Precision spectroscopy in Yb^+ ions

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Precision spectroscopy on trapped ions has emerged as a sensitive tool for tests of physics beyond the Standard Model. A violation of Local Lorentz Invariance (LLI) is suggested in the attempt to unify all fundamental forces at the Planck scale. In the Standard Model Extension such violation would lead to energy shifts of atomic states with non-spherical electron orbitals. With high-precision spectroscopy we constrained the symmetry breaking coefficients of a possible LLI violation at the 10^{-21} level (the most stringent test in the combined electron-photon sector)[1]. The method of dynamic decoupling to achieve a 1st order insensitivity to magnetic field fluctuations was proven to be scalable to a spatially extended multi-ion crystals[2]. Using a holographic phase plate to generate a flat top beam profile we have already excited 8 $^{172}Yb^+$ ions on the highly forbidden octupole (E3) transition from $^2S_{1/2}$ to $^2F_{7/2}$ (Fig.1) to improve the sensitivity of the LLI test further.

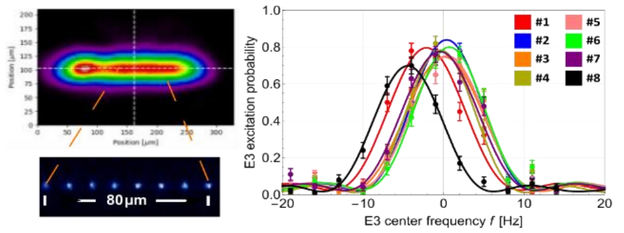

Fig. 1: Left: intensity profile of the flat-top beam and ions. Right: E3 clock resonance in an 8-ion crystal.

The high level of control of magnetic field environment used for the magnetic sensitive E3 transition in the $^{172}Yb^+$ ion enabled us to extend the clock spectroscopy on this transition to all stable even isotopes of Yb^+. By measuring both quadrupole (411 nm) and octupole (467 nm) transitions with an uncertainty at the 6 Hz and 16 Hz level, we can resolve non-linearities in King plots[3] and put new bounds on possible new bosons as proposed in reference[4].

Scaling the ion number for precision spectroscopy is a necessary and successful way to improve the clock sensitivity and to reduce long averaging times[5]. A challenge for multi-ion operation of Yb^+ E3-clocks is the strong Stark shift of the clock states, which prohibits effective excitation of the E3 transition. To exploit the full potential of Yb^+ multi-ion spectroscopy, we will explore clock operation with the odd isotope $^{173}Yb^+$ providing a nuclear spin of $I = 5/2$. $^{173}Yb^+$ is predicted to have nuclear spin quenched, 100 times shorter lifetime of the F-state[6] with thus, significantly reduced AC-Stark shifts. Already a 10 times smaller Stark shift will enable our beam profile (Fig.1) to scale the clock operation to 10s of ions. The scalable ions traps developed in our group allow for simultaneous clock operation of multiple clock ensembles with a few ten ions each.

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