CAMBRIDGE
Cambridge University Press & Assessment
978-1-009-41529-3 — Introductory Quantum Optics
Christopher C. Gerry, Peter L. Knight
Index
More Information

Index

Aharonov–Bohm effect, 177
amplitude squeezing, 212
angular momentum commutation relations, 179, 181
annihilation operator, 24
anti-Jaynes–Cummings model, 331
antinormally ordered operators, 71
atom–field interactions
  classical field, 91–97
  density operator approach, 119–122
  dispersive model, 123–125
  dressed states, 115–119
  Jaynes–Cummings model, 105–115
  perturbation theory, 89–91
  quantized field, 97–102
  Rabi model, 102–105
atomic coherent states, 333
atomic inversion, 104
autocorrelation function, 137

B92 protocol, 367–368
Baker–Campbell–Hausdorff theorem, 46
Baker–Hausdorff lemma, 14
balanced homodyne detection, 209–211
Barnett and Pegg Hermitian phase operator, 42–45, 106
BB84 protocol, 365–366
beam-splitter quantum mechanics
  Bose–Einstein condensation (BEC), 167–168
  classical, 157
  classical states of light, 177–179
  as displacer, 185
  entanglement generation, 238–239
  Heisenberg point of view, 157–162
  photons at input, 168–172
  Schrödinger point of view, 162–165
  single photon, 165–166
  SU(2) formulation, 179–185
  vacuum and coherent state, 172–173
beam-splitter transformation, 377
Bell's inequalities experiments
  Franson's experiment, 301
  optical test of local realities, 294–301
Bell's inequalities violation
  entanglement, 340
  nonlocality, 177
birefringent material, 284, 295
Bloch equations, 257
Bloch sphere, 389–391
Bloch vector, 126–127
Born–Markov approximation, 258
Bose–Einstein condensation (BEC), 167–168
bright and dark periods, 261–262, 268
broadband squeezed light, 232–233

Casimir effect, 35–37
Casimir force, 37
Cauchy's inequality, 148, 237
cavity QED (quantized electromagnetic field)
  high-Q microwave cavity, 315
  microwave versus optical, 332
  Schrödinger-cat states, 320–325
center-of-mass motion (trapped ion), 114
chaotic light beams, 149
characteristic function, 79–82
circuit QED (quantized electromagnetic field), 333
classical bit, 6
classical coherence functions, 134–139
classical current, 56
classical first-order coherence functions, 136–139

© in this web service Cambridge University Press & Assessment www.cambridge.org

CAMBRIDGE
Cambridge University Press & Assessment
978-1-009-41529-3 — Introductory Quantum Optics
Christopher C. Gerry, Peter L. Knight
Index
More Information

classical first-order coherence theory, 135–136
classical limit, 31
C-NOT gate, 372
coherence functions
  classical, 134–139
  quantum, 139–143
  Young's interference, 143–146
coherence functions, higher order
  Hanbury-Brown and Twiss experiment, 146–152
  intensity–intensity correlation functions, 146
  Q-parameter, 152–153
coherent interactions and transients, 4–5
coherent-state wave packet, 59
coherent states
  atomic, 333
  characteristic function, 79–82
  completeness relation, 62–63
  density operators, 68
  displaced vacuum states, 56–58
  function, 63–64
  generation, 60–61
  independence, 63
  minimum uncertainty states, 51–56
  number state, 61–62
  operator matric states, 64–65
  phase-space pictures, 65–67
  phase-space probability distributions, 68–75
  photon number parity operator and Wigner function, 75–78
  Q function, 82, 83
  right eigenstates of annihilation operator, 50–51
  Schrödinger-cat states, 89
  spin, 333
  time evolution, 59–60
  wave packets, 58–59
  Wigner functions, 82
complementarity, 289
complexity classification, 359
Compton effect, 155
Compton wavelength, 34
controlled phase gate, 373, 376
Copenhagen interpretation, 217, 280
correlated double-beam states of light, 216–232
Coulomb gauge, 3
Coulomb potential, 33
Coulomb radiation gauge, 90
creation operator, 15
cryptography
  information processing, 355–356
  quantum, 364–370
crypto-systems
  private, 357–358
  public, 358–360

