
Contents

General Theory and Applications to Unstable Particles

<i>Robert Alicki</i>	1
1 General Theory	1
1.1 Introduction	1
1.2 Completely Positive Dynamical Semigroups	2
1.2.1 Reduced Dynamics	2
1.2.2 Completely Positive Maps	3
1.2.3 Generalized H-theorem	5
1.2.4 Generators of Quantum Dynamical Semigroups	7
1.2.5 How to Construct Generators?	9
1.3 Hamiltonian Models and Markovian Approximation	10
1.3.1 Generalized Master Equation	10
1.3.2 Weak Coupling Limit	11
1.3.3 Low Density Limit	14
1.3.4 Heat Bath, Detailed Balance and Return to Equilibrium	16
1.3.5 Singular Coupling Limit	18
1.4 Extensions of the Formalism	19
1.4.1 Nonconservative Dynamical Semigroups	19
1.4.2 Time-dependent Generators	20
1.4.3 Nonlinear Quantum Dynamical Semigroups	21
1.4.4 Discrete Quantum Boltzmann Equation	22
1.4.5 Nonlinear Schrödinger Equation	23
1.5 A System of N Two-level Atoms	24
1.5.1 The Hamiltonian of the System	24
1.5.2 The Markovian Master Equation	25
1.5.3 Return to Equilibrium and Superradiance	27
2 Quantum Dynamical Semigroups for Unstable Particles	29
2.1 Introduction	29
2.2 Damped and Pumped Quantum Harmonic Oscillator	30

2.2.1	Derivation of the Markovian Master Equation	30
2.2.2	Birth and Death Process, Kinetic Equation	31
2.2.3	Explicit Solutions	31
2.3	Models of Unstable Particles	32
2.3.1	Fock Spaces and Quantum Fields	32
2.3.2	Construction of Markovian Master Equation	34
2.3.3	Single-particle Description	35
2.3.4	Explicit Solutions	36
2.3.5	Hamiltonian Models of Unstable Particles	38
2.3.6	Relativistic Unstable Particles	40
Appendix		
A.1	Banach Spaces $\mathcal{B}(\mathcal{H})$ and $\mathcal{T}(\mathcal{H})$	41
A.2	One-parameter Semigroups	42
A.3	Quantum Correlation Functions	44
References	45

N-Level Systems and Applications to Spectroscopy

<i>Karl Lendi</i>	47
1	Introduction	47
2	General Structure of Quantum Markovian Master Equations for N -level Systems	48
2.1	The Kossakowski-Generator of Infinitesimal Time-evolution	48
2.2	Positive-semidefiniteness of the Relaxation Matrix	49
2.3	Complete Orthonormal Matrix Sets	50
2.4	Coherence-vector Formulation	53
2.5	Relaxing Semigroups	57
3	Two-level Systems: Generalized Magnetic or Optical Bloch-equations	61
3.1	Details of the Full Relaxation Equations for Static External Fields	61
3.2	Alternating External Fields and Constant Relaxation	64
3.3	Modified Lineshapes and Free Induction Decay	66
4	Three-level Systems	69
4.1	General Equations	69
4.2	Bloch-equations for Decaying Systems	70
5	Comparison with Common Versions of Master Equations	73
5.1	General Considerations	73
5.2	Equations for Spontaneous Emission	74
5.3	Equations of Lamb-type	76
6	Open Quantum Systems with Non-constant Relaxation in Time-dependent External Fields	77
6.1	Modifications of the Original Semigroup Generator	77
6.2	A Model with Field-Strength-dependent Relaxation	79

7	Determination of Relaxation Parameters from First Principles	81
7.1	Relationship between Kossakowski- and Davies-generators	81
7.2	A Model for Spin-relaxation by Spin-waves	85
8	Entropy and Irreversibility	89
8.1	Entropy Production	89
8.2	Measure of Irreversibility	94
9	Conclusion	98
	Appendix	
	A.1 Generators and Structure Constants for $SU(N)$, $N = 2, 3, 4 \dots$	99
	A.2 Eigenvalues of the General Two-level Evolution Matrix	102
	A.3 Elements of the Time-dependent Two-level Evolution Matrix . .	104
	References	104
	Recent Developments	
	<i>Robert Alicki and Karl Lendi</i>	109
1	Complete Positivity, Entanglement and Decoherence	109
2	Unbounded Generators and Stochastic Equations	110
3	Nonlinear QDS	111
4	Geometry of States and Symmetries of Generators	111
5	QDS and Thermodynamics	112
6	Applications in Atomic and Molecular Physics	113
7	Beyond a Markovian Approximation	114
	References	117
	Index	123