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Cavity Optical Spring Sensing

TAO LU, Dept. ECE, University of Victoria

Whispering gallery microcavities have been adopted nanodetection and biosensing for decades through the reactive sensing principle. That is, a nanoparticle changes the overall optical path length of the cavity, yielding a detectable shift of the cavity resonance wavelength. Such sensors are fundamentally limited by the thermal refractive noises to sub-femto-meter resolution. On the other hand, light delivered to a microcavity may exert strong optical force that can mechanically oscillate the cavity. Such effect, also known as cavity optomechanical oscillation, has been observed in an aqueous environment. The optomechanically quivering cavity can be approximated as a mechanical spring and an optical spring connected to a mass load in parallel. While particle sensing can be achieved by monitoring the mechanical oscillation frequency change due to the added mass to the oscillation mode, an orders-of-magnitude higher sensitivity can be achieved through the tuning of the optical spring constant. In particular, a nanoparticle landed on the cavity surface changes the cavity resonance through the reactive sensing principle, which transduces to the change of optical spring constant, yielding an amplified shift of mechanical oscillation frequency with noise suppressed. As a result, single Bovine serum albumin (BSA) molecules were observed at a signal-to-noise ratio of 16.8. With incorporation of a plasmonic nanoantenna, ultimate detection limit down to single atoms are predicted.