decoherence
  coherent state generation, 275–276
  nonlinear optical balance, 275–276
  overview, 272–275
  quantum error correction, 380
decoherence-free subspace, 380
degenerate four-wave mixing, 209
degenerate parametric down-conversion, 208
density matrix, 121
density operator
  atom–field interactions, 119–122
  dynamics, 395–396
  overview, 386–389
Deutsch's problem, 374
dipole approximation, 27, 91
dipole interaction, 139
dipole moment, 91
disentangling theorem, 56
dispersive interactions, 123–125
dispersive model, 89
displaced vacuum states, 56–58
displacement operator, 56
dissipative interaction, 6
double-slit experiment, 380
down-conversion processes, 406–407
  entangled photon states, 285–287
  metrology without absolute standards, 304
  paired single-photon states, 281–285
dressed states, 115–119
dual-rail realization, 376

eavesdropper, 356
Ekert protocol, 369–370
Einstein coefficients, 100–101

© in this web service Cambridge University Press & Assessment www.cambridge.org

CAMBRIDGE
Cambridge University Press & Assessment
978-1-009-41529-3 — Introductory Quantum Optics
Christopher C. Gerry, Peter L. Knight
Index
More Information

electric field operator, 18–20
electron shelving, 6
ensembles, quantum mechanics
  decoherence, 272–276
  modeling losses with fictitious beam splitters, 270–272
entangled photon states, 285–287
entanglement
  advantage, 340
  generation, 238–239
  photon, 186–187
  research history of, 7
  two-particle, 390–392
entanglement applications
  Heisenberg-limited interferometry, 343–353
  quantum information processing, 353–381
entanglement theorems
  no-cloning, 342–343
  no-signaling, 341–342
entropy (von Neumann), 127, 394–395
ergodic hypothesis, 135
error circle, 67
error contours, 205
error correction, 380
even coherent states, 218
exponential decay law, 257

factorization
  property, 136
fair sampling assumption, 300
fictious beam splitter, 270–272
field ionization, 310
field quantization
  multimode fields, 20–27
  quantum phase, 37–45
  single-mode field harmonic oscillation, 11–17
  single-mode field quadrature operators, 18–20
  single-mode field quantum fluctuations, 17–18
  thermal fields, 32
  vacuum fluctuations and zero-point energy, 32–37
Fock state basis, 127
Franson's experiment, 301
Fredkin gate, 378
fringe visibility, 136

gauge transformations, 90
Glauber–Sudarshan *P* function, 68
Golden Rule, 96
gravitational waves, 178

Hadamard gate, 371–372
Hamiltonian derivation, 402–405
Hanbury Brown and Twiss experiment, 146–152
harmonic generation, 5
Heisenberg limit, 178
Heisenberg-limited interferometry, 343–353
Hermite polynomials, 59
homodyne detection, 209–210
Hong–Ou–Mandel effect, 170
Hong–Ou–Mandel experiment (HOM experiment), 285–287
Husimi function, 73

idler mode, 240
induced coherence experiment, 290–293
induced quantum coherence experiment, 36
intelligent states, 52
interference
  multiphoton, 186
  non-interference, 186
  one photon, 281–285
  quantum, 3
  two photon, 285–287, 390–392
  Young's, 143–146
interferometry
  classical states of light, 177–179
  interaction-free measurement, 175–177
  LIGO (Laser Interferometer Gravitational-Wave Observatory), 178
  Mach–Zehnder interferometer (MZI), 173, 174
  single photon, 173–175
  SU(2) formulation, 179–185
ion traps, 258
irreversible decay, 101

© in this web service Cambridge University Press & Assessment www.cambridge.org

CAMBRIDGE
Cambridge University Press & Assessment
978-1-009-41529-3 — Introductory Quantum Optics
Christopher C. Gerry, Peter L. Knight
Index
More Information

Jaynes–Cummings model
  atom–field interactions, 105–115
  CQED realization, 316–320, 325–326
  extensions, 125–126
  quantum state engineering, 326–328
  Schmidt decomposition, 126–127
  trapped ion, 328–332
  von Neumann entropy, 127
jumping cat transition, 266–265

Kerr interaction, 223
Kerr-like medium, 222

Lamb–Dicke parameter, 330
laser cooling, 5
light quanta, 2
LIGO (Laser Interferometer Gravitational-Wave Observatory), 178
Liouville equation, 396
local oscillator, 209
logic gates, 371
Lorentz gauge, 90

