DAMOP20-2020-001129
Abstract for an Invited Paper
for the DAMOP20 Meeting of
the American Physical Society

When precision matters: quantum gates and metrology with $^{171}Yb^+$ ions[1]

CHRISTOF WUNDERLICH, University of Siegen

Continuous or pulsed dynamical decoupling (DD) has been successfully used to extend the coherence time of qubits, for example in trapped atomic ions. We report on the experimental realization of a recently proposed, novel DD sequence [2] that not only extends the coherence time, but also results in a tunable two-qubit phase gate with high fidelity. Using both axial motional modes of a two-ion crystal, it allows for higher gate speeds than comparable single-mode gates. We have realized a $\frac{\pi}{4}$-gate with a fringe contrast up to 99(+1-2)%, applying this sequence to two $^{171}Yb^+$ ions in a linear Paul trap using a hyperfine qubit driven by radio frequency radiation. The interaction between motional and internal qubit states necessary for conditional quantum logic is provided by magnetic gradient induced coupling (MAGIC) [3]. We use this DD sequence for Controlled-NOT operations and the creation of Bell states. We investigate the robustness of such conditional quantum gates against typical error sources present when using trapped ion qubits. These include variations of the Rabi frequency (≤ 30 %), the secular frequency (≤ 4 %), and of the mean vibrational excitation $\bar{n}$ of the center-of-mass mode ($\approx 0.3 \leq \bar{n} \leq\approx 100$). The opticlock consortium (www.opticlock.de) develops a compact transportable optical clock for non-specialist users with a projected uncertainty of order 10^{-16}. This clock, based on the $2S_{1/2}$ - $2D_{3/2}$ resonance with wavelength near 436 nm in a single $^{171}Yb^+$ ion, could be further improved using a frequency standard based on multiple ions. For this purpose, a segmented four layer ion trap for confining a linear Coulomb crystal of $^{171}Yb^+$ ions [4] and a compact vacuum interface, allowing for excellent optical access, is used. Here, we will focus on the design aspects and construction process of the new setup and give details regarding optical [5], electrical and vacuum aspects and present the experimental status of the linear trap project.

[1]Funding by the EC Quantum Flagship through the project MicroQC and by the German bmbf under grant no. 13N14385 is acknowledged.

[2]I. Arrazola, J. Casanova, J.S. Pedernales, Z.Y. Wang, E. Solano, M.B. Plenio, Phys. Rev. A **97**, 052312 (2018)

[3]T. Sriarunothai et al., Quantum Sci. Technol. **4** (2019) 015014

[4]M. Brinkmann, A.Didier, T. Mehlstäubler, Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany

[5]S. Brakhane, D. Meschede, Institut für Angewandte Physik der Universität Bonn, Wegelerstr. 8, 53115 Bonn, Germany