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Atom interferometry for fundamental physics and gravitational wave detection

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In recent years, atom interferometry and atomic clocks have made impressive gains in sensitivity and time precision. The best atomic clocks have stability corresponding to a loss of less than one second in the lifetime of the universe. Matter wave interferometers have achieved record-breaking coherence times (seconds) and atomic wavepacket separations (over half a meter), resulting in a significant enhancement in accelerometer and gravity gradiometer sensitivity. Leveraging these advances, atomic sensors are now poised to become a powerful tool for discovery in fundamental physics. I will provide a detailed introduction to light-pulse atom interferometry, and explain various techniques that are being pursued to further enhance sensitivity. I will then discuss several specific applications, including direct detection of dark matter, tests of general relativity, searches for new forces, and gravitational wave detection. I will also describe a new type of atom interferometry based on narrow-line transitions in clock atoms that is central to the Mid-band Atomic Gravitational wave Interferometric Sensor (MAGIS) proposal, which is targeted to detect gravitational waves in a frequency band complementary to existing detectors (0.03 Hz 10 Hz), the optimal frequency range to support multi-messenger astronomy. I will conclude with a brief discussion of MAGIS-100, a 100-meter tall atomic sensor now being constructed at Fermilab that will serve as a prototype of such a gravitational wave detector, and that will be sensitive to proposed ultra-light dark matter (scalar and vector couplings) at unprecedented levels.