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# Diffractive Optics Applications in Optical Micromanipulation

PhD Thesis

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*Dedicated to  
my family,*

*and to*

*the memory of the late Professor Galieno Denardo*

# Abstract

This thesis describes the optical trapping and manipulation of arbitrary arrays of microparticles in two and three dimensions as well as the arbitrarily shaped objects based on the use of Diffractive Optical Elements (DOEs). A new method to design the DOEs has been used in this work, which enables individual fine strength tuning in each of the trap sites. This has allowed the dielectric particle assembly of three dimensional structures and manipulation of red blood cells in desired and controlled configurations.

The thesis is divided into three chapters: Diffractive Optical Elements, Optical Manipulation, and Experimental Results.

Chapter 1 contains a review of the history and theory of diffraction and diffractive optics. Computer simulated examples are considered to illustrate the theory. The predated main DOE design methods including the global optimization, the ray tracing, and the iterative methods are described. A full description of the spherical wave propagation and superposition method on which most of the experimental work is based will be presented. This chapter ends with an overview of the DOE implementation techniques.

Chapter 2 introduces the technique of optical manipulation. A brief introduction to the basic theory, the history, the basic setup for this purpose and an overview of the applications are given. We explain the use of DOEs to generate multiple and multi force arrays of optical traps as well as novel laser beams. The potential of the technique will be argued for by introducing several examples pointing to special applications. Finally, we will show the ability of the technique to manipulate red blood cells in a spatially controlled environment.

Chapter 3 reports several experiments which demonstrate the capabilities of the DOEs designed by spherical wave approach and projected onto the Spatial Light

Modulator (SLM) for generating multiple and multi force dynamic arrays of intensity spots and then optical trapping in such arrays. Details of the setup which is developed to carry out these tasks and the steps to built the setup are explained in the beginning of the chapter. The experimental results for the examples we investigate in chapter 2 computationally, will be presented to confirm the idea. These results consist of beam shaping through experiments that use DOEs, multiple and multi force trapping of microparticles in volume, and optical manipulation of red blood cells. Finally, the results of real time manipulation of red blood cells will be described. A graphical user interface for this stage is considered and will be introduced. This interface helps the user to acquire the real time image of the trapping plane and design the DOE for the desired configuration of the trapping points. The results are achieved by inserting an extension to the first setup enabling simultaneous viewing of the sample in two orthogonal observation planes.

Appendix A provides technical details on the SLMs and the specifications of the available products on the market. Appendix B contains the trap stiffness measurement methods.

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