TOOL FABRICATION FOR AUTOMATED INDIRECT OPTICAL MICRO-MANIPULATION

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Indirect optical micro-manipulation refers to mechanical manipulation of microscopic objects by means of optically trapped micro-tools. Two-photon polymerization is used to prepare the micro-tools, which are then trapped by focused laser beams through their spherical "handle" parts. Simultaneous control of several laser traps by Holographic Optical Tweezers (HOT) allows for positioning (both transfer and rotation) of the micro-tools in 3D. When compared to direct optical manipulation of micron-sized objects, the indirect micro-manipulation (using micro-tools) have several advantages. First, the unwanted interaction of the manipulated objects (e.g. live cells) with the intense laser beams is eliminated. Second, the use of micro-tools makes the manipulation of optically non-trappable objects under microscope possible.
We report on the development of micro-tools and their testing in an automated HOT system. The process of tool fabrication starts with a CAD model design, followed by its slicing, which leads to a set of bitmap images required as an entry for the polymerization apparatus. A micro-injector is used to suck the polymerized structures into a capillary and to transfer them to the sample cell. In the simplest case, the micro-tools are of the shape of a two-tine fork equipped with three spherical "handles" and are used as small "bulldozers" pushing the manipulated object to desired positions.
It is our goal to develop a semi-automated HOT system, with the possibility of precise user-controlled positioning of the micro-tools through haptic devices (touch screen, camera detecting the position of fingers). The control unit exploits the information to define the position of the laser traps. The optimal mutual position of the traps is determined computationally by analyzing the instantaneous image of the micro-tools.
In order to facilitate the manipulation of objects in large systems (exceeding the field-of-view of the trapping microscope objective) the HOT apparatus is equipped with an additional low-resolution microscope. The two live images of the same scene captured with different magnification are useful also from the point of view of autonomous work of the system. These images are processed on the system of several computers communicating each other via local network. Depending on the task, HOT receives processed information about the positions of manipulated particles, optimal trajectory to target avoiding obstacles etc. The automation of some micromanipulation tasks heads towards the field of "light robotics".