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Millimeter Wave Quantum Optomechanics

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Despite incredible experimental progress in quantum optomechanics, the intrinsically weak coupling between light and motion remains a bottleneck for accessing the full potential of these systems. While a strong pump field can parametrically enhance the optomechanical coupling, it also acts to obscure the fundamental nonlinearity of the interaction and hinders integration with single photon devices like detectors or qubits. Here, I will present theory, design and preliminary experiments detailing our approach to address these issues by introducing a new regime of optomechanics whereby mechanical oscillators are coupled to millimeter wave (˜30 GHz) photons. Based on previous vacuum gap capacitor designs, these novel devices integrate the small electromagnetic mode volume of lumped elements with the increased photon energy provided by millimeter waves to generate larger optomechanical vacuum coupling rates. Combined with enhancements to the mechanical quality factor, these devices should allow access to the quantum regime with pump fields of less than a single photon on average, providing a novel quantum information resource, as well as a platform for fundamental studies of quantum mechanics at the mesoscale.

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