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High cooperativity optomechanics with wide-bandgap materials

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Cavity optomechanics provides a platform for exquisitely controlling coherent interactions between photons and mesoscopic mechanical excitations. Cavity optomechanics has recently been used to demonstrate phenomena such as laser cooling, optomechanically induced transparency, and coherent wavelength conversion. These experiments were enabled by photonic micro- and nanocavities engineered to minimize optical and mechanical dissipation rates, γ_o and γ_m, respectively, while enhancing the per-photon optomechanical coupling rate, g_0. The degree of coherent photon-phonon coupling in these devices is often described by the cooperativity parameter, $C = Ng_0^2/\gamma_o\gamma_m$, which may exceed unity in several cavity optomechanics systems for a sufficiently large intracavity photon number, N. Here we demonstrate optical whispering gallery mode (WGM) microdisk cavities that are fabricated from wide-bandgap materials such as gallium phosphide (GaP), and single crystal diamond (SCD). By using wide-bandgap materials high-C can be achieved by reaching high-N before thermal instabilities occur.

We demonstrate GaP microdisks with intrinsic optical quality factors $> 2.8 \times 10^5$ and mode volumes $< 10(\lambda/n)^3$, and study their optomechanical properties. We observe optomechanical coupling in GaP microdisks between optical modes at 1.5 μm wavelength and several mechanical resonances, and measure an optical spring effect consistent with a predicted optomechanical coupling rate $g_0/2\pi \sim 30$ kHz for the fundamental mechanical radial breathing mode at 488 MHz.

We have also demonstrated monolithic microdisk cavities fabricated from bulk SCD via a scalable process. Optical quality factors of 1.15×10^5 at 1.5 μm are demonstrated, which are among the highest measured in SCD to date, and can be improved by optimizing our fabrication process further. In addition to SCD-possessing desirable optical properties, its high Young’s modulus, high thermal conductivity, and low intrinsic dissipation, show great promise for use in high-C optomechanics. Current investigation is focused on characterizing the optical properties of these devices, and optimizing them for applications in nonlinear optics and quantum optomechanics.

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