Progress Report towards an Al^+ Quantum Logic Optical Clock

Stephan Hannig[1], Jannes B. Wübbena[1], Nils Scharnhorst[1], Sana Amairi[1], Ian D. Leroux[1], Tanja E. Mehlstäubler[1] and Piet O. Schmidt[1,2]

[1]QUEST Institute for Experimental Quantum Metrology,
Physikalisch-Technische Bundesanstalt, 38116 Braunschweig, Germany
[2]Leibniz Universität Hannover, 30167 Hannover, Germany

Email: stephan.hannig@ptb.de

We present the status of the PTB aluminium ion optical clock using quantum logic techniques for sympathetic cooling and read-out of the clock ion. The design goals for the frequency standard are a relative inaccuracy below 10^{-17} and relative instability better than 10^{-15} in one second.

$^{27}Al^+$ provides a narrow (8 mHz) clock transition at 267 nm which exhibits no electric quadruple shift and a low sensitivity to black-body radiation[1]. A single $^{27}Al^+$ ion will be confined in a linear Paul-trap together with a $^{40}Ca^+$ logic ion. The Ca^+ ion is used for sympathetic cooling and internal state detection of the clock ion via quantum logic spectroscopy[2].

We present the clock setup, which is based on a modular, fiber-coupled design to provide portability. Our clock laser is locked to an ultra-stable and vibration insensitive 39.5 cm long cavity, providing an estimated thermal noise limit of below 10^{-16} in one second[3]. Its output is amplified and quadrupled to the clock transition wavelength of 267 nm using a waveguide and an external cavity frequency doubler.

The calcium logic laser at 729 nm, the cooling laser at 397 nm and the 866 nm repump laser are phase-locked directly to an optical reference at 1550 nm via a fiber-based frequency comb utilizing a transfer-beat scheme.

Using the stabilized logic laser for Ca^+, we implemented ground state cooling of a single trapped Ca ion. The trap was characterized in terms of trap frequencies, micromotion and heating rates. We will report on the status of the quantum logic state transfer between the two ions.

Currently, a second generation, miniaturized new vacuum chamber including a segmented multilayer linear Paul trap[4,5] is prepared. The new system paves the way towards multi-ion clocks, combining the high accuracy of single ion clocks with high stability.

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