Index

A
Abrikosov lattice, see vortex lattice
angular momentum
for Bose–Einstein condensate (BEC), 187, 300, 336–338
for the vortex-particle model, 190, 201, 208, 211, 212, 214
anomalous mode
dark soliton, 39, 41, 57, 59, 140
DB soliton, 77, 87, 151, 155
NPSE model, 56
ring soliton, 182
vortex, 166, 176, 230, 261
antidark soliton, 67, 92, 94, 114
aspect ratio, 12, 17, 50, 63
azimuthon, 162

B
Bardeen–Cooper–Schrieffer (BEC-BCS) crossover, 123
Biot–Savart, law, 343, 348, 351
Bloch oscillations, 346
Bloch waves, 44
Bogoliubov spectrum, see Bogoliubov–de Gennes (BdG), spectrum
Bogoliubov–de Gennes (BdG)
analysis, 38, 39, 41, 46, 57, 58, 62, 76, 86, 97, 101, 140, 143
equations, 11, 32, 39, 54, 97, 103, 130, 166, 182, 207, 252, 270, 278, 309, 314
Bose–Einstein condensation, see mean-field, for BEC
Bose–Hubbard model, 47
bubble, 346, 360, 363

cigar-shaped BEC, 12, 49, 54
circulation, see vortex circulation
collapse, 123, 159, 161, 162, 247, 266, 346
collective modes, see Tkachenko modes
compact scheme, 371
complex Ginzburg–Landau, 329
compute unified device architecture (CUDA), 376
conserved quantities
for the vortex-particle model, 189
continuation
from the linear limit, 31, 158, 159, 244, 251
parameter continuation, 121, 257, 280
pseudo-arclength continuation, 158
continuous spectrum, 48, 77, 86
counterflow, 68, 72, 78
crow instability, 341, 346
cubic-quintic NLS (cqNLS) equation, 14
cubic-quintic nonlinearity, 56

