

Apolodor Aristotel Raduta

Nuclear Structure with Coherent States

Contents

1	Introduction	1
2	Classical Versus Quantal Features in a Projected Coherent State	5
2.1	Definitions and Preliminaries	5
2.2	Unprojected State	11
2.2.1	The Quadrupole Coordinate and Momentum	11
2.2.2	The Boson Number and Its Conjugate Phase	12
2.3	Projected Spherical States	17
2.3.1	The Case of α, π Coordinates	17
2.3.2	Dispersions of $\hat{N}$ and $\hat{P}$ on Projected States	20
2.4	Numerical Analysis	24
2.5	The Baker-Campbell-Hausdorff Formula for the SU(2) Algebra	30
3	Compact Formulas for Ground Band Energies	39
3.1	Introduction	39
3.2	Holmberg-Lipas Formula for the Ground Band Energies	40
3.3	Angular Momentum Projected State	43
3.3.1	Vibrational and Large Deformation Regime	45
3.4	Semiclassical Treatment of a Second Order Quadrupole Boson Hamiltonian	47
3.5	Numerical Results	54
3.6	Another Compact Formula for the Ground Band Energies	62
3.7	Conclusions	69
4	Description of the Triaxial Rotor	71
4.1	The Triaxial Rotor. Diagonalization.	71

4.2	Semiclassical Description and Quantization	83
4.2.1	Introduction	83
4.2.2	Semiclassical Description of a Triaxial Rotor	83
4.2.3	Boson Representation for Angular Momentum	88
4.2.4	Holstein-Primakoff Boson Expansion	89
4.2.5	The Dyson Boson Expansion	94
4.2.6	An Exponential Boson Expansion	97
4.2.7	A New Boson Expansion	98
4.3	A Harmonic Approximation for Energy	98
4.3.1	The Potential Energy	102
4.3.2	Numerical Application	105
4.4	The Tilted Rotor, Symmetries and Nuclear Phases	106
4.4.1	Quantization of Periodic Orbits	119
4.5	The Quantum Hamiltonian	120
5	Semiclassical Description of Many Body Systems	127
5.1	The Coupling of Individual and Collective Degrees of Freedom	127
5.1.1	The Classical Description of H	130
5.1.2	On the Classical Origin of Boson Expansions	141
5.1.3	Short Numerical Application	146
5.2	Generalized Nucleon-Nucleon Pairing with Isospin and Particle Number Projection	149
5.2.1	Tensorial Properties	150
5.2.2	pp, nn and pn Pairing	151
5.2.3	The Projection of the Particle Number	155
5.2.4	The Projection of the Isospin	158
5.3	Projection of Particle Number and Isospin	160
5.4	Numerical Application for a Single J Shell	162
5.4.1	Unprojected BCS	162
5.4.2	N-Projected BCS	164
5.4.3	Isospin Projected BCS State	164
5.4.4	The Exact Eigenvalues of H	164
5.4.5	Particle Number and Isospin Projection	165
5.4.6	Transition Probabilities	167
5.5	Bogoliubov Transformation for Bosons	170
5.5.1	Bosons with Zero Momentum	170
5.5.2	Boson with Linear Momentum	173
6	The Coherent State Model	177
6.1	The Coherent State Model	177
6.2	The Vibrational and Near Vibrational Regimes	182
6.2.1	Energies	182
6.2.2	Reduced Probability for E2 Transitions	187

