

Contents

1	Introduction	1
1.1	Macroscopic Quantum Mechanics	1
1.2	Instantaneous Velocity of Brownian Motion	3
1.3	Contents of this Dissertation	5
	References	5
2	Physical Principle of Optical Tweezers	9
2.1	Ray Optics Approximation	10
2.2	Rayleigh Approximation	11
2.3	Generalized Lorentz-Mie Theory	15
	References	19
3	Optical Trapping of Glass Microspheres in Air and Vacuum	21
3.1	Launching Microspheres	22
3.2	Trapping Microspheres	27
3.2.1	Optical Levitation Trap	28
3.2.2	Counter-Propagating Dual-Beam Optical Trap	30
3.3	Vacuum System	35
	References	37
4	Measuring the Instantaneous Velocity of a Brownian Particle in Air	39
4.1	Theories of Brownian Motion	39
4.1.1	A Free Particle	39
4.1.2	A Trapped Microsphere	41
4.2	A Fast Detection System	46
4.3	Measured Power Spectra	47
4.4	Measurement of the Instantaneous Velocity of a Brownian Particle in Air	50
	References	57

5	Towards Measurement of the Instantaneous Velocity of a Brownian Particle in Water.	59
5.1	Motivation	59
5.2	Hydrodynamic Theories of Brownian Motion	59
5.2.1	A Free Particle in Water	59
5.2.2	An Optically Trapped Microsphere in Water	61
5.3	Requirements for Measuring the Instantaneous Velocity.	66
5.4	A Simple Optical Tweezer in Water	70
5.5	Interferometer-Enhanced Optical Tweezers.	75
	References	79
6	Millikelvin Cooling of an Optically Trapped Microsphere in Vacuum.	81
6.1	Background	81
6.2	Principle of Feedback Cooling	82
6.2.1	Feedback Cooling	83
6.2.2	Feedback Amplification.	84
6.2.3	Heating Due to Light Scattering	84
6.2.4	Damping Due to the Residual Gas in Vacuum	86
6.3	A 3D Split Detection System	88
6.4	1D Optical Feedback Cooling	90
6.5	Electrostatic Forces	95
6.6	Millikelvin Cooling with 3D Optical Feedback	99
6.6.1	Experimental Setup	99
6.6.2	Results of 3D Optical Feedback Cooling	102
6.7	Loss of Microspheres in Vacuum	105
	References	108
7	Towards Quantum Ground-State Cooling.	111
7.1	Principle of Cavity Cooling	111
7.2	3D Ground-State Cooling with a Single Cavity.	113
7.3	Heating Effects of Laser Noise	116
7.4	Applications of Cooled Microspheres in Vacuum	117
7.4.1	Measuring Weak Forces.	117
7.4.2	Measuring the Impact of Single Molecules.	118
7.4.3	Searching for Gravity-Induced Quantum-State Reduction.	120
	References	121
	Appendix: Physical Properties of Some Common Materials	123
	Curriculum Vitae	125

Fundamental Tests of Physics with Optically Trapped
Microspheres

Li, T.

2013, XII, 125 p., Hardcover

ISBN: 978-1-4614-6030-5