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MOEMS based laser scanner for light-driven microfluidics

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Abstract

In this paper we report on recent experiments using laser controlled thermally induced flows in a microfluidic cell. Control of the laser focus was achieved using MOEMS-technology which offers the possibility for a compact and easy to use variable focus scanning device. In our paper we present the scanner device and show first experimental results indicating possible applications in the field of microfluidics.

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Keywords: micro fluidics, light driven microfluidics, MOEMS, laser-scanner

1. Introduction

In the field of microfluidics and lab-on-a-chip experiments one of the challenges consists in having the ability to remotely manipulate fluids, droplets and particles. Light-driven microfluidics [1] provides one way of accomplishing this challenge by using laser light in order to actuate fluids. A well-chosen light source has the capability to create optical forces that can have highly selective action (e.g. optical tweezers) or, less specifically, to deposit energy in the liquid and to induce thermal flows in the sample solution (e.g. for the manipulation of particles) or to start chemical reactions at specific locations. In all cases, these processes are contactless and sterile which is an important advantage for medical, chemical and biological applications.

From the technical point of view, it is important to have a high accuracy and precise control of the position and shape of the focal spot inside a fluid. The device presented in this paper relies on MOEMS elements to be combined

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with Lab-on-a-Chip technology. Both technologies have a wide range of applications from biotechnology and medicine to communication and inertial sensing. Used together they offer the possibility to develop a compact and easy to use device that serves for several types of laboratory experiments.

2. Experimental

Here we present a MOEMS based laser scanner device, which features an electrically tunable lens [2] for adjusting the focal length of the laser beam and an electrostatically driven quasi-static MOEMS micro-mirror [3] for precise beam steering. The combination of a tunable lens and a dual axis micro-mirror enables positioning of the laser focus at any arbitrary location within a three dimensional working space. Typically a 650 nm laser diode with an optical power of 13 mW was used but other laser sources were tested as well. Spot-sizes below 100 µm were achieved. Figure 1 shows a schematic drawing of the experimental setup.

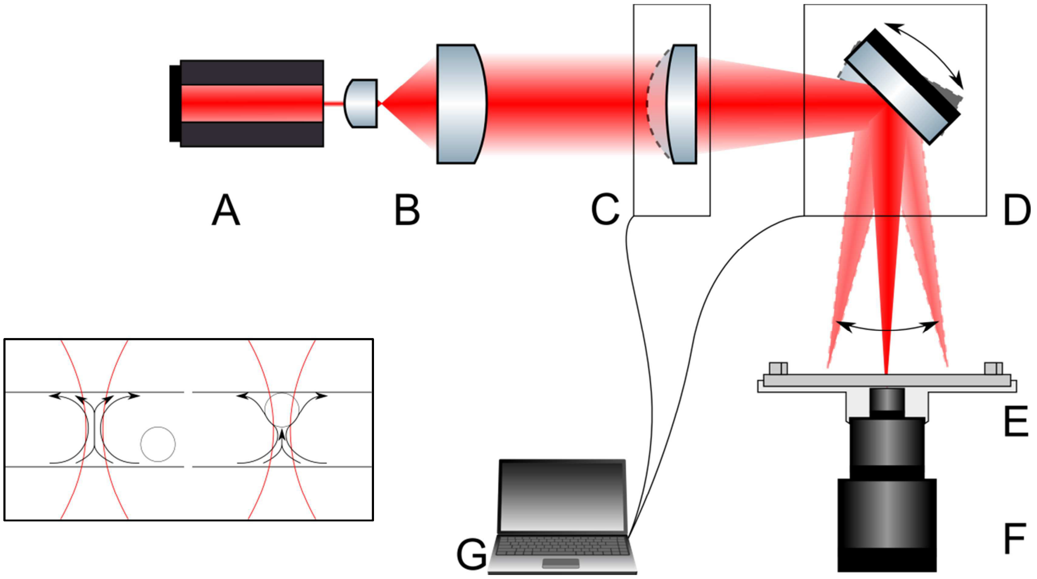

Fig. 1. Schematic layout: A…laser, B…beam expander, C…tunable lens, D… MOEMS mirror, E…microfluidic chip on sample holder, F…microscope, G…computer. The inset shows a schematic drawing of the working principle for the manipulation of microbeads: The beads get pulled towards the focal spot due to convection rolls which are caused by the local heating.

This device features high flexibility, and, due to absence of large mechanical movements, it is highly robust and has low power consumption. This property represents an important asset, when thinking about portable devices.

Demonstration experiments were performed in a microfluidic chip containing unstructured chambers with dimensions of $2.6\times10\times0.2\text{mm}^3$. Observation of the experiments in the microfluidic cell was realized with a digital microscope.

3. Results

To demonstrate the feasibility of light-driven microfluidics with our device, we performed two demonstration experiments. In the first experiment, it was shown, that the laser-power is sufficient to achieve boiling in the liquid, which perturbs the laminar flow in the cell. This is shown in Figs.2. Fig. 2a shows the initial situation where one can see a laminar two-phase flow in the flow cell. The solvent in this case is water and in the left channel a dye was added in order to increase the absorption of the laser and to visualize the liquid flow. Fig. 2b shows the generation of the bubble (indicated by the arrow) and the shockwave, which locally mixes the two flows (seen in the white circle).