Mach–Zehnder interferometer (MZI), 173, 174, 175–177
masers, 4
master equation, 259
Maxwell's equations, 11
metrology, 304
mixed states, 387
momentum entanglement, 301
monochromatic light field, 136–139
Moore's law, 338–339
multimode field quantization
  annihilation and creation operators, 24
  cubicle cavity, 20–21
  dipole approximation, 27
  electric field, 26–27
  field energy, 24
  magnetic contribution, 23–24
  mode density, 22
  transversality condition, 22
  vector potential, 22
multimode number state, 25
multipartite systems, 391
multiphoton interference, 186
mutual coherence, 135

no-cloning theorem, 342–343
nonclassical states of light
  broadband squeezed light, 232–233
  correlated double beams, 216–232
  criterion for, 191
  entanglement generation, 238–239
  pair coherent states, 233–238
  photon antibunching effect, 213–216
  quantum state engineering, 239–247
  Schrödinger-cat states, 216–225
  squeezed states of light, 191–213
quantum non-demolition measurement, 325–326
nonlinear susceptibility, 207–209
nonlocal hidden variable, 280
nonlocality
  Aharonov–Bohm effect, 177
  Bell's inequalities violation, 177
normally ordered operator, 71–72
no-signaling theorem, 341–342
number operator, 15
number–phase uncertainty relation, 211–213
number squeezed states of light, 211–213
number state, 17

odd coherent states, 219
one-photon interference experiments, 281–285
one-time pad, 358
optical cavity QED, 332
optical equivalence theorem, 71
optical frequency standard, 259
optical lattice, 379

π/2-pulses, 324, 372
pair coherent states, 233–238
paired single-photon states, 281–285
parametric amplifier, 211
parametric approximation, 185
parametric down-conversion, 5
parity measurement, 349
parity operator, 75–78
Pauli exclusion principle, 167

© in this web service Cambridge University Press & Assessment www.cambridge.org

CAMBRIDGE
Cambridge University Press & Assessment
978-1-009-41529-3 — Introductory Quantum Optics
Christopher C. Gerry, Peter L. Knight
Index
More Information

Pauli spin algebra, 106
Pegg–Barnett phase operators, 42–45, 106
periodic boundary conditions, 20
perturbation theory, 89–91
phase uncertainty, 178
phonons, 328–329
photodetection, 140
photoelectric effect, 155
photon
  non-interference, 186
photon-added coherent state, 241
photon antibunching effect, 151, 213–216
photon bunching effect, 149
  nonclassical state generation, 239–247
  single-photon beam splitter, 165–166
  single-photon interferometry, 173–175
  single-photon source, 156
photon subtraction, 243
photon tunneling exhibiting superluminal effects, 293–294
photonic band-gap material, 293
photon number parity operator and Wigner function, 293
photons, 20
Planck's radiation law, 32
plane-wave field, 27
Poisson process, 53
polarization, 22
population inversion, 101
π-pulses, 293–294
P-representation, 73
privacy amplification, 366
private key crypto-systems, 357–358
public key crypto-systems, 358–360
pure state, 110–111
purity (in atom–field interactions), 127

Q function, 82, 83
Q-parameter, 152–153
quadrature operator, 19
quadrature squeezed state of light
  detection, 209–211
  generation, 207–209
  overview, 191–207
quadrature variance, 46
quantum algorithm, 6
quantum computation, 6
quantum computation gates
  aspects of, 370–375
  optical realization, 376–379
quantum computers, 338
quantum correlations, 4
quantum cryptography
  B92 protocol, 367–368
  BB84 protocol, 365–366
  Ekert protocol, 369–370
  overview, 364
  quantum key distribution (QKD), 364–365
quantum defect, 308
quantum electrodynamics (QED), 3–4
quantum eraser, 287–290
quantum error correction, 380
quantum estimation theory, 45
quantum gates, 6
quantum information processing
  cryptography, 355–356
  private key crypto-systems, 357–358
  public key crypto-systems, 358–360
  quantum cryptography, 364–370
  quantum random number generator, 360–363
  quantum teleportation, 353–355
quantum information processing, future prospects
  decoherence and error correction, 380
  gate optical realization, 376–379
  quantum computation gates, 370–375
quantum interference, 3
quantum jump method, 262–266
quantum key distribution (QKD), 364–365
quantum measurement theory, 398–401
quantum mechanical first-order coherence functions, 141–143
quantum mechanics
  ensembles, 266–276
  interaction-free measurement, 175–177
  nonlocality, 177

