that is inherently stable with respect to thermal effects. Moreover, intensity stabilization is realized using a feedback loop with a sample-and-hold circuit.
By comparing these two methods of quantum control of trapped $^9Be^+$ ions, we aim to improve the performance of microwave-driven quantum gates in our setup. We will report on the status of the project and on a new generation of segmented multi-ion trap chips to be implemented in this environment.

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