Advances in Holographic Optical Trapping

MARTIN PERSSON

Akademisk avhandling för avläggande av
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Fakultetsopponent:	Prof. Tomas Cizmar The University of Dundee, Scotland
Examinator:	Prof. Dag Hanstorp Institutionen för Fysik, Göteborgs universitet
Huvudhandledare:	Docent Mattias Goksör Institutionen för Fysik, Göteborgs universitet

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UNIVERSITY OF GOTHENBURG

Institutionen för fysik
Göteborgs universitet
412 96 Göteborg
Sweden

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MARTIN PERSSON
Department of Physics
University of Gothenburg

ABSTRACT

Holographic optical trapping (HOT) is a technique for non-invasive dynamic manipulation of multiple microscopic objects, which has been used for many applications in the life sciences during the past decade. The technique uses holographic beam steering with a spatial light modulator (SLM) to direct light to the desired positions of optical traps. In many cases, the control of the optical intensity of the traps is impaired by imperfections in the SLM. This has limited the use of HOT for applications sensitive to variations in the trap intensities, such as optical force measurement (OFM). Also, the algorithms for optimization of holograms used in HOT are computationally demanding, and real-time manipulation with optimized holograms has not been possible.

In this thesis, four different methods for improving the accuracy of holographic beam steering are presented, along with a novel application for the combination of HOT and position measurement. The control of trap intensities is improved by compensating for crosstalk between pixels, and for spatial variations of the phase response of the SLM; and by dumping a controlled amount of light to specified regions away from the traps. Variations in trap intensities occurring when updating the SLM with new holograms are suppressed by enforcing a stronger correlation between consecutive holograms. The methods consist of modifications of the algorithm used for hologram generation, or alternative methods for post-processing of generated holograms. Applications with high stability requirements, such as OFM with HOT, will benefit from the presented improvements. A method for reducing computation time for hologram optimization is also presented, allowing the accuracy improvements to be used also for time critical applications.

Further, it is shown that position measurement of nanowires, held by multiple optical traps, can be used to probe the orientational structure and defects in liquid crystal materials.

Keywords: Optical tweezers, holographic optical trapping, optical force measurement, CUDA, spatial light modulator, holographic beam steering, liquid crystals.