dark soliton, 2, 18, 55, 65, 359
adiabatic dynamics, 34
anomalous mode, see anomalous mode, dark soliton
antidamping, 44, 49, 130, 137, 143
black, 19, 37, 38, 58, 64
collision-induced phase shift, 27
collisions, 28, 359
cross, 180, 182, 224, 319, 321
dissipative dynamics, 136
energy, 21, 34
formation, 112
generation, 20, 24
gray, 19, 37, 54
Hamiltonian perturbation theory, 34
integrals of motion, 21
Lagrangian approach, 36
Landau dynamics, 37
mass, 22
oscillation frequency, 35, 37, 55, 61, 63
oscillations, 32, 41
persistence, 48
perturbation methods, 2, 181
phase jump, 18
planar, see dark soliton, stripe
radiation, 42
repulsive interaction, 29, 58, 63, 143
ring, 51, 161, 180, 182, 187, 204, 207, 223, 331
ring, curvature, 52
shallow, 19, 22, 25, 37, 38, 43, 55, 137
spherical, 51
stationary, 31
stripe, 50, 173, 175, 176, 179, 182, 187, 203, 236, 267, 275, 283, 309, 312, 323, 360
two-soliton, 27, 57, 59, 60
dark-bright (DB) soliton, 26, 67, 76–78
adiabatic dynamics, 73, 150
anomalous mode, see anomalous mode, DB soliton
antidamping, 151
collisions, 81
dissipative dynamics, 149
energy, 74
excitation spectrum, 76
Hamiltonian perturbation theory, 74
interaction energy, 83
interaction force, 84
interactions, 83, 85
molecule, 83, 87, 89
multiple, 73, 81, 86, 88
oscillation frequency, 76, 79, 151
ring, 305
solution, 69
spinor BEC, 104
stationary, 77, 85, 151
two-soliton, 83, 85, 87, 92, 155
dark-dark (DD) soliton, 67, 88
beating, 68, 71, 90, 92
interactions, 92
solution, 70
spinor BEC, 104
density engineering, 24, 25, 346
dimensionality crossover, 12, 42, 55, 62, 78
dimensionality parameter, 12, 54, 55, 62
dipole mode, 39, 57, 167, 230
discrete nonlinear Schrödinger (DNLS) equation, 45, 47, 239, 243
discrete spectrum, 20
disk-shaped BEC, 49
dissipation, 167, 169, 172, 173
dissipative GPE (DGPE), see Gross–Pitaevskii equation, dissipative
domain wall, 50, 67, 89, 102, 104, 318, 346, 359
domain wall cross, see dark soliton, cross
double well, 27, 63, 116
two-dimensional, 239
vortex-induced, 314
doubly charged vortex, 165, 179, 252, 256
doubly charged vortex ring, 352
dragging an obstacle, 24, 109, 110, 115
dromion, 50
E
energetic instability, 40
energy, 17
two-component BEC, 74
energy cascade, 344
energy functional, 8
Euler’s fluid, 343
Euler–Lagrange equations, 18, 36, 58, 79
exciton-polariton BEC, see polariton BEC
anisotropic, 359
F
Faraday pattern, 14
Feshbach resonance, 67, 123, 320
management, 53, 123, 266
finite differences, 371
finite temperature, 40, 130, 170, 191, 263, 302
BEC, 131
damping regimes, 137, 151
dark soliton, 138, 140
form of dissipation, 131
relaxation dynamics, 134, 148
three-dark soliton state, 144
two-dark-soliton state, 142
Floquet analysis, 91
fluid dynamics, 340, 341
fluid velocity, 70, 168, 231, 255, 274, 276, 342–344
fluid vorticity, 168, 255, 274, 276
G
Galerkin approach, 117, 176, 177, 235, 237, 239
gap soliton, 45, 104
Gerbier–Muñoz Mateo–Delgado equation (GMDE), 13, 79
Goldstone mode, 39, 41, 57, 85, 230, 232
graphical processing unit (GPU), 370, 376
Gross–Pitaevskii equation, 2, 7, 8
damping, 132
dissipative, 131, 133, 135, 139, 145, 148, 169, 263
rigorous validation, 9
stochastic, 131, 138, 139, 147
ground state, 10, 13
H
Hamiltonian
for BEC, 34, 74, 115, 141, 142
for spinor BEC, 302
for the vortex-particle model, 189, 193, 196, 201, 212
single-particle, 11, 176
harmonic trap, 4, 10, 12, 20, 25, 31, 35, 39, 43, 46, 53, 63, 76, 86, 111, 116, 137, 157, 166, 176, 188, 228, 244, 266, 273, 288, 295, 307, 311,
330, 352, 366
healing length, 12, 46, 54, 112, 131, 175, 272, 276, 297, 338, 343, 347
helical waves, see Kelvin modes
heteronuclear BEC, 66
high-order (compact) scheme, 371
Hopf bifurcation, 88, 101, 304
hydrodynamic formulation, 341, 343
I
impurity potential, 266, 275, 278, 344, 364
integrals of motion, 17, see dark soliton, integrals of motion
interaction potential, 8
inverse scattering transform (IST), 2, 20, 68, 104, 106
K
Kadomtsev–Petviashvili (KP) equation, 50
Kelvin modes, 338, 343, 348, 354, 355
Kelvons, see Kelvin modes
Kohn mode, see dipole mode
Kolmogorov power law, 298, 344
Korteweg–de Vries (KdV) equation, 2, 22, 23, 29, 38, 53, 104
Krein signature, 40, 41, 48, 140, 141, 144, 151, 166, 170, 182, 207, 230, 264
Kronig–Penney model, 124
L
Lagrangian
density, 18
two dark solitons, 58
Landau dynamics, 33
linear momentum
for the vortex-particle model, 190
linear Schrödinger equation, 245
local density approximation, 33, 35, 37, 38
localized induction approximation, 343
M
Madelung transformation, 15, 23, 341
magnetic trap, see harmonic trap
Manakov system, 68, 92, 104
many-body
calculation, 38
Hamiltonian, 7
quantum mechanical problem, 8
matter-wave interference, 24, 26, 51, 63
mean-field
for BEC, 7, 55, 66, 95, 130, 307
miscibility
BEC, 67, 313, 318
parameter, 67, 319, 320, 323
modulational instability (MI), 11, 12, 18, 99, 100, 124, 173, 268
transverse, 50, 267, 285
modulus-squared Dirichlet (MSD), boundary conditions, 373, 374
momentum, 17
multicomponent BEC, 66, 166, 250, 293, 301, 362, 363
multiply charged vortex, 352
multivortex line configuration, 339
N
NLS equation, see nonlinear Schrödinger (NLS) equation
noncondensed atoms, see thermal cloud
nonlinear interference, 344
nonlinear Schrödinger (NLS) equation, 2, 4, 13, 15, 17, 19, 27, 32, 47, 68, 98, 104, 109, 116, 125, 241, 335, 346, 347, 363, 370–372, 374, 376, 377
cubic-quintic, see cubic-quintic NLS (cqNLS) equation
discrete, see discrete nonlinear Schrödinger (DNLS) equation
perturbed, see perturbed NLS equation
nonpolynomial Schrödinger equation (NPSE), 13, 55, 61, 62, 79
normal modes of vibration, see Tkachenko modes
Nozaki–Bekki hole, 330
number of atoms, 8
number of particles, 17
O
optical lattice, 43, 44, 63, 116
nonlinear, 260
superlattice, 45, 47
two-dimensional, 243
optical trap, 346
P
Peierls–Nabarro, 47
perturbed NLS equation, 22, 34, 36, 74, 135, 136
phase engineering, 346, 359
phase imprinting, 24
phase separation, 67
phase-imprinting, 24, 51, 68
pitchfork bifurcation, 121, 177, 202, 212, 214, 238, 243, 317
polariton BEC, 329
pseudospinor BEC, 66
Q
quadrupole mode, 39, 57
quantum pressure, 342, 344, 351
quantum turbulence, 295, 343, 344
quantum-state engineering, 24, 26
quasimomentum, 44
quintic NLS equation, 38
R
rarefaction pulse, 341, 346, 354, 356
reductive perturbation method, 22
ring soliton, see dark soliton, ring

