New BioPhotonics Workstation for parallel and real-time trapping, manipulating and characterizing of microscopic specimens

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New BioPhotonics Workstation for parallel and real-time trapping, manipulating and characterizing of microscopic specimens.

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Abstract
A unique BioPhotonics Workstation has been developed for generating arrays of currently 100 fully reconfigurable laser-traps making 3D real-time optical manipulation and characterization possible with the use of a joystick or computer vision. A patented spatial mapping is used to obtain real-time reconfigurable optical traps in the sample volume where the manipulation of a plurality of nano-featured micro-objects takes place.

Introduction
In the mesoscopic regime very small forces due to light-matter interaction are strong enough to significantly influence the motion of tiny particles [1]. Until just a few years ago virtually all laser manipulation schemes were based on this principle of trapping particles inside a single strongly focused beam and subsequent movement to a desired position by translating the laser focus [2]. Now, two decades later a great deal of progress has been achieved in optical trapping and manipulation, both in terms of applications and within the technical developments. Particularly, it has been realized that much more versatile and general manipulation of particles and cell colonies is possible by using specially tailored structures of light. Such light patterns have unprecedented potential for manipulating mesoscopic objects and have already been successfully used to organize small particles, including micro-organisms, in desired patterns and to sort samples of particles according to their size to mention but a few applications [3, 4]. For example, optical trapping and manipulation of a plurality of micro-particles, which opens up promising themes of studies for many interdisciplinary fields including those of biological and medical relevance, are now viable using reconfigurable patterns of optical fields [5]. With the advent of computer-addressable spatial light modulators, the reconfigurability of light patterns that can act as confining optical potential landscapes is made even more feasible with a great degree of interactive user-control.

The BioPhotonics Workstation
The all-optical BioPhotonics Workstation [6] has been specifically invented and developed by us for trapping, manipulating and characterizing microscopic specimens in parallel. The BioPhotonics Workstation employs an optical mapping from a beam modulation module to obtain reconfigurable intensity patterns corresponding to two independently addressable regions relayed to the sample volume where the optical manipulation of a plurality of micro-objects takes place. The generated array of counter-propagating trapping-beams is easily aligned using a computer-guided alignment procedure [7]. The spatial addressing of the expanded laser source is done in real-time through a high-speed computer controlled spatial light modulator that is integrated in the beam modulation module. Through a computer interface, the operator can simply select, trap and move the desired objects with a mouse or joystick. Once trapped, arbitrary motion patterns can also be programmed for the micro-objects and complicated moving patterns of many independent samples can be orchestrated. The fluid-borne microscopic particles can be ushered in through a rectangular cuvette where they are trapped and steered in three dimensions using the real-time reconfigurable matrix of counter-propagating structured laser beams. The counter-propagating geometry currently

generates up to 100 powerful optical traps using well-separated objectives, which eliminates the need for high numerical aperture oil immersion objectives required in conventional optical tweezers. This generates a large field of view and leaves vital space for integrating other enabling tools for probing the trapped particles, such as linear and nonlinear microscopy or micro-spectroscopy [8].

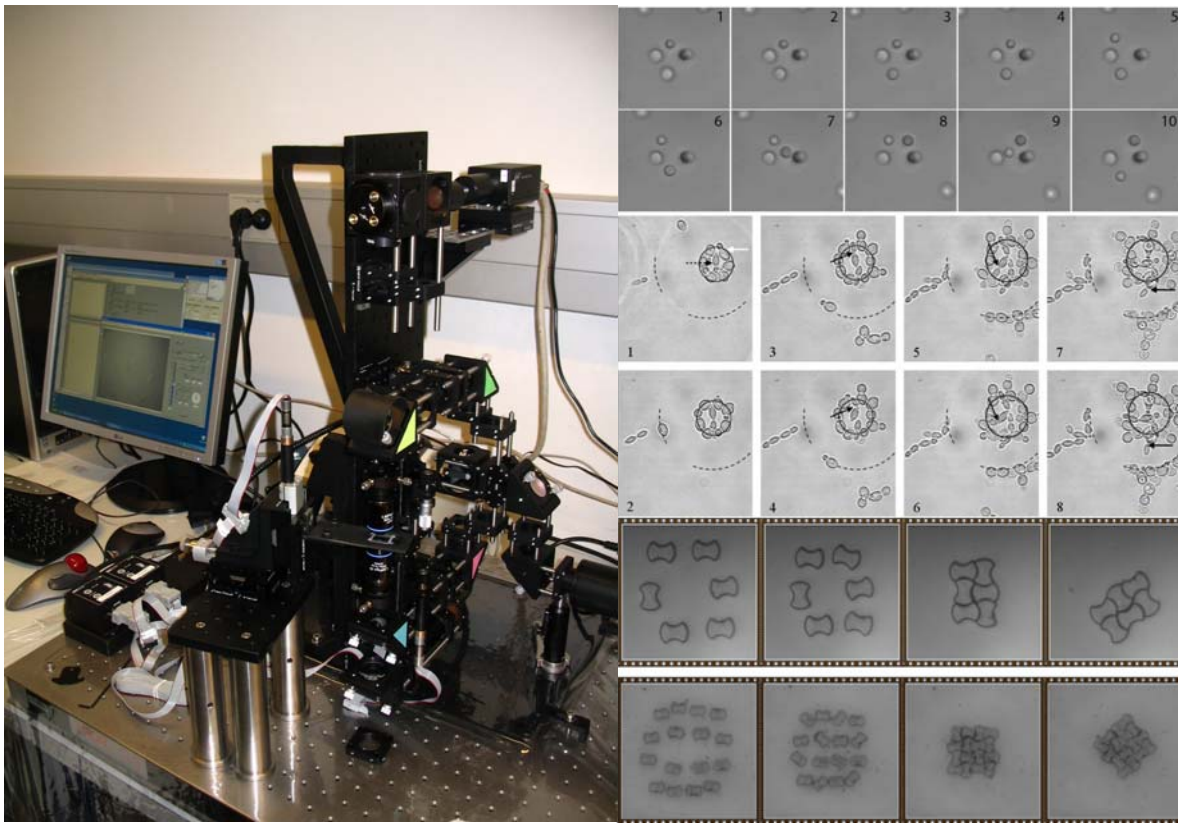

Fig. 1: The BioPhotonics Workstation and examples of different real-time 3D experiments.

Conclusions

We have successfully implemented a portable BioPhotonics Workstation including self-contained hardware modules and supporting software. This system has enabled us to demonstrate a variety of optical micro-manipulation experiments in 3D real-time including the first truely autonomous multi-particle laser-manipulation and tracking in a micro-fluidic environment. Supported by the modest processing power of a laptop computer, the BioPhotonics Workstation demonstrated that it is capable of detecting, locking and trapping particles or cells at a much faster rate than possible for a human operator.

4. References

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