Microspherical Photonics: Giant Resonant Propulsion Forces

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In 1977, Arthur Ashkin and Joseph M. Dziedzic demonstrated that optical forces possess narrow spectral peaks determined by the internal resonances in microdroplets [1]. These resonant optical forces open up a unique way of high-volume sorting of nearly identical “photonic atoms”. However, to date, only relatively subtle resonant effects have been observed.

Recently, we proved the existence of giant optical force peaks by studying the propulsion of dielectric microspheres in evanescent fields created by tapered microfibers [2]. We observed that the small fraction of the polystyrene microspheres in resonance with a tunable laser beam traveled through water up to 10 times faster than those of other sizes. For some of the spheres with 20 µm mean diameters the measured propelling velocities ($v_{\text{max}}$ ~0.45 mm/s for guided powers limited at $P_0 = 43$ mW) exceeded previous measurements with various evanescent couplers by more than an order of magnitude.

![Microfluidic fiber-integrated platform with optical tweezers.](image)

**FIG. 1.** (a) Microfluidic fiber-integrated platform with optical tweezers. (b) Maximal propelling velocity as a function of mean sphere diameters. Dashed blue area represents multiple measurements on spheres with 1% size deviations. (Inset) Snapshots of resonant propelling of 20 µm spheres. (c) Theoretical model. (d) Calculated propulsion force.

We studied the mechanism of ultra-high propulsion forces for a cylindrical resonator located near to a surface wave [3]. We showed that under resonance with whispering gallery modes (WGMs) the momentum flow carried by the surface wave is imparted to the object, giving it a propulsion force ($F_z$) which reaches the total absorption limit. We show that the transverse optical force can be either attractive or repulsive depending on the particle-to-surface distance and other conditions. We show that the spheres with the desired positions of high-quality ($Q > 10^4$) WGM peaks can be sorted by using a tunable laser source.