Contents

Preface *XI*

List of Contributors *XVII*

1 Fifteen Years of Microcavity Polaritons *1*
Vincenzo Savona *1*

1.1 Introduction *1*
1.2 The Past *4*
1.2.1 The Beginning of the Microcavity Polariton Era *4*
1.2.2 Energy Relaxation and Polariton Photoluminescence *6*
1.2.3 The Problem of the Polariton Spectral Linewidth *7*
1.2.4 Influence of Structural Disorder *8*
1.3 The Present *10*
1.3.1 Parametric Amplification and Photoluminescence *10*
1.3.2 Quantum Correlation and Non-Classical Properties *13*
1.4 The Future *16*
1.4.1 Polariton Quantum Collective Phenomena *16*
1.4.2 Engineering Quantum Confined Polariton Nanodevices *19*
1.5 Conclusions *21*
References *21*

2 MBE Growth of High Finesse Microcavities *31*
Ursula Oesterle, Ross P. Stanley, and Romuald Houdré *31*

2.1 Introduction *31*
2.2 Principles of MBE Growth *31*
2.2.1 Growth of $Al_xGa_{1-x}As$/AlAs DBRs *32*
2.2.2 Growth of (In,Ga)As Quantum Wells *33*
2.2.3 Growth of Vertical Cavity Structures *33*
2.3 Characterization and Properties of Vertical Cavity Structures *35*
2.3.1 Error Tolerance *35*
2.3.2 Structural Properties *36*
2.3.3 Optical Measurements of High Finesse Microcavity Structures *39*
2.4 Conclusion *42*
References *43*

Physics of Semiconductor Microcavities: From Fundamentals to Nanoscale Devices
Edited by Benoit Deveaud

ISBN: 978-3-527-40561-9

3 Early Stages of Continuous Wave Experiments on Cavity-Polaritons *45*
Romuald Houdré *45*

3.1 Introduction (1992) *45*
3.2 First Liquid Nitrogen and Room Temperature Observation (1993) *48*
3.3 Cavity-Polariton Dispersion Curve (1994) *50*
3.4 Bleaching of the Oscillator Strength (1995) *56*
3.5 Continuous Wave Photoluminescence Experiments (1995–1996) *58*
3.5.1 Nonresonant Excitation *58*
3.5.2 Resonant Excitation *62*
3.6 Linewidth, Disorder Effects and Linear Dispersion Modelling (1995–1997) *63*
3.6.1 More on Linear Dispersion Modelling *63*
3.6.2 Disorder Effects and Inhomogeneous Broadening (1995) *65*
3.6.3 The Second Generation of Samples (1996) *68*
3.6.4 Inhibition of Acoustic Phonon Broadening (1996) *70*
3.6.5 Test of Linear Dispersion Theory (1997) *73*
3.7 Rayleigh Scattering (2000) *76*
3.8 Nonlinear Continuous Wave Effects (1999–2000) *79*
3.9 Conclusion *82*
References *83*

4 Exciton-Polaritons and Nanoscale Cavities in Photonic Crystal Slabs *87*
Lucio Claudio Andreani, Dario Gerace, and Mario Agio *87*

4.1 Introduction *87*
4.2 Mode Dispersion and Linewidths in Photonic Crystal Slabs *88*
4.3 Exciton-Polaritons in Photonic Crystal Slabs *91*
4.4 Nanoscale Cavities in Photonic Crystal Slabs *96*
4.5 Strong Exciton-Light Coupling in Nanocavities *98*
4.6 Conclusions *101*
References *102*

5 Parametric Amplification and Polariton Liquids in Semiconductor Microcavities *105*
Jeremy J. Baumberg and Pavlos G. Lagoudakis *105*

5.1 Introduction *105*
5.2 Parametric Scattering at the Magic Angle *106*
5.2.1 Ultrafast Experiments on Semiconductor Microcavities *106*
5.2.2 Simple Pair Scattering *106*
5.2.3 Quasimode Theory of Parametric Amplification *109*
5.2.4 Multiple Scattering at the Magic Angle *111*
5.2.5 Double Resonant On-Branch Multiple Scattering *112*

5.3 Local Deformations of the Dispersion: Beyond Pair Scattering *114*
5.3.1 Polariton Liquids at the Bottom of the Polariton Trap *114*
5.3.2 Local Oscillator Strength Model *116*
5.3.3 Direct Time-Resolved Emission During Parametric Amplification *117*
5.4 Historical Perspective (JJB) *118*
References *121*

6 Quantum Fluid Effects and Parametric Instabilities in Microcavities *123*
Cristiano Ciuti and Iacopo Carusotto *123*

6.1 Preface *123*
6.2 Introduction *123*
6.3 Hamiltonian and Polariton Mean-Field Equations *124*
6.4 Stationary Solutions in the Homogeneous Case *126*
6.5 Linearized Bogoliubov-Like Theory *127*
6.5.1 Stability of the Stationary Solutions *128*
6.5.2 Complex Energy of the Collective Excitations *130*
6.5.2.1 Excitation Near the Inflection Point of the LP Dispersion *132*
6.5.2.2 Excitation Near the Bottom of the LP Dispersion *134*
6.5.2.3 Simplified Analytical Model for Excitation Close to the Bottom of the LP Dispersion *137*
6.6 Response to a Static Potential: Resonant Rayleigh Scattering *138*
6.6.1 Weak Excitation Regime and Elastic RRS Ring *139*
6.6.2 Superfluid Regime *142*
6.6.3 Precursors of Parametric Instabilities and Branch Sticking *144*
6.6.4 Cherenkov Regime *146*
6.7 Conclusions *149*
References *149*

