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New limits on variations of the fine-structure constant and ultralight dark matter

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The 171Yb+ ion features two narrow optical transitions: an electric octupole (E3) transition as well as an electric quadrupole (E2) transition. Because they have a large differential sensitivity to the fine structure constant α , 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 α , 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/c²) 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 \leftrightarrow 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/c² [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].

- [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).

Primary authors: FILZINGER, Melina (Physikalisch-Technische Bundesanstalt (PTB)); DÖRSCHER, Sören; LANGE, Richard; KLOSE, Joshua; STEINEL, Martin (Physikalisch-Technische Bundesanstalt); BENKLER, Erik; PEIK, Ekkehard; LISDAT, Chistian; HUNTEMANN, Nils (Physikalisch-Technische Bundesanstalt)

Presenter: FILZINGER, Melina (Physikalisch-Technische Bundesanstalt (PTB))

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