Optofluidic microlasers based on liquid droplet resonators for biophotonics applications

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Abstract

Optofluidic sources of laser light that can be integrated into lab-on-a-chip systems enable dynamic control of the laser resonator geometry and gain medium and, thus, open up new paradigms in bio-sensing. With their unique features, liquid droplets stand out among various optical resonators for developing optofluidic lasers. Thanks to their spherical geometry and smooth surface, droplet-based cavities host high quality optical resonances called whispering gallery modes. These low-loss resonant modes allow droplet lasers to operate at low threshold pump powers. Liquid droplets are easy to produce using aerosol generators in air or flow focusing / T-junction geometries in a microfluidic chip. Upon generation, droplets can be captured and manipulated using optical micromanipulation techniques such as optical tweezing or stretching. Their easily deformable nature makes them attractive for developing tunable optical components, e.g. tunable light sources. In addition, water-based droplet cavities are also biologically compatible, permitting the use of aqueous solutions of biologically relevant molecules as laser gain media.

We introduce several variants of optofluidic microlasers based on active optical resonant cavities formed by dye-doped droplets that are either deposited on a supporting solid substrate or confined in an optical trap. To this end, both aerosols and emulsion droplets are exploited. We show it is possible to achieve tunable dye lasing with optically pumped droplets of oil dispersed in water and stretched by light in a dual-beam optical trap. We also report lasing in airborne glycerol/water droplets localized using optical tweezers and illuminated with a pulsed laser beam. In addition to direct optical pumping of the gain medium, we explore the possibility of using non-radiative energy transfer to achieve lasing. Furthermore, biological lasing in droplets supported by a superhydrophobic surface is demonstrated using a solution of Venus variant of the yellow fluorescent protein or *E. Coli* bacterial cells expressing stably the Venus protein. Our results may lead to new ways of sensitive chemical and biological analysis, exploiting the high sensitivity of stimulated emission to small perturbations in the shape, size, and composition of the droplet cavity.