© in this web service Cambridge University Press & Assessment www.cambridge.org

CAMBRIDGE
Cambridge University Press & Assessment
978-1-009-41529-3 — Introductory Quantum Optics
Christopher C. Gerry, Peter L. Knight
Index
More Information

single realizations, 262–265
quantum mechanics, history
coherent interactions and transients, 4–5
entanglement, 7
factorization, 6
ion trap, 6–7
Jaynes–Cummings model, 5–6
masers, 4
nature of light rays, 2
phase-sensitive noise, 5
photon, 2–3
quantum computation, 6
quantum electrodynamics (QED), 3–4
quantum information processing, 4
quantum interference, 3
quantum memories, 7
quantum nonlinear optics, 5
quantum optics, 4
quantum theory of coherence, 4
wave and particle properties, 3
quantum memories, 7
quantum nonlinear optics, 5
quantum phase, 18, 37–45
quantum processor, 7
quantum random number generator, 360–363
quantum register, 370–371
quantum state engineering, 239–247
quantum state tomography, 85
quantum teleportation, 353–355
quantum theory of coherence, 4
quantum trajectory approach, 258
quasi-probability distribution, 4

Rabi model, 102–105
Ramsey interferometry, 317
rate equations, 258
Rayleigh–Jeans limit, 312
Rayleigh's law, 31
realism, 280
renormalization, 3
resonance fluorescence, 5
right eigenstates of annihilation, 50–51
rotated quadrature operators, 195
rotating-wave approximation, 89
Rydberg atoms
cavity–field interaction, 311–315
CQED experiments, 308
overview, 308–311

Schmidt decomposition, 126–127, 392–394
Schrödinger-cat states, 89, 216–225
second-order quantum coherence, 149
Segal–Bargmann space, 63
semigroup relations, 57
signal mode, 208
single-ion traps, 259
single realizations
jumping cat transition, 266–265
quantum jump method, 262–266
V system, 259–262
single-mode field quadrature operators, 18–20
single-mode field quantization
canonical variable replacement, 12–15
equivalence to harmonic oscillator, 11–12
harmonic oscillation energy levels, 16
operator replacement, 12–17
single-mode field quantum fluctuations
number state, 17
quantum phase, 18
uncertainty of the field, 17
vacuum fluctuations, 18
space-like separations, 280
s-parameterized function, 80
spin
coherent states, 333
Pauli spin algebra, 106
spin coherent states, 333
spontaneous emission, 33, 101–102
squeezed states of light
interferometric measurement, 178–179
number, 211–213
quadrature, 191–211
standard quantum limit, 178
Stark shift, 317
state reduction, 225
state vector collapse, 398
states of light
classical, 177–179
displaced number, 185

© in this web service Cambridge University Press & Assessment www.cambridge.org

CAMBRIDGE
Cambridge University Press & Assessment
978-1-009-41529-3 — Introductory Quantum Optics
Christopher C. Gerry, Peter L. Knight
Index
More Information

states of light (cont.)
interference containing multiple photons, 186
nonclassical, 191–247
phase uncertainty, 178
squeezed, 178–179
statistical mixture, 163
Stefan–Boltzmann law, 32
SU(2) formulation of beam splitters and interferometry, 179–185
sub-Poissonian statistics, 152
superluminal tunneling, 293–294
super-radiance, 332
Susskind–Glogower (SG) operator, 39

tempered distribution, 71
temporal coherence, 136–139
thermal distribution, 230
thermal fields, 29, 32
thermal radiation, 33
time evolution, 59–60
time standard, 261
time–energy uncertainty, 18
transition rate, 96
transversality condition, 22
transverse gauge, 22
twin beams, 228
two photon interference experiments
entanglement, 390–392
Hong–Ou–Mandel interferometer, 285–287
Schmidt decomposition, 392–394
two-mode squeezed vacuum states of light, 216–232

uncertainty of the field, 17
uncertainty principle, 297

V system, 259–262
vacuum-field Rabi oscillations, 109
vacuum fluctuations
defined, 18
displaced, 56–58
field quantization, 32–37
vacuum Rabi frequency, 314
vibrational motion, 178, 308
von Neumann entropy, 394–395

wave packets, 58–59
Wien's displacement law, 32
Weisskopf–Wigner theory, 3–4
which-path information, 289
Wien's law, 32
Wigner functions, 73

Young's interference, 143–146
Yurke–Stoler state, 219

zero-point energy (ZPE)
Casimir effect, 35–37
Lamb shift, 33–35

© in this web service Cambridge University Press & Assessment www.cambridge.org