# Precision Metrology with Photons, Phonons and Spins: Answering Major Unsolved Problems in Physics and Advancing Translational Science

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The Quantum Technologies and Dark Matter research laboratory has a rich history of developing precision tools for both fundamental physics and industrial applications. This includes the development and application of novel low-loss and highly sensitive resonant photonic and phononic cavities, such as whispering gallery and re-entrant cavities, as well as photonic band gap and bulk acoustic wave structures [1]. These cavities have been used in a range of applications, including highly stable low noise classical and atomic oscillators, low noise measurement systems, highly sensitivity displacement sensors, high precision electron spin resonance and spin-wave spectroscopy, high precision measurement of material properties and applications of low-loss quantum hybrid systems, which are strongly coupled to form polaritons or quasi-particles. Translational applications of our technology has included the realization of the lowest noise oscillators and systems for advance radar, the enabling of high accuracy atomic clocks and ultra-sensitive transducers for precision gravity measurements .

Meanwhile, there is currently a world-wide renascence to adapt precision and quantum measurement techniques to major unsolved problems in physics. This includes the effort to discover “Beyond Standard Model” physics, including the nature of Dark Matter, Dark Energy and the unification of Quantum Mechanics with General Relativity to discover the unified theory of everything [1]. Thus, the aforementioned technology has been adapted to realize precision measurement tools and techniques to test some of these core aspects of fundamental physics, such as searches for Lorentz invariance violations in the photon, phonon and gravity sectors, possible variations in fundamental constants, searches for wave-like dark matter and test of quantum gravity. This work includes: 1) Our study and application of putative modified physical equations due to beyond standard model physics, to determine possible new experiments: 2) An overview of our current experimental program, including status and future directions. This includes experiments that take advantage of axion-photon coupling and axion-spin coupling to search for axion dark matter. High acoustic Q phonon systems to search for Lorentz violations, high frequency gravity waves, scalar dark matter and tests of quantum gravity from the possible modification of the Heisenberg uncertainty principle.

[1] https://www.qdmlab.com/publications