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Integrated Micro-Optics for Microfluidic Systems

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Generation of multiple traps within a microfluidic channel is a subject with practical applications e.g. in life sciences. In the approach presented here a diffractive optical element, integrated in the channel walls, is used to generate the necessary spot pattern.

1 Introduction

Microfluidic systems have a large variety of applications in biomedicine and life sciences. One of the problems occurring in practical systems is the adhesion of cells and micro-particles to the walls of microfluidic channels and reservoirs. For scientific examinations, e.g. for drug testing, it is necessary to expose specific test cells to different media. The cells are moved between the reservoirs e.g. by optical tweezers and kept there for a specific period of time [1,2]. This is a very time consuming experiment if the cell under examination must be kept in the laser trap during the whole reaction cycle. Introducing an array of fixed traps in the reservoir keeping a few cells, each in its own trap, would make total control of the experiment possible. In this case the movable optical trap is required only for transport from one reservoir to another. In this project we investigate possibilities to integrate optical functionality in the microfluidic system to generate the static weak optical traps without additional optical components which would have to be aligned to the microfluidic system. Alternatively this system setup could be used to generate light distributions for sorting particles within a flow [3].

2 Goal of work

Until now, microfluidic- and optical systems have not been integrated into the same substrate. Using planar integrated free space optical (PIFSO) systems it is possible to integrate both functionalities within one substrate. The idea of PIFSO systems is to integrate common free space optics into a glass substrate [4]. This means the optical axis is folded and the light travels on a zigzag path between the reflection coated surfaces (see fig. 1). The optical elements, commonly diffractive elements, need to be corrected for the oblique incidence of light and are etched with sub micron precision into the surfaces of the substrate. No optomechanical alignment of the individual optical components is necessary the whole system is integrated monolithically. These systems are ready for use immediately after fabrication. It was shown by various authors that PIFSO systems have applications in fields such as optical communication and security [5,6]. Combination of PIFSO systems with microfluidic systems is straightforward as both applications use the same technical fabrication. At present, these PIFSO systems are fairly inefficient and need to be optimised e.g. by integration of refractive components [7].

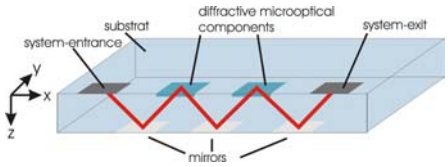

Fig. 1 *Principle setup of a PIFSO system.*

3 Basics requirements for optical trapping

Optical tweezing systems are a common technology and are commercially available. Most of the tweezing systems are single trap tweezing systems which can handle only one test particle at a time. Optical tweezers are normally built up with microscope objectives with a high numerical aperture (NA), e.g. NA = 1.3 with oil immersion and a magnification of 100x. These objectives are well corrected for aberrations and focus the light to a diffraction limited focus. The focused wave field exerts two kinds of forces on “larger” (>wavelength) particles which allow the trapping. One is the radiation pressure, pushing the particles along the optical axis out of the focus and the other is the axial gradient force pulling the elements into the focus. For optical tweezing it is necessary that the gradient force is stronger than the radiation pressure to keep the particles within the focus of the laser beam. For smaller objects, down to 5nm, the trapping is based on developing an electric dipole moment in response to the light’s electric field [3].

4 Preliminary experimental setup

In a preliminary experiment we demonstrate that it is possible to generate the spot pattern, required for keeping particles away from the walls, within a

semi-integrated system. The channel system is built up by a microscope cover slip with a PDMS layer containing the microfluidic system. The combination of these materials allows one to set up a system sealed against leakage of the liquids. On the other side of the cover slip is a silica substrate. This substrate contains the diffractive beam splitter, calculated to generate four spots in a square. For the preliminary test system the distance between the spots is designed to measure 15µm and the distance to the channel surface between splitters have been designed to meet this requirement. In order to achieve the largest possible numerical

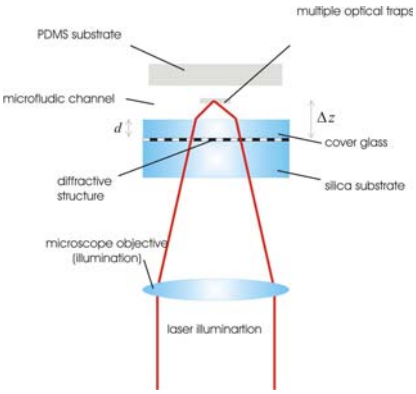

Fig. 2 *Preliminary setup.*

aperture for higher trapping forces an additional diffractive lens is integrated in the diffractive optical element, which provides additional focusing power. The lithographic fabrication of diffractive optics makes it possible to combine the beam splitter and the additional lens within one substrate. To achieve this, the phase structures of both elements are added. This procedure is shown in Figure 3. Since the beam splitter is an element of about 37 by 37 pixels, it needs to be replicated periodically in order to fit the size of the lens (approx. 350 by 350 pixels). When varying with the minimum feature size (s_{min}= 2µm-1µm) of the diffractive elements the numerical aperture varies: NA=1.01…1.28. This is good enough for trapping at least smaller particles within such a system.

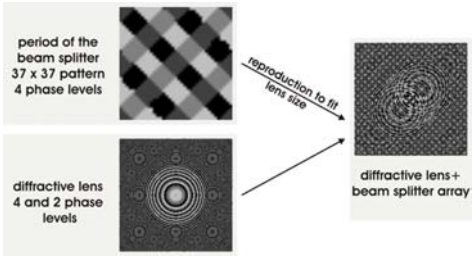

Fig. 3 *Combination of a diffractive beam splitter and a diffractive lens Experiment*

The diffractive optical element is calculated and fabricated to work with a Nd:YVO_4 laser at 1064nm. This is the wavelength typically used to handle biological objects. The output power of the laser is > 200mW. Within the experimental setup we use a Nikon 20x / 0.5 long working distance microscope objective for trapping and an Olympus 40x / 0.55 objective for observing the result. Objects for trapping are 0.5µm polystyrene spheres. These spheres are fluorescent to make them more visible with the Olympus objective. With this setup it is possible to trap the particles within the calculated four spots as seen in fig. 4a. After turning off the laser all trapped particles move away (see fig. 4b).

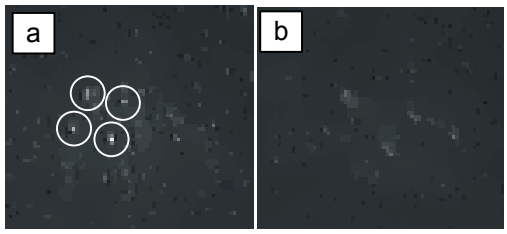

Fig. 4 *(a) Four particles are trapped in the diffractive pattern and (b) particles disappear after turning off the laser*

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