Optical Microfluidics

J.-P. Delville[1], **R. Wunenburger**[1], **and C. Baroud**[2]

[1]Université Bordeaux, France
[2]LadHyX, France

The development of applications based on microfluidic technology is still hindered by the lack of robust fundamental building blocks that constitute any fluidic system: pumps, valves and mixers for instance. Yet, these building blocks run into the limits of miniaturization and most of the designs used in human-scale flows are either impractical or completely inapplicable to micron-scale flows. On the other hand, while large scale flows are rather insensitive to small leaks, miniaturized fluidic devices become increasingly sensitive to such imperfections. This problem is made worse by the difficulty of micron-scale fabrication, especially when moving parts are involved. An attractive route is optical actuation because light fields are non invasive and dynamically reconfigurable, and solutions have been proposed through the use of optical tweezers to manipulate small particles in flows. By controlling the position and rotation of many particles independently, pumps, valves and particle sorters have been demonstrated in microfluidic channels. The extension of these techniques to multiphase flows is nevertheless difficult because colloidal particles interact with fluid-fluid interfaces.

Here, we propose two types of optical forcing to drive microfluidic two-phase flows or, conversely to answer the requirements enumerated above, namely to block, merge, divide or sort individual droplets flowing in a microchannel. First, we investigate the effect of the optical radiation pressure on fluid interfaces and analyze microfluidic flow regimes in laser-induced jetting, either droplet dripping or continuous transport in laser-sustained liquid columns (Fig. 1). Then, we investigate a dissipative coupling consisting in heating locally an interface between two immiscible fluids to produce thermocapillary stresses along this interface. This effect, known as the optical Marangoni effect, is implemented in adequate microchannel geometry to devise fundamental building blocks for two-phase flows in microfluidic devices (Fig. 2). This allows the creation of contactless optical actuators such as mixers, valves, droplet sorters and switch, droplet dividers or droplet mergers.

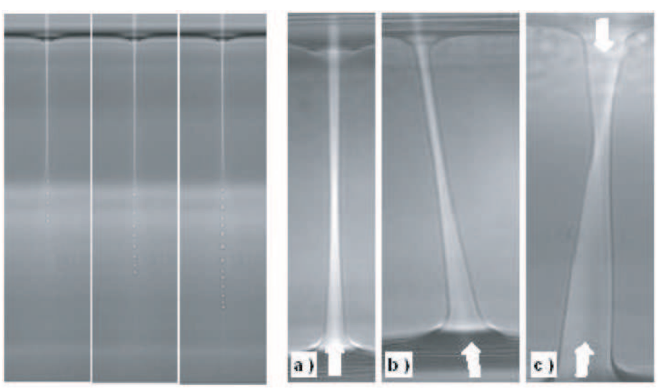

Figure 1: Microfluidic flows driven by the optical radiation pressure, (1) Dynamics of droplet emission during laser-induced jetting (1 fps); (2) Different sort of liquid columns (liquid optical fibres) induced and stabilized by radiation pressure largely beyond the Rayleigh-Plateau instability onset.

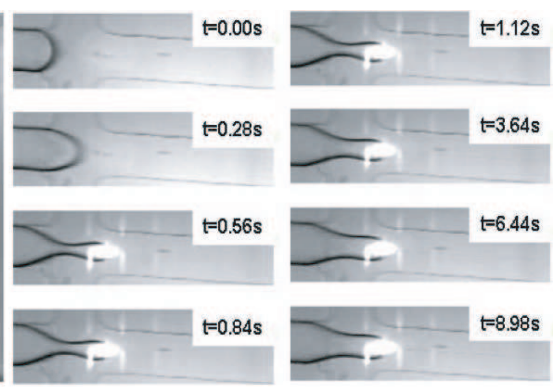

Figure 2: Optical actuation of a water flow in a microchannel, Implementation of an optical valve: the laser pins the interface for several seconds by thermocapillary stresses, producing larger drops of calibrated volume without changing flow rates.