Single-quantum-dot devices for photonic quantum technologies: Design, deterministic nanofabrication, and application perspectives

Stephan Reitzenstein

Institute of Solid State Physics, Technische Universität Berlin, Germany

The application of solid-state quantum emitters in real-world quantum information technologies requires precise nanofabrication platforms with high process yield. Self-assembled semiconductor quantum dots (QDs) with excellent emission properties have proven to be among the best candidates to meet the needs of high-performance quantum photonic devices. However, their spatial and spectral positions vary statistically on a scale that is far too large for their system integration via fixed lithography and inflexible processing schemes. We solve this severe problem by introducing a flexible and deterministic manufacturing scheme based on precise and convenient cathodoluminescence spectroscopy followed by high-resolution electron-beam lithography [1].

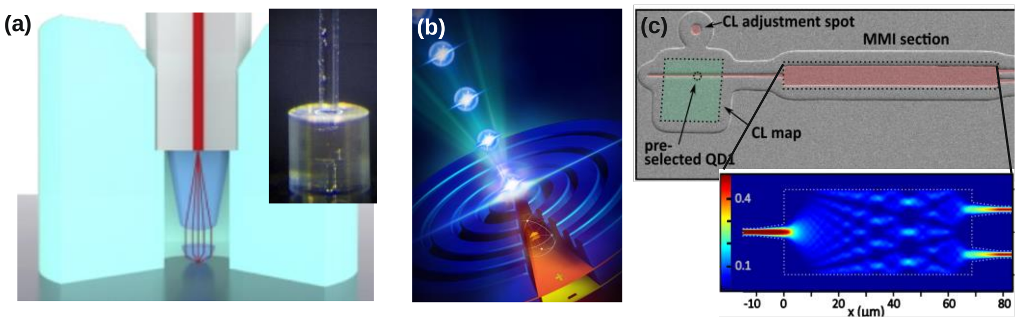

Fig. 1: (a) Fiber-coupled QD SPS. (b) Schematic of an electrically controlled quantum dot molecule device. (c) Integrated quantum circuit realized by in-situ electron beam lithography.

In this talk, I describe basics and application examples of in situ electron-beam lithography (iEBL) acting as advanced deterministic nanofabrication platform for photonic quantum devices. Details about the iEBL process, including machine learning enhanced iEBL [2] are discussed, and its high potential for the deterministic fabrication of single-emitter devices for applications in photonic quantum technology is presented. Examples include electrically controlled high-performance single-photon sources (SPSs) based on circular Bragg gratings to enhance their brightness [3, 4], fiber-coupled single-photon sources for direct network integration [5,6], and scalable integrated quantum circuits [7-9].

References

[1] S. Rodt, S. Reitzenstein, Nano Express 2, 014007 (2021)
[2] J. Donges et al., Nanoscale 14, 14529 (2022)
[3] J. Schall et al., Advanced Quantum Technologies 4, 2100002 (2021)
[4] S. Wijitpatima et al., arXiv:2406.08057 (2024)
[5] A. Schlehahn et al., Scientific Reports 8, 1340 (2018)
[6] A. Musial et al., Advanced Quantum Technologies 3, 2000018 (2020)
[7] P. Schnauber et al., Nano Letters 18, 2336 (2018)
[8] P. Schnauber et al., Nano Letters 19, 7164 (2019)
[9] S. Li et al., ACS Photonics 10, 2846 (2023)