6.3	Large Deformation Regime	189
6.3.1	Energies	191
6.3.2	Reduced Probabilities for the E2 Transitions	193
6.4	The Intrinsic Frame of Reference	195
6.4.1	Useful Information Coming from the Intrinsic Frame	198
6.5	Some Numerical Applications.	203
6.5.1	Energies	203
6.5.2	Electric Transition Probabilities	207
6.6	Applications of Compact Formulas	212
6.6.1	Energies	212
6.6.2	E2 Transition Probabilities.	216
6.6.3	Conclusions	227
7	Pear Shaped Nuclei.	235
7.1	CSM Extension for Pear Shaped Nuclei.	235
7.1.1	Energies	240
7.1.2	Electric Transition Probabilities	246
7.1.3	The Dipole Bands.	248
8	Coupling of One, Two and Three Quasiparticles to a CSM Core.	255
8.1	Coupling Quasiparticles to a CSM Core	255
8.1.1	Even-Even Systems.	255
8.1.2	Even-Odd Systems	261
8.1.3	Parity Partner Bands in Even-Odd Nuclei	264
8.1.4	The Description of the $K^\pi = \frac{3}{2}^\pm, \frac{5}{2}^\pm$ Bands.	268
8.1.5	Transition Probabilities	269
8.1.6	Numerical Results.	269
9	The Generalized Coherent State Model	277
9.1	CSM Extension to p-n Systems	277
9.1.1	The M1 and E2 Transitions	281
9.1.2	Numerical Results.	284
9.2	Deformation Properties of the M1 Mode	287
10	Two Applications of GCSM	291
10.1	Chiral Symmetry in Even-Even Nuclei	291
10.1.1	Introduction	291
10.1.2	Proton and Neutron Bosons Angular Momenta	293
10.1.3	A Possible Extension of the GCSM	296
10.1.4	About the Chiral Symmetry	297
10.1.5	Magnetic Dipole Transitions.	303
10.1.6	Numerical Results and Discussions	307

10.2	Monopole Charge Properties Within the GCSM	318
10.2.1	Introduction	318
10.2.2	The Charge Density	320
10.2.3	Electric Monopole Transition	325
10.2.4	Numerical Results.	327
11	Boson States Basis	335
11.1	Eigenstates for a Harmonic Hamiltonian	335
11.2	The Degeneracy of the Boson Basis	342
12	Unified Single Particle Basis	347
12.1	Projected Spherical Single Particle Basis	347
12.1.1	Nucleon Density Function	353
12.1.2	The Quadrupole Moment for the First 2^+	355
12.1.3	Shell Filling Order: Magic Numbers and the Spin of Odd System Ground State	358
12.1.4	The Model Parameters.	359
13	Boson Hamiltonians	363
13.1	Semiclassical Study of Some Fourth Order Boson Hamiltonians	363
13.1.1	TDVP for a Fourth Order Boson Hamiltonian	363
13.1.2	Stationary Points of $\mathcal{H}$	366
13.1.3	The RPA Like Equations.	368
13.1.4	Large Amplitude Motion	373
13.1.5	Summary and Conclusions.	377
13.2	Solvable Sixth Order Boson Hamiltonians	380
13.2.1	A Sextic Boson Hamiltonian	380
13.2.2	The Classical Description.	383
13.2.3	Results for an “U” Energy	389
13.2.4	Results for a “B” Energy	391
13.2.5	Results for an “O” Energy	393
13.2.6	The Virtual Motion Under the Hump	394
13.2.7	Numerical Application.	395
13.3	Quantization of Periodic Trajectories.	398
13.3.1	Numerical Results.	399
13.3.2	Another Boson Hamiltonian.	402
13.3.3	Summary and Conclusions.	404
14	Comparison of CSM with Some Other Models.	407
14.1	Solvable Models and Hamiltonian Symmetries	407
14.1.1	Introduction	407
14.1.2	The Starting Hamiltonian.	409
14.1.3	The Treatment of the β Hamiltonian	410

14.1.4	The Sextic Oscillator with a Centrifugal Barrier	414
14.1.5	The Description of γ Degree of Freedom	416
14.1.6	An Exact Solution Which Preserves Periodicity and Hermiticity.	419
14.1.7	Mathieu Equation	421
14.1.8	A Possible Relationship of the SMA and the CSM . . .	431
14.2	Lipas's Projection Method	436
14.3	Rotation Vibration Model	442
14.3.1	Comparison of the RVM and the CSM	446
14.3.2	The Triaxial Rotation Vibration Model	449
14.4	The Generalized Collective Model	454
14.4.1	Comparison with the CSM.	457
14.5	Interacting Boson Approximation	458
14.5.1	Comparison with the CSM.	463
15	Conclusions	467
15.1	Summary and Conclusions.	467
	Appendices	473
	Bibliography	511