Study program : Physics

Type and level of studies: Doctoral studies

Course unit: Open quantum systems theory

Teacher in charge : professor Miroljub Dugić

Language of instruction English

ECTS: 15

Prerequisites: Set semester

Semester III (Winter semester second year course)

Course unit objective

The students will be familiarized with the basic concepts and fundamentals of modern open systems theory as well as basic models. Ubiquity of openess of quantum systems, starting from the systems as simple as the hydrogen atom, is the main qualitative objective of the course. Universal applicability of the theory is particularly emphasized in physics, chemistry, materials science and quantum biology.

Learning outcomes of Course unit

The students will be able to work independently in research and in critical assessment of the others' research results in the foundations and some basic applications of the theory.

Course unit contents

Theoretical classes

Banach space and operations. Closed versus open quantum systems. Dynamical maps: positivity, complete positivity (Jamiolkowski and the alternative criteria for finite-dimensional spaces) and trace preservation. Universal dynamical maps and contractions; the inverse of a universal dynamical map. Markov processes: Chapman-Kolmogorov criterion in a quantum form. Differential form of Markovian dynamics; semigroups and the Lindblad form of master equations. Nakajima-Zwanzig projection method. Markovian dynamics as a limiting case of the weak-coupling and the singular-coupling limit. Steady states of homogeneous Markov processes. Quantum optical master equation. Quantum Brownian motion (Caldeira-Leggett model); decoherence versus friction. Damped harmonic oscillator. Continuous variable systems: Gaussian states as the approximate pointer basis states. Outlook: non-Markovian dynamics.

Literature

1. Á. Rivas, S. F. Huelga, "Open quantum systems. An introduction", Springer Briefs in Physics, Springer 2011; also available at http://arxiv.org/abs/1104.5242 .
2. H.-P. Breuer, F. Petruccione, "The theory of open quantum systems", Clarendon Press, Oxford, 2002.

Additional literature:

3. Á. Rivas, S. F. Huelga, M. B. Plenio, "Quantum non-Markovianity: characterization, quantification and detection", *Reports on Progress in Physics* **77**, 094001 (2014); also available at http://arxiv.org/abs/1405.0303 .

Number of active teaching hours				**Other classes**
Lectures:	Practice:	Other forms of classes: mentoring 5	Independent work: 2	

Teaching methods

Examination methods (maximum 100 points)

Exam prerequisites	**No. of points:**	**Final exam**	**No. of points:**
Student's activity during lectures		oral examination	40
practical classes/tests		written examination	
Seminars/homework	**60**	.....	
Project			
Other			

Grading system

Grade	**No. of points**	**Description**

10	**91-100**	Excellent
9	**81-90**	Exceptionally good
8	**71-80**	Very good
7	**61-70**	Good
6	**51-60**	Passing
5	**<51**	Failing

(Table 5.2) Course unit description