7 Non-Linear Dynamical Effects in Semiconductor Microcavities *151*
Jean-Louis Staehli, Stefan Kundermann, Michele Saba, Christiano Ciuti, Augustin Baas, Thierry Guillet, and Benoit Deveaud *151*

7.1 Introduction *151*
7.2 Experimental *154*
7.2.1 The Microcavity *154*
7.2.2 Pump–Probe Experiments and Parametric Amplification *156*
7.3 A Simple Theoretical Model *159*
7.4 Coherent Control *161*
7.5 Measurements Resolved in Real Time *165*
7.6 Conclusions *168*
References *168*

8 Polariton Correlation in Microcavities Produced by Parametric Scattering *171*
Wolfgang Langbein *171*

8.1 Introduction *171*
8.2 Investigated Sample and Experimental Details *172*
8.3 Parametric Scattering for a Single Pump Direction *173*
8.4 Parametric Scattering for Two Pump Directions *176*
8.5 Polariton Quantum Complementarity by Parametric Scattering *180*
8.6 Conclusions *184*
References *185*

9 Spin Dynamics of Exciton Polaritons in Microcavities *187*
Ivan A. Shelykh, Alexei V. Kavokin, and Guillaume Malpuech *187*

9.1 Introduction *187*
9.2 Experimental Results *189*
9.3 Pseudospin Formalism and Pseudospin Rotation *193*
9.4 Interplay Between Spin and Energy Relaxation *198*
9.5 Spin-Dynamics of Polariton–Polariton Scattering *205*
9.6 Perspective: Toward "Spin-Optronic" Devices *209*
References *210*

10 Bose–Einstein Condensation of Microcavity Polaritons *211*
Vincenzo Savona and Davide Sarchi *211*

10.1 Introduction *211*
10.2 Bose–Einstein Condensation: Basic Facts *212*
10.3 Review of Exciton and Polariton BEC *216*
10.4 Some Considerations on Microcavity Polariton BEC *222*
10.5 Afterword *224*
References *224*

11 Polariton Squeezing in Microcavities *227*
Antonio Quattropani and Paolo Schwendimann *227*

11.1 Introduction *227*
11.2 Squeezed States *228*
11.3 Intrinsic Squeezing of Polaritons *230*
11.3.1 Intrinsic Squeezing of Bulk Polaritons *230*
11.3.2 Intrinsic Squeezing of Polaritons in Confined Systems *234*
11.4 Squeezing for Interacting Microcavity Polaritons *236*
References *242*

12 High Efficiency Planar MCLEDs *245*
Reto Joray, Ross P. Stanley, and Marc Ilegems *245*

12.1 Introduction *245*
12.2 Microcavities *246*
12.2.1 Fundamentals *246*
12.2.2 State of the Art Planar Semiconductor MCLEDs *248*
12.3 Novel Concepts *252*
12.3.1 Phase-Shift Cavity *252*
12.3.2 Oxide DBR *254*
12.4 Conclusions *256*
References *257*

13 Progresses in III-Nitride Distributed Bragg Reflectors and Microcavities Using AlInN/GaN Materials *261*
Jean-François Carlin, Cristof Zellweger, Julien Dorsaz, Sylvain Nicolay, Gabriel Christmann, Eric Feltin, Raphael Butté, and Nicolas Grandjean *261*

13.1 Introduction *261*
13.2 AlInN Alloy: Growth and Characterization *262*
13.2.1 AlInN: Motivation and Difficulty *262*
13.2.2 Growth of AlInN and AlInN/GaN DBRs *263*
13.2.3 Structural Characteristics: X-ray Evaluations and TEM Images *264*
13.2.4 Optical Index Contrast to GaN *266*
13.2.5 Bandgap and Dispersion of Refractive Index *269*
13.2.6 Photoluminescence and Stokes Shift *272*
13.3 Microcavity Light Emitting Diode *273*
13.4 High Reflectivity DBR and Residual Absorption *277*
13.5 Epitaxial Microcavities *281*
13.6 Conclusion *284*
References *285*

14 Microcavities in Ecole Polytechnique Fédérale de Lausanne, Ecole Polytechnique (France) and Elsewhere: Past, Present and Future *287*
Claude Weisbuch and Henri Benisty *287*

14.1 Introduction *287*
14.1.1 The Light–matter Interaction in Semiconductors *287*
14.1.2 The Impact of Electronic Motion Quantization *288*
14.1.3 The Impact of Photon Mode Quantization *290*
14.2 The Interplay of Photon and Electron Dimensionalities *290*
14.3 Looking Backwards: a Short History of Microcavities in Solids *293*
14.4 The Birth of the Microcavity Effort in Lausanne *296*
14.5 Why We Like Microcavities! *298*
14.6 The Future: What Are We Looking For? *300*
References *301*

Subject Index *303*