Controlled microactuation using thermocapillary convective flow

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Non-contact micromanipulation has received a lot of interest in recent years. Different from the contact manipulation techniques, non-contact micromanipulation uses force fields remotely applied to manipulate the object. Several actuation principles are available such as magnetic actuation, laser trapping in the form of optical tweezers and dielectrophoresis.

The proposal is to use thermocapillary convective flow as actuation principle to manipulate particles between 100-1000 μm lying at the water-air interface on a controlled closed-loop system. Thermal Marangoni effect appears when a surface tension gradient is generated at the interface between two mediums product of a temperature gradient. The surface tension gradient will produce a flow from the hot regions towards the colder ones proportional to the temperature gradient. If the thermal gradient is directly imposed at the interface, the generated flow is known as thermocapillary convective flow. The advantage of this type of convection is that it does not depend on an instability to happen, and so, any temperature gradient at the interface will generate a convective flow.

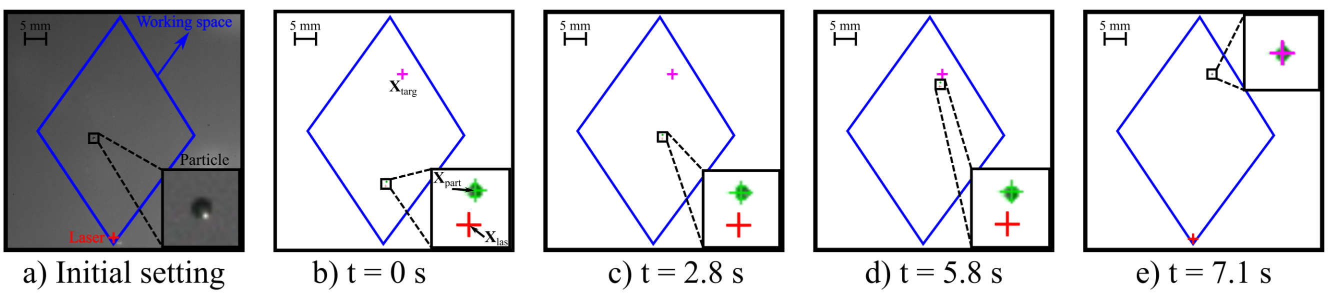

Fig. 1: Controlled manipulation: a) Initial setting: a 500-μ*m*-diameter spherical steel particle is floating on the surface of a water layer with the controller turned off, so the laser spot (red cross) is placed at the bottom part of the working space (blue rhombus). b) The backlight is turned on an then, at t = 0 s, the controller is turned on. The particle is at position $\mathbf{X}_{part}$ (green cross) and the goal is to displace it to the target position $\mathbf{X}_{targ}$ (magenta cross) by changing the position of the laser spot $\mathbf{X}_{las}$ (red cross). c, d) The particle is displaced towards the target position. e) The particle reaches the tolerance region around the target position and the controller is turned off.

The control goal is to manipulate the particle lying at the water-air interface from an initial position Xpart towards a target position Xtarg by changing the position of the laser spot Xlas. For this purpose the system was identified, and a model for the system was obtained and used to develop a PID controller for the system. Using this controller, the particle can be displaced towards a target position as shown in Figure 1. In this work it is shown that the thermal induced Marangoni effect can be used as an actuation principle to drive the movement of particles lying at the water-air interface. Velocities in the range of 4-7 mm/s were obtained, which are in top performance compared to other actuation principles.