Solid-state quantum optics

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Quantum light is the natural information carrier in quantum networks. It also offers unique advantages in other quantum technologies, such as metrology, computation and simulation. Scaling optical quantum technologies requires efficient single-photon sources and photon-photon gates. Both can be obtained making use of the single photon sensitivity of two-level system. In this context, artificial atoms in the solid-state, such as semiconductor quantum dots, colour centres in diamonds, or molecules offer the potential of scalability and integration.

In this lecture, we will briefly discuss how to describe and characterize quantum light fields, the basics of linear-optical quantum technologies as well as the necessary resources (1). We will then discuss how quantum light, both single photon sources and entangled photon pairs can be generated with solid-state artificial atoms. The various sources of decoherence induced by the solid-state environment will be discussed as well as the mitigating solutions that the scientific community has developed over the years (2). The various approaches developed to fabricate efficient atom-photon interfaces will then be described, as well as their use for obtaining efficient integrated quantum light sources (3). Finally, progresses toward the development of efficient photon-photon gates, making use of the single-photon non-linearity of the artificial atoms will be reviewed as well as future challenges (4).

Lecture 1: Introduction to optical quantum technologies

- Linear optical quantum technologies: protocols and applications
- Description of quantum light (discrete variables)
- Generation of quantum light:
    - With non-linear media
    - With single emitter sources

Lecture 2: Generating quantum light with semiconductor quantum dots

- Basics of semiconductor growth
- Quantum dot energy levels
- Single photon emission
- Generation of entangled photon pairs
- Generation of indistinguishable photons:
- State of the art

Lecture 3: Light-matter interfaces: bright quantum light sources

- Light-matter interfaces:
- Cavity-QED based light matter interfaces
- Waveguide based light-matter interfaces
- Other approaches
- Deterministic technologies
- Bright sources of single photons and entangled photon pairs
- Cavity enhanced performances

Lecture 4: Toward non-linear quantum optics - Applications and future challenges

- Linear photon-photon gates: limitations
- Few-photon optical non-linearities
- Toward non-linear quantum gates
- First applications of single photon sources
- Future challenges