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Towards improved experimental control of calcium ion experiments

In our laboratory, we focus on quantum state engineering with beryllium and calcium ions, including recent demonstrations of squeezed states and spin-motion entangled state interferometry by combining reservoir engineering with unitary operations (Kienzler et al.). In order to improve the quality with which we control our ions, we are currently working to upgrade the system.

One of the primary problems in working on motional state control (including the control required for two qubit gates) is laser frequency noise at the trap frequency. This is problematic because it leads to off resonant carrier excitation when driving sideband transitions. In our system we address the calcium quadrupole transition using a 729 nm laser with a narrow spectrum. The current laser system consists of a Pound-Drever-Hall locking scheme onto a ULE high finesse cavity. The servo-system's limited bandwidth leads to an amplification of frequency components detuned by about 1 MHz, which is close to trap frequencies which we would like to use. I am working to solve this problem by building a laser system based on a filter cavity with subsequent laser power amplification by diode injection and backward seeding of a tapered amplifier.

A strong source of decoherence for our calcium ions are magnetic field fluctuation, which arises due to noise coming from the power lines going to the laboratory and also directly from the current driving our Helmholtz coils. The latter is exacerbated by working at relatively high (11.9 mT) magnetic field at which a field independent quibt is available in beryllium. I will describe different approaches to cancel the mains magnetic fluctuations as well as the fluctuations due to noise in the Helmholtz current.

Summary

Progress in improving our laser spectra and suppressing magnetic field fluctuations in our laboratory are discussed.

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