Module: Elective Advanced Lectures: Theoretical Physics

Module No.: physics70c

Course: Quantum chaos: tools and applications (T)

Course No.: physics7517

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	5	WT

Requirements for Participation:

Preparation:
Classical mechanics, Quantum mechanics, Statistical mechanics (recommended). Special interest in quantum dynamics and nonlinear systems.

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Knowledge on the theory of chaos, tools to analyze it in quantum systems with examples, as well as its manifestation in many-body systems that can be realized on the experimental platforms.

Contents of the Course:
1. Introduction and classification of dynamical systems
- From macroscopic, mesoscopic to microscopic systems, Different dynamics: simple to complex.

2. Chaos in classical systems
- Discrete dynamical system: One dimensional maps
- Hamiltonian systems: Phase space and Hamilton's equation
- Poincare map
- Stroboscopic Maps of Periodically Driven Systems: Kicked rotor
- KAM theorem
- Lyapunov exponent, Kolmogorov-Sinai entropy

3. Aspects of quantum chaos
- Quantum classical correspondence
- EBK quantization
- Gutzwiller's Trace formula
- Phase space densities and Wigner function
- Anderson and dynamical localization

4. Level statistics: Application of Random Matrix Theory
- Gaussian Ensembles of Hermitian Matrices
- Level Spacing Distributions
- Unfolding Spectra
- Eigenvector statistics
- Dyson's Brownian-Motion Model

5. Quantum chaos and ergodicity in many-body systems
- Quantum butterfly effect
- Out-of-time-ordered correlator (OTOC)
- Ergodicity and quantum scar
- Example from collective quantum systems: Dicke model, Josephson junction

Recommended Literature:
- F. Haake, Quantum Signatures of Chaos, Springer Science and Business Media (Springer, 2013).
- S. Wimberger, Nonlinear Dynamics and Quantum Chaos: An Introduction (Springer, 2014).
- H.-J. Stöckmann, Quantum Chaos, An Introduction (Cambridge University Press, 1999).