

Studies in Quantum Chaos : Entanglement, Decoherence and All that

A THESIS

submitted for the Award of Ph.D degree of
Mohan Lal Sukhadia University
in the
Faculty of Science

BY

Jayendra Nath Bandyopadhyay



Under the Supervision of

Professor R. E. Amritkar

THEORETICAL PHYSICS & COMPLEX SYSTEM DIVISION
PHYSICAL RESEARCH LABORATORY, AHMEDABAD.

MOHANLAL SUKHAJIA UNIVERSITY, UDAIPUR

Year of submission: 2004

Contents

Acknowledgement	vii
Abstract	ix
1 Introduction	1
1.1 Hamiltonian system	1
1.1.1 Integrable systems	2
1.1.2 Nonintegrable systems	3
1.2 Chaos in Hamiltonian systems	5
1.3 Chaos in Higher-dimensional systems : Arnold Diffusion	7
1.4 Quantum manifestations of classical chaos : Quantum chaos	8
1.4.1 Ionization of Rydberg states of the Hydrogen atom inside microwave cavity : Dynamical localization	9
1.4.2 Semiclassical Quantization	11
1.4.3 Statistical properties of the quantum chaotic spectra	12
1.4.4 Semiclassical properties of the eigenstates	15
1.5 Chaos and Entanglement	17
1.5.1 Entanglement	18
1.5.2 Chaos-Entanglement : Present scenario	26
1.6 Decoherence : A consequence of entanglement	29
1.6.1 Decoherence in chaotic systems	31
1.6.2 Decoherence in quantum computation and quantum information processing	32
1.7 Motivation for the thesis	34
1.7.1 Outline of the thesis	38
2 Time dependent nonlinear integrable systems	39
2.1 The classical singular oscillator	43
2.1.1 The kicked singular oscillator	44

2.1.2	The classical evolution operator of the kicked singular oscillator	47
2.2	Quantum dynamics of the kicked singular oscillator	54
3	Coupled Kicked Tops	57
3.1	Derivation of the classical map corresponding to coupled kicked tops	58
3.2	Dynamical properties of the single kicked top	61
3.3	The transition from regular to chaotic dynamics: A detailed study	62
4	Quantum Entanglement and Random Matrix Theory (RMT)	70
4.1	Initial States	71
4.2	Numerical Scheme	72
4.3	Numerical Results	73
4.4	Analytical formulation using RMT	75
4.5	Discussion on some Related Works	78
5	Entanglement Production in Coupled Chaotic Systems	88
5.1	Reduced Husimi function	89
5.2	Second moment of Husimi function	91
5.2.1	Single top	92
5.2.2	Coupled tops	96
5.3	Entanglement production : Numerical results	100
5.3.1	Coupling $\epsilon = 10^{-2}$	100
5.3.2	Coupling $\epsilon = 10^{-3}$	103
5.3.3	Coupling $\epsilon = 10^{-4}$	104
5.4	Decoherence in coupled chaotic systems	104
5.5	Entanglement production in coupled strongly chaotic systems : An analytical study	106
6	Mixed state entanglement and Operator entanglement	115
6.1	Mixed state entanglement	118
6.1.1	Measure of the mixed state entanglement	118
6.1.2	Numerical results	120
6.1.3	Saturation of the subsystem linear entropy : A random matrix estimation	129
6.2	Operator entanglement	135
6.2.1	Operator Schmidt decomposition	135
6.2.2	Measure of operator entanglement	137
6.2.3	Numerical results	138

6.2.4 Operator entanglement and state entanglement : A relation	142
Summary and Future Outlook	145
References	149
List of Publications	157

For Fulltext Please Contact
To

jayendra@prl.res.in