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New optical clocks based on Cu II, Yb III, Hf II, Hf IV, and W VI ions which may be used to search for dark matter and variation of the fine structure constant

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We study the prospects of using several metastable excited states of Cu II, Yb III, Hf II, Hf IV, and W VI ions as clock transitions in optical clocks. The transitions between ground and metastable states in these systems are the $s - d$ transitions which ensure high sensitivity to the variation of the fine structure constant. Cooling E1 transitions are available. Energy levels, Landé g-factor , transition amplitudes for electric dipole (E1), electric quadrupole (E2), and magnetic dipole (M1) transitions, lifetimes, and electric quadrupole moments are investigated using a combination of several methods of relativistic many-body calculations including the configuration interaction (CI), linearized coupled-cluster single-doubles (SD) and many-body perturbation theory (CI+SD), and also the configuration interaction with perturbation theory (CIPT). Scalar polarizabilities of the ground states and the clock states have been calculated to determine the black body radiation (BBR) shifts. We have found that the relative BBR shifts for these transitions range between $10^{-16} - 10^{-18}$. The second-order Zeeman shifts of Cu II and Yb III, whose stable isotopes have non-zero nuclear spins (I), have also been calculated. A linear combination of two clock transition frequencies allows one to further suppress BBR. Studying possible variation of the fine structure constant may be used to search for dark matter causing this variation. The enhancement coefficient for α variation reaches K = 8.3. As these atomic systems have multiple isotopes, King plots can be made and new interactions may be found mediated by scalar particles or other mechanisms.

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