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Tabletop particle physics and cosmology with precision quantum-logic spectroscopy

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The extreme precision and accuracy of state-of-the-art optical atomic clocks can be used to look for very small deviations from the predictions of the Standard Model, offering a tool to search for beyond Standard Model (BSM) physics complementary to particle accelerators. These searches are based on measuring the frequency ratio of two transitions that depend differently on interactions with BSM particles or fields. In this talk, I will begin with a brief review of optical atomic clocks, focusing on clocks based on quantum-logic spectroscopy of Al^+. I will proceed to present a frequency ratio measurement between Al^+ and Yb clocks at NIST that used a new coherent clock comparison protocol called differential spectroscopy in order to achieve the highest precision of any interspecies ratio measurement to-date. I will conclude with a discussion of two new experiments being set up at UCLA aimed at performing precision quantum-logic spectroscopy of transitions with much higher sensitivity to BSM physics in a variety of sectors. In the first, precision measurements of the 148 nm nuclear isomer transition in sympathetically laser cooled $^{229}Th^{3+}$ ions will be used to search for proposed ultralight scalar dark matter models such as the relaxion and for time-variation of the fundamental constants predicted by theories that seek to unify general relativity with quantum mechanics. In the second, quantum control and quantum-logic spectroscopy of polyatomic molecules will be used to study and search for fundamental symmetry violations in the weak and strong force sectors.

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