Wideband wavelength conversion using cavity optomechanics

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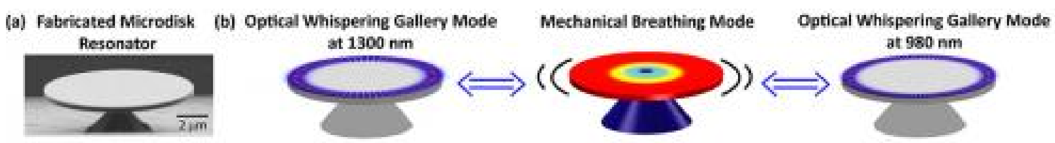

Optical wavelength conversion mediated by radiation pressure interaction with a mechanical mode. (a) A scanning electron micrograph of a fabricated silicon nitride microdisk resonator. (b) Schematic showing wavelength conversion between optical "whispering gallery" modes at 1300 nm and 980 nm wavelengths. The conversion is achieved through interaction with a mechanical breathing mode that serves as a bridge between the two optical modes.

A team of researchers at the NIST Center for Nanoscale Science and Technology (CNST), the University of Maryland, and the California Institute of Technology have demonstrated optical wavelength conversion using interactions between radiation pressure and mechanical vibrations in a nanoscale cavity optomechanical system. Along with recent demonstrations by other groups, this work shows that radiation pressure forces may be useful in a variety of signal transduction applications. In particular, wavelength conversion interfaces based on cavity optomechanics can operate over ranges and in material systems in which traditional frequency conversion techniques cannot be applied.

Working in the CNST NanoFab allowed the researchers to fabricate an optomechanical resonator consisting of a 350 nm thick, 10 μm-diameter silicon nitride disk supported on a small silicon pedestal whose top is less than 200 nm in diameter. The microdisk simultaneously confines optical modes, frequencies of light that circulate around the disk's periphery in "whispering gallery" orbits, and a mechanical "breathing" mode that results in the expansion and contraction of the disk out from its center. The disk motion, which changes its size, also influences the optical modes because their frequencies are dependent on the disk circumference. Additionally, the tight optical confinement present in these structures makes the radiation pressure forces strong enough to influence the mechanical motion. Thus, the system's optics and mechanics interact with each other, allowing energy to be converted between the optical and mechanical systems.

The researchers use the interaction of two whispering gallery optical modes with the mechanical breathing mode. Optical energy at an input wavelength aligned with one of the optical modes is transferred to an output wavelength aligned with a second optical mode. This is accomplished through the interaction with the mechanical system, which serves as a bridge to link the two optical modes together. The researchers demonstrated that they can upconvert and downconvert signals over an optical wavelength span of 300 nm, between the 1300 nm and 980 nm wavelength bands that are frequently used in telecommunications. They believe that even wider ranges of wavelength conversion should be possible using the same geometry.

Future work will focus on improving the conversion efficiencies, which are currently limited to about 20 % within the cavity and 0.5 % for the device as a whole. Reducing noise, including thermal noise, which is the dominant noise source in current devices, can enable operation with extremely weak input signals, potentially all the way down to the single photon states of light used in quantum information processing applications.

More information: Liu, Y. et al. Electromagnetically induced transparency and wideband wavelength conversion in silicon nitride microdisk optomechanical resonators, *Physical Review Letters* 110, 223603 (2013).

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