

Contents

Chapter 1. Quanta and information, S.Ya. Kilin (Minsk, Belarus)	1
Introduction	3
§ 1. The quantum concept	3
1.1. Schrödinger and his famous paper of 1935	4
1.2. Quantum objects and their states	6
1.2.1. Superposition and the Schrödinger-cat paradox	6
1.2.2. Entangled states	9
1.2.2.1. How can one generate entangled states?	12
1.2.2.2. How can one measure (project) entangled states?	13
1.2.3. The impossibility of cloning quantum states	15
§ 2. Information	16
2.1. Shannon and his classical paper	16
2.2. Discrete objects	17
2.2.1. Bits and combinatorial interpretation of information	17
2.2.1.1. Block coding	19
2.2.2. Probabilistic interpretation of information	22
2.2.2.1. Data compression, typical sequences, and Shannon's noiseless coding theorem	22
2.2.2.2. Error corrections and Shannon's noise coding theorem	23
2.2.2.3. Distinguishability, code distance, and error-correcting Hamming code	24
2.3. Information of continuous functions	26
2.3.1. Sampling theorem	26
2.3.2. Constraints, fidelities, and information of images	27
2.4. Algorithmic information; Kolmogorov complexity	29
§ 3. Quantum information	30
3.1. Quantum communication	30
3.1.1. Signaling by two coherent states	32
3.1.1.1. Nonconclusive measurements, Hamming distances, and quantum data compression	32
3.1.1.2. Block coding, nonlinear resources, and entanglement creation	36
3.1.2. Communication of images by coherent states, image recognition and quantum limit of phase space partition	38
3.1.2.1. Quantum phase space partition theorem	38
3.1.2.2. Optimal encoding of images	39
3.1.3. Quantum teleportation	41
3.1.3.1. Experimental quantum teleportation	41

3.1.3.2. Quantum teleportation as a new class of physical communication channels and the problem of quantification of entanglement transformations	48
3.1.4. Quantum cryptography	51
3.2. Quantum computations and computers	56
3.2.1. Reversible and irreversible classical processors	56
3.2.2. Quantum computers	60
3.2.2.1. Power of Hilbert space, quantum logical operations	60
3.2.2.1.1. Recording (preparation) of the initial state	61
3.2.2.1.2. Computation (unitary transformations performed over the initial states)	61
3.2.2.1.3. Reading out the result (measurement, or projection, of the final state)	63
3.2.2.2. Quantum computers and mathematical problems	64
3.2.2.2.1. Shor's quantum factoring algorithm	64
3.2.2.2.2. Simulations of quantum factorization algorithm and the problem of physical resources	67
3.2.2.2.3. Grover's search algorithm	67
3.2.2.2.4. Other quantum algorithms	68
3.2.2.3. Quantum computers and physical problems	69
§ 4. The problem of decoherence	74
4.1. Relaxation as a nonunitary evolution of a state; quantum reservoirs engineering	75
4.2. Relaxation as a quantum stochastic process; purity of conditional states	78
4.3. Error correction by means of feedback	79
4.4. Hamming code and quantum error corrections	80
§ 5. Conclusions	82
Acknowledgements	84
References	84

Chapter 2. Optical solitons in periodic media with resonant and off-resonant nonlinearities, G. Kurizki, A.E. Kozhekin, T. Opatrný (Rehovot, Israel) and B.A. Malomed (Tel Aviv, Israel) 93

§ 1. Introduction	95
§ 2. Solitons in Bragg gratings with cubic and quadratic nonlinearities	99
2.1. Kerr nonlinearity	99
2.2. Quadratic nonlinearities	102
§ 3. Self-induced transparency (SIT) in uniform media and thin films	105
3.1. SIT in uniform media	105
3.2. SIT in thin films	107
3.3. Collisions of counterpropagating SIT solitons	108
§ 4. SIT in resonantly absorbing Bragg reflectors (RABR): the model	109
4.1. Maxwell equations	109
4.2. Two-level systems (TLS) in infinitely thin layers	113
4.3. Finite width of TLS layers	115
4.4. Energy densities	118
4.5. Linearized spectrum	119

§ 5. Bright solitons in RABR	120
5.1. Standing (quiescent) self-localized pulses	120
5.1.1. Stability	124
5.2. Moving solitons	124
5.3. Numerical simulations	128
5.4. Collisions between gap solitons	129
§ 6. Dark solitons in RABR	129
6.1. Existence conditions and the form of the soliton	129
6.2. Background stability	131
6.3. Direct numerical stability tests	133
6.4. Coexistence of the dark and bright solitons	134
6.5. Moving dark solitons	134
§ 7. Light bullets (spatiotemporal solitons)	136
§ 8. Experimental prospects and conclusions	139
Abbreviations	142
Acknowledgments	142
References	142

