Contents

1 Introduction 1
1.1 Surface Plasmon Resonances in Metal Nanoparticles 1
1.1.1 The Underlying Physics 1
1.1.2 Plasmonics: Application Highlights 4
1.1.3 Optical Characterization of Plasmonic Devices 6
1.2 Scanning Near-Field Optical Microscopy (SNOM) 8
1.2.1 The Diffraction Limit 8
1.2.2 Principles of Sub-wavelength Optical Microscopy 15
1.2.3 Basic Configuration and Practical Realizations 16
1.2.4 Artifacts and Challenges 23
1.3 SNOM for Imaging the Magnetic Field of Light 24
1.3.1 Imaging the Electromagnetic Field Components by SNOM 25
1.3.2 Fundamental Challenges in Imaging the Magnetic Field of Light 26
1.3.3 Experimental Setup for Imaging the Magnetic Field of Light 28
References 29

2 Imaging the Magnetic Near-Field of Plasmon Modes in Bar Antennas 35
2.1 Introduction 35
2.2 Results and Discussion 37
2.2.1 Individual Probe and Sample Characterization 38
2.2.2 Probe-Sample Coupling: Imaging of the $|H_y|^2$ Near-Field Distribution of an $l = 3$ Plasmon Mode in a Gold Bar 39
2.2.3 Imaging of the $|H_y|^2$ Near-Field Distribution of Different Plasmon Modes in a Gold Bar 43
2.2.4 Plasmon Dispersion Relation Obtained by SNOM 43

2.3 Conclusions . . . 46
2.4 Methods . . . 47
2.4.1 Sample Fabrication . . . 47
2.4.2 FDTD Simulations . . . 47
2.4.3 Electric and Magnetic Field Profiles at the Apex of the Probe . . . 48
References . . . 49

3 A Near-Field Aperture-Probe as an Optical Magnetic Source and Detector . . . 53
3.1 Introduction . . . 53
3.2 Results and Discussion . . . 54
3.2.1 Hollow-Pyramid Aperture Probe as a tangential H_y Dipole Source: Intuitive Physical Justification . . . 54
3.2.2 Correspondence Between the Fields of the Hollow-Pyramid Probe and a tangential H_y Dipole: Simulations . . . 57
3.2.3 Scanning of the Probe Over a Sample . . . 58
3.2.4 Experimental Evidence for Equivalence of Collection and Illumination Mode SNOM . . . 60
3.3 Conclusions . . . 61
References . . . 62

4 Magnetic Near-Field Imaging of Increasingly Complex Plasmonic Antennas . . . 63
4.1 Introduction . . . 63
4.2 Results and Discussion . . . 65
4.2.1 Simple Antennas . . . 66
4.2.2 Complex Antennas Consisting of Assembled Bars . . . 68
4.3 Conclusions . . . 72
4.4 Methods . . . 73
4.4.1 Sample Preparation . . . 73
4.4.2 Simulations . . . 73
4.5 Supporting Information . . . 73
4.5.1 Simulation of the $|H_y|^2$ Near-Field Map of an Elementary Horizontal Bar . . . 75
4.5.2 Simulation of the $|H_y|^2$ Near-Field Map of an Elementary Vertical Bar . . . 75
4.5.3 Simulation of the $|H_y|^2$ Near-Field Map of Complex Antennas . . . 75
4.5.4 Electromagnetic Field Components of a Representative Complex Antenna . . . 77
References . . . 78

5 Conclusions and Outlook 81
5.1 Conclusions 81
5.2 Outlook 83

Curriculum Vitae 85

http://www.springer.com/978-3-319-28792-8

Optical Characterization of Plasmonic Nanostructures: Near-Field Imaging of the Magnetic Field of Light

Denkova, D.

2016, XXVI, 88 p. 36 illus., 35 illus. in color., Hardcover
ISBN: 978-3-319-28792-8