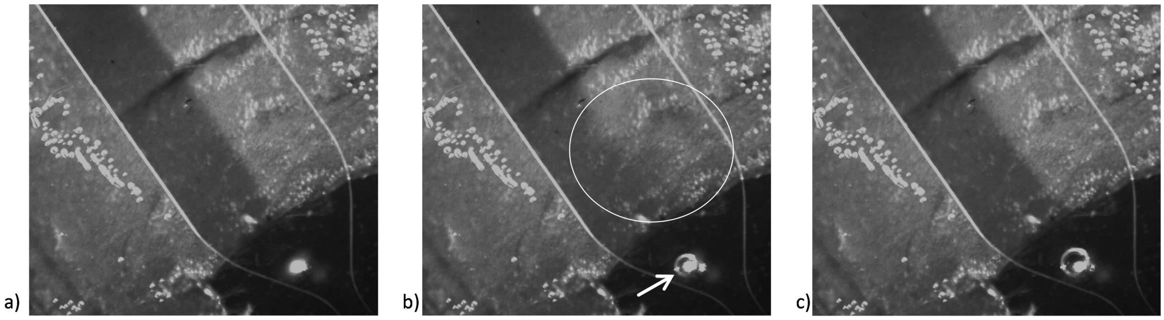

Fig. 2. Shockwave in a laminar flow: a) Situation when the laser spot is turned on. b) Creation of a bubble generates a shock wave, which perturbs the laminar flow. c) The bubble further expands and stays centered at the laser focus until the laser is turned off.

The last Figure of the sequence shows the final situation, with the generated bubble at the location of the laser spot. By moving the laser slowly, the bubble actually can be displaced within the liquid (not shown in this Figure).

Tuning the optical power, it is possible to find conditions where thermal flows are induced in the microfluidic systems, which can be used to manipulate micrometer sized particles. This was tested in a second series of experiments. Figure 3 shows snapshots of such an experiment. Polystyrene microbeads with a diameter of 45 μm were dissolved in a stationary solution of water and ink. When heating the liquid with the laser light, convective flows are generated at the position of the laser spot, (c.f. inset of Fig. 1). The beads get attracted towards the focus of the laser spot, which enables the generation of a spot pattern, where each spot features a conglomeration of beads (Fig. 3c). The pattern that we created in this experiment remained in the same position even after the laser was turned off, proving that the beads were moved by the thermal flows, that were generated in the microfluidic chamber by the laser.

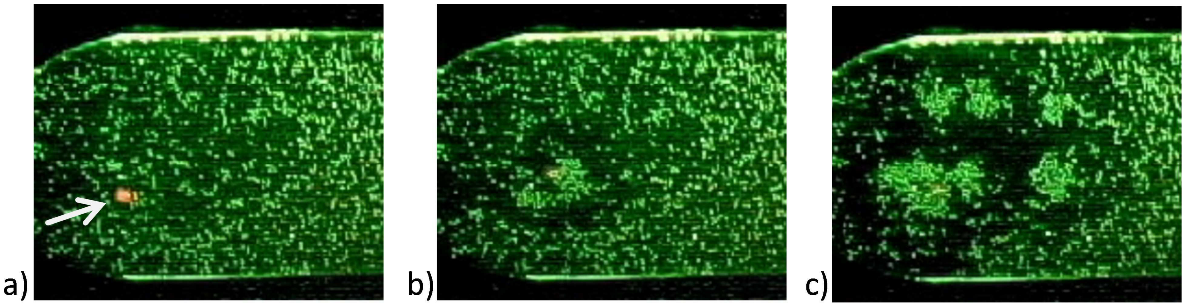

Fig. 3. Light-driven manipulation of micro-beads into arranged groups. (a) Image of the laser spot in a homogenous distribution of beads. (b) Beads get pulled towards the position of the laser spot. (c) Formation of a pattern.

Overall these first experiments were successful and confirm the usability of the MOEMS based hardware used in setting up the device. The set-up based on a tunable lens and a micro-mirror provides an efficient and flexible mechanism to steer the laser spot to any position in the working space. Even though, we used rather low laser powers and also the laser spot, in the current set-up, is relatively large, boiling of the liquid and steering of micro beads were achieved easily.

4. Conclusions

In this paper we presented our novel device and showed the results from two proof-of-principle experiments. We demonstrated that the manipulation of microbeads is possible using optically induced thermal flows within a liquid. Furthermore we showed that the generation of bubbles within the liquid is also possible, which leads to the generation of shock waves, which could be used for mixing.

The whole technique is conceptually very simple and relies on relatively simple hardware, since standard diode lasers and focusing optics can be used. At the same time, it enables manipulation of the beads within an unstructured environment, which is a formidable task. Other possible applications, which could be targeted with our scanner device, include the manipulation of cells as well as the initiation of chemical reactions in microfluidic systems.

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