Chapter 3. Quantum Zeno and inverse quantum Zeno effects, P. Facchi and S. Pascazio (Bari, Italy) 147

§ 1. Introduction	149
§ 2. Two-level systems and Bloch vector	152
§ 3. Pulsed observation	155
3.1. Survival probability under pulsed measurements	155
3.2. Quantum Zeno and Inverse quantum Zeno effects	157
3.3. Pitfalls: "repopulation" and conceptual difficulties	160
§ 4. Dynamical quantum Zeno effect	163
§ 5. Continuous observation	167
5.1. Mimicking the projection with a non-Hermitian Hamiltonian	167
5.2. Coupling with a flat continuum	169
5.3. Continuous Rabi observation	170
§ 6. Novel definition of quantum Zeno effect	173
§ 7. Zeno effects in down-conversion processes	175
7.1. The system	176
7.2. Pulsed observation	180
7.3. The nonlinear coupler: continuous observation	183
7.4. Competition between the coupling and the mismatch	186
7.5. Dressed modes	188
§ 8. Genuine unstable systems and Zeno effects	191
§ 9. Three-level system in a laser field	199
9.1. The system	200
9.2. Schrödinger equation and temporal evolution	202
9.3. Laser off	204
9.4. Laser on	205

9.5. Photon spectrum, dressed states and induced transparency	209
§ 10. Concluding remarks	213
Acknowledgments	214
References	214

Chapter 4. Singular optics, M.S. Soskin and M.V. Vasnetsov (Kiev, Ukraine) 219

§ 1. 1. Introduction	221
§ 2. Anticipations of singular optics	223
§ 3. Wave-front dislocations – phase defects	226
§ 4. Circular and linear edge dislocations	231
§ 5. Screw wave-front dislocation – axial OV	239
§ 6. Reflection, refraction, interference and diffraction of OVs	244
§ 7. Topology of wave fronts and vortex trajectories	249
§ 8. Gouy phase shift in singular optics	258
§ 9. Statistics of phase dislocations	261
§ 10. Optical vortices in frequency conversion processes	263
§ 11. Applications	268
§ 12. Conclusions	271
References	272

Chapter 5. Multi-photon quantum interferometry, G. Jaeger and A.V. Sergienko (Boston, MA) 277

§ 1. Introduction: practical optical tests of Bell inequalities	279
§ 2. Two-photon interferometry with type-I phase-matched SPDC	283
§ 3. Two-photon interferometry with type-II SPDC	290
§ 4. Higher multiple-photon entanglement	311
References	320

Chapter 6. Transverse mode shaping and selection in laser resonators, R. Oron, N. Davidson, A.A. Friesem (Rehovot, Israel) and E. Hasman (Haifa, Israel) 325

§ 1. Introduction	327
§ 2. Transverse modes	328
2.1. Transverse modes in laser resonators	328
2.2. Methods of analysis and design	330
2.2.1. Fox–Li	331
2.2.2. Gerchberg–Saxton	332
2.2.3. Propagation-matrix diagonalization	332

§ 3. Intra-cavity elements and resonator configurations	334
3.1. Graded phase mirrors	335
3.2. Diffractive elements	337
3.3. Binary phase elements	341
3.4. Spiral phase elements	346
3.5. Self-imaging and Fourier resonators	354
3.6. Polarization-selective resonators	356
3.7. Unstable resonators	362
3.8. Alternative methods	363
3.9. Fabrication of intra-cavity elements	364
§ 4. Properties of the laser output beams	366
4.1. Beam quality	367
4.1.1. Second-order moments (M^2)	367
4.1.2. Wigner distribution function (WDF)	368
4.1.3. Coherence and entropy	369
4.2. Intensity and phase distributions	371
4.2.1. Uniform phase distribution	371
4.2.2. Binary phase distribution	371
4.2.3. Helical phase distribution	372
4.2.4. Several transverse modes	377
4.3. Selected applications	381
§ 5. Concluding remarks	383
Acknowledgements	383
References	383
Author Index for Volume 42	387
Subject Index for Volume 42	401
Contents of Previous Volumes	405
Cumulative Index, Volumes 1–42	415