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Searching for ultralight dark matter using highly charged ion clocks

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Highly charged ions (HCIs) offer exceptional prospects for next-generation optical clocks due to their suppressed sensitivity to external perturbations and their potential to probe physics beyond the Standard Model, which could help lift the veil on the nature of dark matter and dark energy. Among them, californium (Cf) ions host optical transitions with predicted ultra-narrow linewidths and enhanced sensitivity to variations in the fine-structure constant, which can be linked, for example, to virialized dark matter scalar fields, making them promising candidates for probing ultralight dark matter. We present our program toward the realization of a Cf-based HCI clock. We introduce our experimental apparatus, which enables charge breeding of HCIs in an electron beam ion trap and their sympathetic cooling in a cryogenic Paul trap. We report on the current status of our experiment, in which we have implanted Xe HCIs into a Coulomb crystal of Ca^+ ions and are currently performing ion-trap characterization. Our results outline a pathway to a new class of optical frequency standards, bridging precision metrology and searches for new physics.

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