- ► Compute Mixing Efficiency
- ► Curved Microchannel Flow
- ► Droplet Based Lab-on-Chip Devices

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Microfluidic Optical Devices

BARBAROS CETIN , DONGQING LI
Department of Mechanical Engineering,
Vanderbilt University, Nashville, TN, USA
barbaros.cetin@vanderbilt.edu

Definition

Microfluidic optical devices are classified into two groups of devices: (1) devices using microscale on-chip optical methods/components for biochemical sensing or for manipulation of fluids or particles in Lab-on-a-Chip devices; and (2) devices using microfluidics to manipulate light at the microscale.

Overview

Microfluidic optical devices (MODs) represent an emerging technology that combines today's microfluidics technology with optics. Devices based on optofluidics – manipulating fluids and light at the microscale – are examples belonging to this class of microfluidic devices. (An excellent review on optofluidics can be found elsewhere [1].)

In many biological applications, microfluidics and optics technology are already being used in combination: microfluidics for control and manipulation of samples and optics for sensing. However, MODs can be classified as the integration of these two technologies rather than the combination of them. This integration results in integrated detection systems for microfluidic application (which increases the portability of the entire system) [2–4], a sensitivity increase for the existing detection system [5, 6], cell manipulation [7–9], tunable optical fibers [10] and variable-focus liquid lenses [11].

Chabinyc et al. [2] succeeded in the integration of a fluorescence detector based on a microavalanche photodiode into a polydimethylsiloxane (PDMS)-based microfluidic device. Their detection system was reusable, and the microfluidic device was disposable. The elimination of the index matching problem which occurs in some micromachined devices, the elimination of the need for collection optics and the inexpensiveness are the superiority of the design. Those authors also addressed some further improvements for the performance of the device.

Mazurczyk et al. [3] fabricated an integrated fluorescence detection system with a microfluidic Lab-on-a-Chip device. Various arrangements were tested for the fluorescence beam detection: free space optics, fiber optics and fully waveguiding optics. Free space optics was found to have the higher sensitivity, but it needed a bulk microscope-based detection system. Fiber and fully waveguiding optics seemed to be a possible option to overcome the need for a bulk microscope setup, but their sensitivity was not found to be sufficient especially for high-sensitivity applications. Anyhow, those authors showed the feasibility of their device for electrophoretic separations by performing some preliminary experiments. They proposed usage of soda lime glass for the fabrication of their device and envisaged fabrication of more sophisticated systems.

Heng et al. [4] developed a novel on-chip microscope system, which was called an optofluidic microscope (OFM). The feasibility of the OFM was demonstrated. Its images were comparable to those of a conventional microscope. Those authors suggested the possible use of multiple OFMs on a single microfluidic chip either for increasing imaging throughput in the case of parallel usage or sequential imaging of the same target in the case of serial usage.

Camou et al. [5] used two-dimensional optical PDMS lenses to improve the performance of fluorescence spectroscopy detection carried out on a portable chip using optical fibers. The fibers were directly inserted into channels ending with PDMS optical lenses. Compared to convention flat interfaces, these optical lenses increased the intensity of the fluorescent response close to the fiber which leads to a higher sensitivity of the on-chip detection method for fluorescence spectroscopy. Chen et al. [6] implemented a simple, on-chip arrayed waveguide excitation and detection scheme based on scattering. Detected signals were processed, and not only was sensitivity enhancement observed, but particles moving with different velocities were also detected accurately.

Kruger et al. [7] proposed a miniaturized flow cytometer using the latest photonics technology to perform detection, enumeration and sorting of fluorescent species. They successfully performed sample injection, single-file flow through the detection system and sorting of fluorescent microbeads. They could not achieve fully autonomous cell sorting, but they indicated that as a future direction. They also demonstrated the feasibility of high-gain avalanche photodiodes for more sensitive measurements of fluorescent signals compared to conventional detection techniques.

Optical tweezers are devices that use the force of strongly focused light to trap and move small objects whose dimensions are below tens of micrometers. The exerted force range and the resolution for optical tweezers are very suitable for biological and macromolecular systems. They have been used in many applications [8]. A detailed review on optical tweezers can be found elsewhere [8]. Besides optical tweezers, Mandal and Ericson [9] illustrated the optical transport of microparticles in a liquid core waveguiding structure over long lengths, which has great potential for much more precise particle separation and particle transport without flow field manipulations. The light–particle interaction length of their proposed technique was orders of magnitude larger than that of existing systems.

Mach et al. [10] presented microfluidics-based fiber optics. They demonstrated a multifunctional all-fiber filter. They achieved independent tuning over a broad range of both transmission wavelength and attenuation by locating and manipulating the locations of microfluidic plugs with adjustable position and optical properties.

Another interesting application of microfluidics and optics is the use of variable-focus liquid lenses, which was developed by Philips Research Eindhoven [11]. The lenses which are composed of two immiscible liquids of different refractive indices can be manipulated by electrowetting. By electrowetting, the meniscus curvature of the lenses can be changed, which also changes the effective focal length of the lenses.

Ruano-Lopez et al. [12] demonstrated a simple, inexpensive, new and reliable fabrication process for optical Lab-on-a-Chip devices. They used SU-8 waveguides as sensing elements, and fabricated their cladding by diluting SU-8-50 in a liquid aliphatic epoxy resin.

Cross References

- ► Optofluidics–Applications
- ► On Chip Waveguides

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Microfluidic Platforms

► Microfluidic Devices in Tissue Engineering

Microfluidic Reactor for Biomolecular Synthesis

► Biomolecular Synthesis in Microfluids