

Contents

CHAPTER 1	Introduction	1
CHAPTER 2	Optical trapping and tracking	5
2.1	Introduction	5
	Optical tweezers, 5 • Atomic force microscopy, 6 • Photonic force microscopy, 6 • Outline of this chapter, 9.	
2.2	Photonic force microscope setup	9
	Overview, 9 • Trapping and detection optics, 9 • Illumination and imaging, 12 • Sample positioning, 12 • Sample mounting, 13 • Sample heating, 13 • Piezo repositioning, 17.	
2.3	Optical trapping	18
	Theory of optical forces, 18 • Optical force profiles, 20 • Trap calibration - Langevin method, 22 • Trapping position relative to the focus, 24.	
2.4	Optical tracking	26
	Position detection signals, 26 • Trapping position and unique detector range, 30 • Lateral signal sensitivity, 31 • Control of relative radiation pressure, trapping position and 3D tracking region, 31.	
2.5	Tracking of nano-cylinders - a theoretical study	35
	Arbitrarily shaped particles in focussed fields, 37 • Nano-cylinder tracking signals, 37.	
2.6	Discussion	42
CHAPTER 3	Phagocytosis experiments	45
3.1	Introduction	45
	Overview, 45 • Binding and uptake, 47 • Intracellular transport and degradation, 48 • Filopodial dynamics, 49 • Outline of this chapter, 50.	
3.2	Materials and Methods	51
	Cell culture, 51 • RNA silencing, 52 • Fluorescence labeling, 53 • Bead coating, 54.	
3.3	Dynamics of membrane-bead binding	57
	Implementation of the experiments, 57 • Binding time point, 60 • Transition from unbound to bound state, 62 • Mechanical cell	

response upon binding, 64.	
3.4 Phagocytic tentacle retraction	64
Filopodial and ruffle retraction, 64 • Stepwise retraction, 66 •	
F-actin and microtubules, 69 • Myosin motors, 69 •	
Force-velocity relation, 72 • Energetics, 73 • Single molecular	
motor model, 74 • Multiple motor model, 77 • Mechanical	
parameters of the putative motor, 78 • Number of active motors, 79.	
3.5 Phagocytic uptake and intracellular transport	80
Tweezers-induced phagocytosis, 80 • Tracking of phagocytic	
uptake, 82 • Tracking of intracellular phagosomal transport, 84.	
3.6 Discussion	84
Dynamics of membrane-bead binding, 84 • Filopodial retraction, 87	
• Intracellular transport, 89.	
CHAPTER 4 Brownian dynamics simulation	91
4.1 Introduction	91
4.2 Theory of Brownian motion	92
Langevin equation, 92 • Mean-square displacement, 93 •	
Reynolds number, 93 • Translational and rotational motion, 94 •	
Numerical simulation, 94.	
4.3 Precision of the trap calibration	95
Probing time, 95 • Sampling rate, 98.	
4.4 Bead-membrane interactions	100
Dynamics of sequential bead-receptor binding, 100 • Binding	
potentials, 105.	
4.5 Discussion	105
CHAPTER 5 Bacterial growth and killing in macrophages	109
5.1 Introduction	109
5.2 Mathematical model for bacterial growth and killing	110
Principle of the model, 110 • Periodic vs. constant killing activity, 111.	
5.3 Discussion	112
CHAPTER 6 Summary	115
CHAPTER 7 Outlook	121
Bibliography	125