Scattering length, 8, 122

Schrödinger equation
  linear, see linear Schrödinger equation
  nonlinear, see nonlinear Schrödinger (NLS) equation
  nonpolynomial, see nonpolynomial Schrödinger equation (NPSE)

Self-induced velocity of vortex ring, 343, 351

Shock wave, 25, 112

Skyrmion, 364

Small-amplitude approximation, 22, 33, 37, 50, 105

Small-amplitude excitations, 11

Snaking instability, 26, 48, 50, 161, 173, 268

Soliton
  antidark, see antidark soliton
  dark, see dark soliton
  dark-bright, see dark-bright (DB) soliton
  dark-dark, see dark-dark (DD) soliton
  gap, see gap soliton
  symbiotic, see symbiotic soliton
  vector, see vector soliton
  vortex-bright, see vortex-bright soliton

Solitonic vortex, 54, 238, 360, see vortex line

Sound speed, 12, 19, 23, 109, 113, 115, 344, 363

Sound waves, 12, 32, 42, 341, 344

Spherical BEC, 50

Spinor BEC, 66, 95, 362–364
  antiferromagnetic, 96
  DB soliton, 104
  DB soliton oscillation frequency, 108
  ferromagnetic, 96, 104
  modulational instability, 97
  single-mode approximation, 97, 104, 115
  spin-polarized states, 97, 102

Spontaneous symmetry breaking, 116, 121, 155, 239

Stochastic GPE (SGPE), see Gross–Pitaevskii equation, stochastic

Strongly interacting Bose gas, 15, 33, 38
  SU(2) rotation, 68, 69, 92
  SU(2) rotational symmetry, 326

Superfluid
  4He, 338, 343, 344, 346
  turbulence, 285, 292

Superfluid-to-Mott insulator, 47

Superfluidity, 45, 47, 109, 199, 292, 293
  binary BEC, 113
  critical velocity, 110, 112–115
  Landau criterion, 109, 110
  symbiotic solitons, 69

Symmetry-breaking bifurcation, see pitchfork bifurcation

Thermal cloud, 31, 40, 44, 130, 137, 147, 169, 191, 286, 302, 329

Thermodynamic instability, 40, 167, 170

Thomas–Fermi approximation, 34, 129, 159, 167, 275, 288, 309, 318, 320, 325
  cloud, 20, 74, 91, 92, 102, 134, 148, 149, 170, 174, 231
  limit, 11, 62, 67, 134, 166, 229
  radius, 131, 132, 147, 174, 189, 198, 201, 207, 229, 273, 281

Tight-binding approximation, 45

Tkachenko modes, 340

Tonks–Girardeau gas, 15, 38

Transverse instability, 173, 266, 285

Trap frequencies, 10

Turbulence, decay of, 343

Two-component BEC, 294, 301, 311, 312, 318, 340, 346, 362

Two-mode approximation, 117

Variational approach, 20, 36, 83, 85

Varicose wave, 339

Vector soliton, 66, 67

Viscosity, 343

Vortex, 26, 165
  aligned cluster, 179, 182, 219, 229, 235
  aligned quadrupole, 178, 203, 233
  antivortex, 51, 116
  capture, 282
  circulation, 343, 351
  cluster, 179, 182, 187, 229, 233, 297, 310
  core, 338, 339, 343, 347, 351
  creation by interference, 287
  dipole, 198, 230, 237, 293, 294, 348, 352–354
  doubly charged, see doubly charged vortex dragging, 280
  filament, 340, 341, 343, 352
  filament method, 343, 352
  formation, 3, 109
  formation by defect dragging, 293
  generating function, 220
  guiding center equilibria, 193
  in nonlinear optical lattice, 260
  in optical lattice, 251
  interaction with localized impurity, 275
  knot, 348
  lattice, see vortex lattice
  line, see vortex line
  motion in anisotropic traps, 228
  N + 1 configuration, 218
necklace, 53, 162, 178, 181, 187, 286, 310
pair, 346, 347, 352, 359
polygon, 181, 205, 208
precession, 166, 187, 194, 201, 207, 219, 224, 228, 276, 281, 311
quadrupole, 203, 235, 237
quintupole, 178, 237
ring, see vortex ring
splitting instability, 260
square, 217
stability, 165
string, 237
tangle, 292, 295
Tkachenko modes, 228
triangle, 217
tripole, 178, 202, 232, 237
vortex lattice, 165, 218, 225, 228, 237, 329, 339
in exciton-polariton condensates, 331
vortex line, 178, 188, 201, 335, 339, 343, 359, 360
reconnection, 340, 341
S-shaped, 337
U-shaped, 337
vortex ring, 25, 26, 48, 344
generation, 344
leapfrogging, 348, 352, 363
mergers, 353
scattering, 353, 355, 358
splits, 353
vortex-bright soliton, 301
dipole, 312
vorticity, 336, 341, 343, 344
W
Wannier functions, 45
wavenumber spectrum, 297
weakly interacting BEC, 8, 13, 38
Y
Yajima–Oikawa (YO) system, 106
Z
Zaremba–Nikuni–Griffin (ZNG) approach, 130