Contents

Near-Field Imaging of Magnetic Domains
Gereon Meyer, Andreas Bauer, Günter Kaindl 1

1 Introduction 1
2 Magneto-Optical SNOM 2
2.1 Faraday Effect and Kerr Effect 2
2.2 Sagnac Interferometer 4
2.3 Kerr Microscopy 7
2.4 Domain Contrast in SNOM 8
3 Experimental Details 11
3.1 UHV System 11
3.2 UHV-SNOM Setup 14
3.3 Sagnac-SNOM Setup 16
3.4 Performance Tests 18
4 Magnetic Domains in Ultrathin Films 23
4.1 Spin-Reorientation Transition 24
4.2 Stripe-Domain Patterns 25
4.3 Domain Contrast 27
4.4 Study of Magnetization Reversal 30
4.5 Transformation of Stripe Domains 33
5 Summary and Future Prospects 36
References 38

Improvement of Interface Quality in Cleaved-Edge-Overgrowth GaAs Quantum Wires Based on Micro-optical Characterization
Masahiro Yoshita, Hidefumi Akiyama 43

1 Introduction 43
2 T-Shaped Quantum Wires Grown by Cleaved-Edge Overgrowth Method 44
2.1 Cleaved-Edge Overgrowth Method with MBE 44
2.2 Micro-PL Imaging and Spectroscopy Setup to Characterize T Wires 46
2.3 PL of T Wires Grown by the Original CEO Method 47

3 Interface Roughness and Modulated Electronic States in (110) GaAs QWs 48
3.1 Preparation of (110) GaAs QWs 48
3.2 Macro-PL of the (110) GaAs QWs 49
3.3 Micro-PL Spectroscopy of the (110) GaAs QWs 50
3.4 Interface Roughness in the (110) GaAs QWs and T Wires Grown by the CEO Method 54
4 Formation of an Atomically Flat Surface on the (110) GaAs Grown by the CEO Method 54
4.1 Atomic Arrangements of the (001) and (110) GaAs Surfaces 55
4.2 Growth-Interrupt in situ Annealing Technique 56
4.3 Formation of Atomically Flat CEO Surfaces by Growth-Interrupt Annealing 56
4.4 Surface Morphology of the Annealed Surface with Fractional Monolayer Coverage 59
4.5 Step-Edge Kinetics on the (110) GaAs Surface during Annealing 61
4.6 First-Principles Calculations of Adatom Migration Barrier Energies on (110) GaAs 64
4.7 Toward Formation of a Wider Atomically Flat (110) GaAs Surface 67
5 Fabrication of a High-Quality (110) GaAs QW with Atomically Smooth Interfaces 67
5.1 Preparation of a (110) GaAs QW with Atomically Smooth Interfaces 69
5.2 Micro-PL of the (110) GaAs QW 69
6 Fabrication of a High-Quality Single-Quantum-Wire Laser Structure and its Lasing Properties 73
6.1 Preparation of a Single-T-Wire Laser Structure 73
6.2 Spatial Uniformity of the Electronic States in the T Wire 75
6.3 Lasing from a Single-Quantum-Wire Laser 76
7 Concluding Remarks and Future Perspective 77
References 79

Recombination Dynamics in $In_xGa_{1-x}N$-Based Nanostructures
Yoichi Kawakami, Akio Kaneta, Kunimichi Omae, Yukio Narukawa, Takashi Mukai 83

1 Introduction 83
2 Material Parameters of $In_xGa_{1-x}N$ 85
2.1 Bandgap Energies in $In_xGa_{1-x}N$ Alloys 85
2.2 Alloy Broadening Factor in $In_xGa_{1-x}N$ Alloys 86
2.3 Piezoelectric Fields in Strained $In_xGa_{1-x}N$ Layers 87

3 General Transition Models 89
3.1 Localization versus Screening of Piezoelectric Field 89
3.2 Photoinduced Change of Optical Density Induced by Two Major Effects 92
4 Pump and Probe Spectroscopy on $In_xGa_{1-x}N$ Thin Layers and Quantum Wells 95
5 SNOM-Luminescence Mapping Results 100
5.1 Instrumentation 100
5.2 SNOM-PL Mapping at Low Temperature under Illumination–Collection Mode 104
5.3 Multimode SNOM at RT 113
6 Conclusion 121
References 122

Quantum Theory of Radiation in Optical Near Field Based on Quantization of Evanescent Electromagnetic Waves Using Detector Mode
Tetsuya Inoue, Hirokazu Hori 127

1 Introduction 127
1.1 Half-Space Problems and Angular-Spectrum Representation 128
1.2 Quantization of Evanescent Electromagnetic Fields and Radiative Decay in Optical Near Field 130
1.3 Detector-Mode Description for Radiation Problem 131
1.4 Outline 132
2 Classical Theory of Radiation from an Oscillating Electric Dipole in Free Space 133
2.1 Dipole Radiation in Free Space 133
2.2 Total Radiation Intensity in Free Space 137
3 Classical Theory of Radiation Based on Angular-Spectrum Representation 139
3.1 Angular-Spectrum Representation 140
3.2 Angular-Spectrum Representation of Scattered Electromagnetic Fields 142
3.3 Angular Spectrum of Dipole Radiation Fields in Optical Near-Field Regime 146
3.4 Evaluation of Radiation Based on Angular-Spectrum Representation 148
4 Radiative Decay of Oscillating Electric Dipole in Half-Space Based on Angular-Spectrum Representation 150
4.1 Half-Space Problems 150
4.2 Angular-Spectrum Representation of Radiation Fields in Half-Space 154
4.3 Electric Dipole Radiation into Medium 156

4.4 Electric Dipole Radiation into the Vacuum-Side Half-Space ... 157
4.5 Interaction between Electric Dipole and Dielectric Surface ... 158
5 Quantum Theory of Dipole Radiation Near a Dielectric Surface Based on Detector Modes ... 161
5.1 Normal Modes as the Basis of Field Quantization in Half-Space Problems; Triplet and Detector Modes ... 162
5.2 Detector-Mode Functions ... 165
5.3 Electric Field Operator in Half-Space Problems ... 168
5.4 Spontaneous Emission into Right Half-Space ... 170
5.5 Spontaneous Emission into Left Half-Space ... 172
5.6 Radiative Decay Rate and Lifetime of Electric Dipole in Half-Space ... 173
5.7 Dependence of Radiative Lifetime on Magnetic Quantum Number of Atom in Half-Space Problems ... 176
6 Quantum Theory of Multipole Radiation in Optical Near-Field Regime ... 181
6.1 Multipole Transition Matrix Elements ... 182
6.2 Spontaneous Decay Rate of Multipoles in Half-Space ... 184
7 Tunneling Picture of Optical Near-Field Interactions ... 188
7.1 Energy Transport via Tunneling in Optical Near-Field Interactions ... 189
7.2 Fundamental Process in Nano-Optics Device ... 192
Appendices ... 193
A Vector Spherical Wave ... 193
B Expansion of the Vector Plane Wave in Terms of the Vector Spherical Waves ... 195
C Multipole Expansion of Transition Current ... 196
References ... 198

Index ... 201