Advanced all-fiber optofluidic devices

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Abstract

Significant technological advances of the last years have been possible by developments in Optofluidics, which is a field that deals with the integration of optics and microfluidics into single devices.

The work described in this thesis is based on five scientific publications related to the use of fiber optic technology to build integrated optofluidic devices. The first three publications are within the field of life-science and point towards in-vivo and point-of-care applications, whereas the last two publications cover the study and the use of plasmonic nanoparticles for electrical modulation of light.

Aiming at developing useful tools for in-vivo biological applications, the first publication consists of designing and testing a functional optical fiber for real-time monitoring and selective collection of fluorescent microparticles. This probe relies on a microstructured optical fiber with a hole along its cladding, which is used to selectively aspirate individual particles of interest once their fluorescence signal is detected. On the same line of research, the second publication contemplates the fabrication of a fiber probe that traps single microparticles and allows for remote detection of their optical properties. This probe is also based on a microstructured fiber that enables particle trapping by fluidic forces. The third publication addresses the development of an all-fiber miniaturized flow cytometer for point-of-care applications. This system can analyze, with excellent accuracy and sensitivity, up to 2500 cells per second by measuring their fluorescence and scattering signal. A novel microfluidic technique, called Elasto-inertial microfluidics, is employed for aligning the cells into a single-stream to optimize detection and throughput.

The fourth publication involves the experimental and theoretical study of the electrical-induced alignment of plasmonic gold nanorods in suspension and its applicability to control light transmission. This study is done by using an all-fiber optofluidic device, based on a liquid-core fiber, which facilitates the interaction of light, electric fields, and liquid suspensions. Results show that nanorods can be aligned in microseconds, providing a much better performance than liquid-crystal devices. Finally, the fifth publication consists of an upgrade of the previous device by integrating four electrodes in the cladding of the liquid-core fiber. This improvement enables nanosecond response time and the possibility of digitally switching nanorods between two orthogonal aligned states, overcoming the limitation of slow thermal relaxation.

The work presented here shows that optofluidics based on optical fibers is a robust and convenient platform, as well as a promising direction for the developing of novel instruments in fields such as life-science, non-linear optics, plasmonic, and sensing.
Key Words
Fiber optics, functional fiber probes, optofluidics, microfluidics, plasmonic, all-fiber technology, instrumentation for life-sciences.