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JOHANNES GUTENBERG UNIVERSITÄT MAINZ

Seminar über Quanten-, Atom- und Neutronenphysik (QUANTUM)

Nov. 23, 2023 at 2 p.m.
IPH Lorentzraum 05-127

Dr. Nils Huntemann
PTB Nationales Metrologieinstitut

Searches for new physics effects with optical atomic clocks

The 171Yb+ ion features two narrow optical transitions: an electric octupole (E3) transition as well as an electric quadrupole (E2) transition. Both transitions are suitable for the realization of an optical clock and accepted as secondary representations of the SI unit second and a composite system that relies on the spectroscopic information provided by both transitions can even provide superior clock performance.

Because both transitions also show a large differential sensitivity to the fine structure constant á, its possible variations can be probed by comparing the transition frequencies at various positions in spacetime. We find improved bounds on a linear temporal drift of á, as well as its coupling to the gravitational potential of the sun, from a long-term optical clock comparison [1,2]. Additionally, the couplings of so-called ultralight bosonic dark matter (m « 1 eV/c^2) to standard model particles would lead to coherent oscillations of constants, with an oscillation frequency corresponding to the Compton frequency of the dark matter mass [3]. We conduct a broadband dark-matter search by comparing the frequency of the E3 transition to that of the E2 transition, and to that of the 1S0 ↔ 3P0 transition in 87Sr. We find no indication for significant oscillations in our experimental data. Consequently, we put limits on oscillations of the fine-structure constant and thus improve existing bounds on the scalar coupling of ultralight dark matter to photons for dark-matter masses of about 1E−24 to 1E−17 eV/c^2 [2]. Couplings to quarks and gluons can also be investigated with optical frequency ratio measurements by considering the effect an oscillating nuclear charge radius would have on electronic transitions [4].

Finally, I will report on our efforts towards clocks in which co-trapped 88Sr+ ions [5] enable even superior 171Yb+ clock performance.

[1] Lange et al., Phys. Rev. Lett. 126, 011102 (2021).
[2] Filzinger et al., Phys. Rev. Lett. 130, 253001 (2023).
[3] Arvanitaki et al., Phys. Rev. D 91, 015015 (2015).
[4] Banerjee et al., arXiv:2301.10784 (2023).
[5] Steinel et al., Phys. Rev. Lett. 131, 083002 (2023).

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