Selective acoustical tweezers and acoustical vortices

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Selective optical tweezers, introduced by A. Ashkin in 1987, led to tremendous developments in fundamental physics and life science and were recently awarded the Nobel prize. However, since particles trapping with optical tweezers relies on the optical radiation pressure, a force inversely proportional to the (high value) light speed, the range of forces which can be applied with optical tweezers is very limited. In addition, the high beam intensity required for particle manipulation can lead to detrimental heating, hence severely limiting their use for many life science applications.

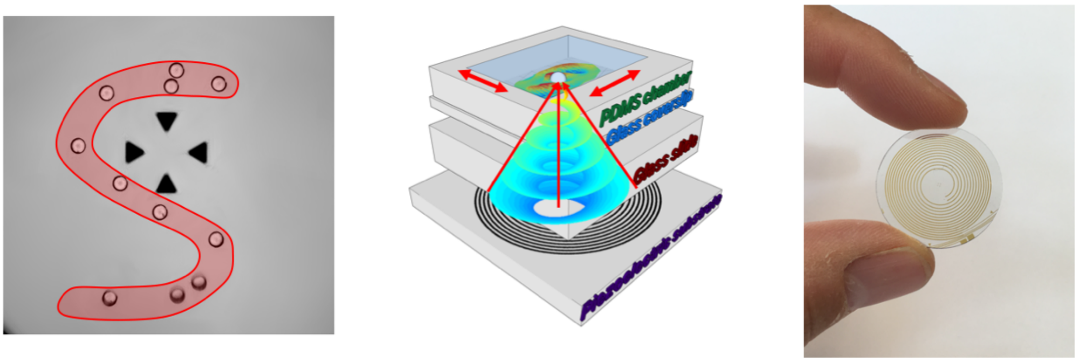

Figure 2: Left: Set of 11 polystyrene particles of 75 microns organized to form the letter S with the acoustical tweezers presented in ref. [2]. Center: Scheme illustrating the principle of selective acoustical tweezers: an acoustical vortex is synthesized by activating spiraling electrodes sputtered at the surface of a piezoelectric medium. This acoustic vortex traps the particle in a microfluidic chamber. Moving the tweezers with respect to the microfluidic chamber enables particles manipulation. Right: Picture of actual acoustical miniaturized acoustical tweezers.

In these lectures, we will discuss the tremendous possibilities offered by their acoustical counterparts, acoustic tweezers, for particle and fluid selective micromanipulation. Indeed, given the same amount of wave power input, acoustic waves can exert five order larger forces than electromagnetic waves, which follows from the principle that sound waves travel in fluids at a speed five order slower than light.

After the introduction of key concepts in nonlinear acoustics (acoustic radiation pressure, acoustic streaming), we will highlight the emergence of some specific wavefields, called acoustical vortices, as a mean to manipulate selectively particles. We will also demonstrate how these fields can produce hydrodynamic vorticity fields whose topology relies on the one of the acoustic wavefield. Then we will explain how the concepts of holography, Fresnel lenses and MEMs can be gathered in a single miniaturized device to manipulate microscopic objects and in particular cells in a standard microscopy environment. Finally, we will conclude these lectures by introducing some recent work on particles assembly with acoustical tweezers.

References

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