UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

SYLLABUS DEL CORSO

Quantum Photonics

2425-1-FSM01Q023

Aims

This course will guide students through the field of quantum optics, with a special focus on how to implement quantum technologies like quantum communication and sensing using optical techniques and photonic circuits. Students will have the possibility to get acquainted with materials and methods needed to create, manipulate, and read out quantum states of light. Major achievements and future challenges in the field will be discussed, including photonic quantum computation and quantum internet.
The main goal of this course is to provide a basic knowledge of the quantum description of light. In addition, the course will provide an experimental perspective on phenomena based on light-matter interaction. The discussions of relevant applications will expand the student's background in optics and will aim at providing technological insights into materials for quantum photonics.

Contents

• Photon statistics and materials for quantum emitters
• Light-matter interaction and photodetection
• Quantum information processing and quantum cryptography
• Interferometry, entangled states, teleportation
• Quantum internet and photonic computing

Detailed program

Photon statistics: classification of light by statistics, coherent sources, shot noise and quantum theory of photodetection.

Quantization of the electromagnetic field: Fock and squeezed states, vacuum fluctuations and the Casimir effect, gravitational wave detection.

Interferometry: materials platforms for single photon sources and detectors, Hanbury Brown-Twiss experiment, Hong-Ou-Mandel interference, quantum eraser, photon bunching and anti-bunching.

Quantum cryptography: Principles of classic and quantum cryptography, quantum random number generation, quantum key distribution using single photons, BB84 protocol.

Entangled states: entangled photon pairs, experimental tests of Bell’s theorem, CHSH inequality, and quantum teleportation. Entanglement swapping.

Spin-photon interfaces: Optical spin orientation, quantum internet.

Advanced applications: materials and principles for photonic quantum computing, photonic logic gates and boson sampling.

Prerequisites

Students should have knowledge of electromagnetic waves, quantum mechanics and structure of matter at the level of undergrad introductory courses. Knowledge of atomic physics and optical properties of solids is advantageous.

Teaching form

The instructor explains and formally derives the new concepts using a tablet always through conventional in-presence lectures (so-called 'didattica erogativa'). Two lectures per week, two hours per lecture during the whole semester. Formal derivations are always followed by applications. At the beginning of each lesson, the instructor briefly recalls the content of the previous lecture.

Textbook and teaching resource

Lecture notes and papers made available to students through this e-learning platform. Adopted Text (also available in e-book format through the university library): Mark Fox, Quantum Optics, Oxford University Press.

Semester

First semester

Assessment method

The assessment relies on a final oral test. During the examination, the instructor evaluates the student's learning level, the capacity of critical thinking and the communication capabilities pertaining to the specific field. Regarding the latter point and to refine the soft-skills, there will be the additional opportunity to deliver a short presentation on a specific topic introduced during the lectures. There will be no intermediate tests.

Office hours

From Monday to Friday at any working hour, provided that students ask for an appointment with the instructor by email.

Sustainable Development Goals

INDUSTRY, INNOVATION AND INFRASTRUCTURE | SUSTAINABLE CITIES AND COMMUNITIES