Inside their cytometer, which is the size of a U.S. quarter, cells are individually transferred past a laser beam while the device detects light scattered from the cells as well as the fluorescent emission from antibody tags. By exploiting the slight angular difference between refraction and total internal reflection, the researchers have successfully created waveguides that preferentially include light originating from the cell and that exclude light coming from short distances. This solves the ever-present problem of low signal-to-noise ratio in fluorescence measurements. In Godin's words, their technique may allow for a truly integrated, low-cost optofluidic flow cytometer cartridge with performance rivaling that of a standard commercial device. The mold-replicated device integrates tapered, solid-core waveguides and optics in a monolithic design that is easy to reproduce.

Hollow-core waveguides are another example of optical elements that can be integrated with microfluidics. A team of researchers at the Institute for Electromagnetic Sensing of the Environment in collaboration with the Seconda Università degli Studi di Napoli and the Technical University of Delft in the Netherlands have developed a highly sensitive optofluidic Mach-Zehnder interferometer (MZI) based on waveguides with hollow cores filled with liquid. The group used anti-resonant reflecting optical waveguides to develop an MZI in which both the light and the liquid filling the waveguides are guided in the same small channels.

The use of a liquid-core waveguide permits one to probe the liquid sample directly with very high interaction efficiency in a design that requires no additional channels for sample delivery. Their device layout is based on T-shaped channel branches and bent waveguides that effectively minimize the intensity imbalance between the two arms of the interferometer. Measuring a mere 2.5 mm in length, the device requires a liquid volume of only about 160 pl and is capable of detecting a refractive index variation as small as one part in ten thousand.

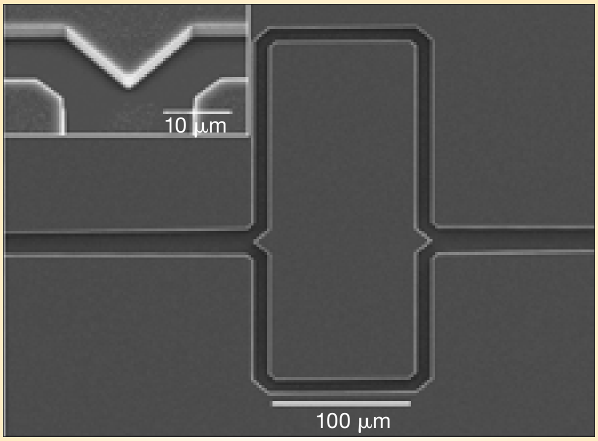
In a different example of microfluidic integration with optical trapping, scientists from the University of Glasgow and the Universita di Roma "La Sapienza" have used laser tweezers within a microfluidic chip to measure the velocity vectors of flow fields in three dimensions. Trapping first a probe particle with the tweezers and placing it within different places inside the channels of the chip, they accurately monitored the displacement of the particle in the flow as it accelerated inside the flow stream upon its release. The team managed to repeat this process 50 times per second in order to obtain a precise estimate of the local velocity of the fluid, including its direction, around obstacles within the chip, where the flow changes rapidly. Furthermore, using this minimally invasive technique, they successfully mapped the flow around a living cell.

Recently, researchers at the Centre for Micro-Photonics at the Swinburne University of Technology in Australia demonstrated another interesting application, in which the characteristics of the fluid can be inferred with optical means. Researchers at the Centre have successfully mapped the shear stress inflicted upon optically trapped particles of different sizes by the flow of liquid around them. Direct measurements of the Stokes drag force on the spheres inside microscopic channels with different shapes enabled them to measure shear stress at arbitrary positions inside the channels. Using a numerical model, they compensated for the proximity of the channel walls and found that particles of different sizes actually move at different velocities inside the channels.

Many of the recent developments in optofluidic technology could not have been anticipated when the field first started—and there's no way of knowing exactly where the field will go from here. Optofluidics certainly holds promise for many exciting applications, in biophotonics, sensing and beyond. It is up to the innovative thinking of new generations of researchers to come up with new and exciting technological developments.

ONLINE EXTRA: Visit www.osa-opn.org for videos of the optical trapping and propulsion of red blood cells.

[Optofluidic Mach-Zehnder interferometer]



Optofluidic MZI fabricated with hollow-core waveguides. The waveguide cladding materials were deposited in layers with precisely calculated thicknesses in order to realize very high reflectivity mirrors by atomic layer deposition on a silicon substrate. Within the waveguides, light is confined in a low-refractive-index liquid core. This device was fabricated at the Delft Institute of Microsystems and Nanoelectronics.

Courtesy of Romeo Bernini, IREA-CNR

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