Towards Overcoming Performance Barriers in Optomechanical Quantum Information Platforms

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Integrated optomechanical systems are among the foremost platforms for the manipulation, sensing, and distribution of quantum information, allowing for precise detection of motion using light at and beyond the standard quantum limit. These systems enable the measurement of acceleration, displacement, mass, and forces at both room and cryogenic temperatures, and the transduction of quantum information between disparate energy scale. Additionally, using dispersive optomechanics, the successful teleportation of polarization-encoded optical input states has been demonstrated. However, temperature increases due to residual optical absorption still set the ultimate limit on performance for these applications. In this talk, we will explore different routes that could lead to solutions for the challenge posed by thermal phonons. Firstly, we will delve into dissipative optomechanical systems operating in the sideband-resolved regime, exhibiting a two-order-of-magnitude increase in mechanical frequency and a tenfold rise in dissipative coupling rates compared to previous works, showcasing the untapped potential of dissipative interactions. Next, we will explore two-dimensional optomechanical crystal geometry as a possible route to alleviate thermal limitations, through increased thermal anchoring to the surrounding material. We will show how device orientation relative to silicon crystallography significantly influences mechanical band structures, making devices more prone to fabrication imperfections, and discuss potential solutions for these challenges.