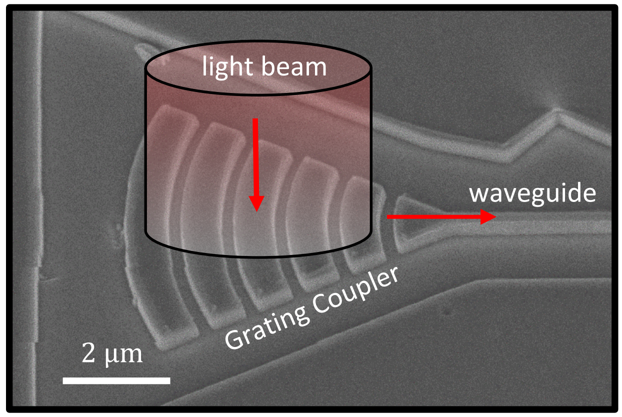
Master thesis on Nanophotonic Quantum Memories

Prof. Kai Mueller's group, Walter Schottky Institut

Topic

Simulation and measurement-based optimization of Integrated Photonic Circuits for a hybrid Nanophotonic Quantum Memory approach



Thesis Outlook

Realizing quantum photonic circuits crucially depends on its building blocks. Hence, the scope of the thesis is to further develop our integrated photonic platform with the focus on a 1D cavity. This cavity is further used for investigations of light-matter interactions with the aim to realize an on-chip quantum memory.

During the thesis you will start by supporting the characterization and analysis of grating coupler designs in order to get familiar with the experimental setup, the fabrication process and data analysis techniques. Further, by using the simulation software Lumerical and the optical setup you will be trained with to measure the spectral response of the cavity, you will design, simulate and optimize a 1D waveguide. In addition, you will assist the fabrication and nanoanalysis process by sample preparation, characerization of fabricated samples using nanoanalysis techniques, such as scanning electron microscopy, ellipsometry, etc. to assess the quality and performance of the fabricated device.

Note: The specific tasks and responsibilities within the scope of work may be further refined and adjusted based on the candidate's skills, interests, and project requirements.

Literature: Study of coupled Er^{3+} ions in an integrated photonic cavity [1]

[1] S. Qurari, et. al, "Indistinguishable telecom band photons from a single erbium ion in the solid state", arXiv:2301.03564v 9 Jan 2023

Project Background

Quantum memories are one of the most promising approaches to bring quantum communication and quantum computation in real-life applications. For example, quantum repeaters where quantum memories are embedded extend the quantum entanglement so that a long-distance quantum key distribution becomes achievable. Storing non-classical information in quantum memories and on-demand retrieving the information lead quantum computation to be superior to state-of-the-art supercomputers, so the quantum advantage. [2,3]

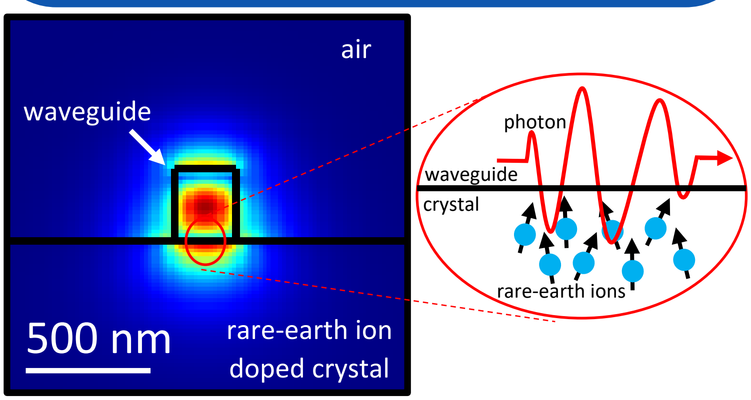
The goal of the project is the development of a nanophotonic quantum memory, where a quibit is stored-into an ensemble of rare-earth ions. For this purpose we developed an integrated photonic circuit using numerical simulations and e-beam lithography. This platform allows us to guide the light on-chip and force it to evanescently couple to rare-earth ions doped in the substrate beneath. Moreover, we study the quantum behavior of the doped ions in the crystals for a deeper understanding of the physics and limitations of this application. In order to implement this hybrid approach as a single photon Quantum Memory, we will analyse different storage protocols making use of the physics provided by the behavior of our material system under applied laser pulses, magnetic and electric fields at cryogenic temperatures.

Literature: Hybrid approach design (highly recommended to have a look at) [4]

[2] K. Heshami, *et. al*, "Quantum memories: emerging applications and recent advances", Journal of Modern Optics (2017)

[3] F. Bussieres, et. al, Journal of Modern Optics 60, 18, 1519-1537 (2013)

[4] I. Craiciu, *et. al*, "Multifunctional on-chip storage at telecommunication wavelength for quantum networks", optica (2021)



Learning experiences (skills & knowledge)

- Quantum optical simulations
- Cleanroom fabrication techniques
- Photonic Quantum Memories
- Nanoanalytical tools
- Physics of integrated photonic circuits including nano-cavities and QED
- Spectroscopic techniques
- Quantum optical measurements
- MATLAB/Python based data analysis

Your profile

You will work closely together in a small team, so teamwork is essential. Furthermore, a background in solid-state physics as well as hands-on experience in optics, programming, simulations or cleanroom fabrication will be beneficial but secondary to your personal motivation and commitment to this fascinating project.

If you want to contribute to this exciting research, we are looking forward to your application.

Please send your CV, transcript of records and Bachelor thesis to Prof. Kai Müller (kai.mueller@wsi.tum.de), including Fabian Becker (fabian.becker@wsi.tum.de) in cc.

Date: Mai 2023