COURSE OF STUDY *Physics (LM-17)*

ACADEMIC YEAR *2023-2024*

ACADEMIC SUBJECT *Laboratory of Quantum Optics*

General information	
Year of the course	2nd
Academic calendar (starting and ending date)	1st semester: September – December 2023
Credits (CFU/ECTS):	6
SSD	FIS/03
Language	English
Mode of attendance	Compulsory

Professor/ Lecturer	
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Department and address	Dipartimento Interateneo di Fisica, Via Amendola 173, 70126 Bari (BA)
Virtual room	vamqudt
Office Hours (and modalities: e.g., by appointment, on line, etc.)	Mon & Wed from 3 to 4 pm, office and online

Work schedule			
Hours			
Total	Lectures	Hands-on (laboratory, workshops, working groups, seminars, field trips)	Out-of-class study hours/ Self-study hours
150	32	30	88
CFU/ECTS			
6	4	2	

Learning Objectives	Knowledge and understanding of the limits of validity of classical optics, evolution of concepts in the transition from classical to quantum optics (quantum states of radiation, entangled states, counting of photons, interference and coherence, …), measurement of correlations, interferometry and quantum imaging.
Course prerequisites	Background knowledge on classical e.m. theory, classical optics, statistical physics and quantum mechanics.

Teaching strategies	Frontal teaching using slides: experimental and historical approach, discussion of crucial experiments. Laboratory activities: group work for the preparation for laboratory activities, the conduct of experiments, and the discussion and critical analysis of the results. Report of lab experiences in different formats: internal note, conference presentation, scientific article.
Expected learning outcomes in terms of	
Knowledge and understanding on:	o Understanding the scientific method, the nature, and the methods of research in Physics o Knowledge of quantum information and quantum technologies o Limit of validity of classical optics o Evolution of the optical concepts going from classical to quantum optics

	o Theoretical model for describing quantum states of radiation o Peculiarities of quantum optics with special attention to entangled states, o Practical consequences and technological applications of quantum optics.
Applying knowledge and understanding on:	o Ability to identify the essential elements of a phenomenon o Ability to use analogy to apply known solutions to new problems (problem solving) o Ability to use analytical and numerical mathematical computation tools o Ability to solve complex practical problems in the framework of quantum optics o Designing and implementing an optical setup for measuring the typical characteristics of a non-classical light source (spectrum, intensity, coherence, etc.)
Soft skills	● **Making informed judgments and choices** o Ability to work with increasing levels of autonomy, including taking responsibility in project planning and managing facilities o Students are encouraged to choose optical instruments and experimental devices for implementing typical quantum optics experiments, as well as to grasp delicate aspects of contemporary research such as innovative technologies, fundamental interest of basic research,..) ● **Communicating knowledge and understanding** o Competence in communication in Italian and English in advanced fields of Physics o Knowing how to properly expose and master the presentation of topics and problems of quantum optics o Writing a technical report on quantum optics experiments performed in the lab o Presenting a topic in the form of a short seminar with slides and practical examples o . ● **Capacities to continue learning** o Acquisition of basic knowledge tools for continuous learning and knowledge updates o Know-how on typical experimental techniques in quantum optics o Ability to update knowledge with particular regard to research on entangled states.
Syllabus	
Content knowledge	***Basics of quantum optics:*** Quantum theory of e.m. radiation: Field quantization and Fock states Other states of e.m. radiation: thermal light, coherent states Photon statistics and photon counting ***Theory of coherence:*** Review of classical theory of interference and coherence Mutual coherence function and degree of coherence: ● Temporal coherence and spectrum; ● Spatial coherence Coherence and stellar interferometers: ● Michelson stellar interferometer ● Hanbury-Brown and Twiss interferometer Quantum theory of coherence: ● Correlation functions and their measurement ***Quantum entanglement in optics*** Pure states and mixed states, factorizable and entangled states SPDC: a source of entangled photons EPR paradox Some historical experiments on multi-photon interference Quantum imaging with entangled photons and thermal light ***Esperienze di laboratorio (30 ore)***

	● Photon statistics ● HBT interferometer Ghost imaging with pseudo-thermal light
Texts and readings	Scully & Zubairy, *Quantum Optics* Gerry & Knight, *Introductory Quantum Optics* *Scientific papers*
Notes, additional materials	Slides available in dropbox folder shared with students
Repository	

Assessment	
Assessment methods	Lab report and oral exam
Assessment criteria	● Knowledge and understanding of the salient elements of quantum optics covered ● Knowledge and understanding applied to the creation of experimental apparatus for the study of typical phenomena of quantum optics and their use ● Independent judgment in the analysis and interpretation of experimental data ● Written and oral communication skills, assessed through the various forms of proposed reports (internal notes, conference presentation, scientific article)
Final exam and grading criteria	20% lab reports, 80% oral exam (20% for each of the above criteria)
Further information	
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