Quantum Sensors of Physics beyond the Standard Model

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As a viable and scalable alternative to high-energy particle colliders, we present a novel class of quantum sensors of fundamental Physics beyond the Standard Model, based on absolute frequency metrology of cold molecular spectra. In particular, we describe an experiment being set up for placing new bounds on putative fifth forces, by accomplishing sub-kHz-accuracy line-centre frequency determinations for selected hydrogen deuteride (HD) ro-vibrational transitions in the (1,0) fundamental band at 2.7-micron wavelength. To address this challenge, a second-generation buffer-gas-cooling (BGC) machine is under construction, incorporating a pulse-tube cryocooler in ultra-low vibration mode. Then, radiation from a metrological-grade optical parametric oscillator (OPO), ultimately referenced to a frequency standard with superior accuracy and stability (Cs fountain or Yb lattice clock) delivered by the Italian Quantum Backbone (IQB), will be coupled to a high-finesse cavity surrounding the buffer-gas-cooled HD sample. Eventually, comparison of the target transition frequencies, as measured by saturated-absorption cavity ring-down (SCAR) spectroscopy, with state-of-the-art ab initio calculations will constrain the coupling strength of extra long-range (Angstrom length scales) hadron-hadron interactions below $10^{-10}\alpha$ (being α the fine-structure constant), one order of magnitude better than the present limit. Finally, emerging applications in quantum distributed sensing across the IQB, based on the entanglement between buffer-gas-cooled acetylene samples and single photons at Telecom wavelengths, will be mentioned.

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