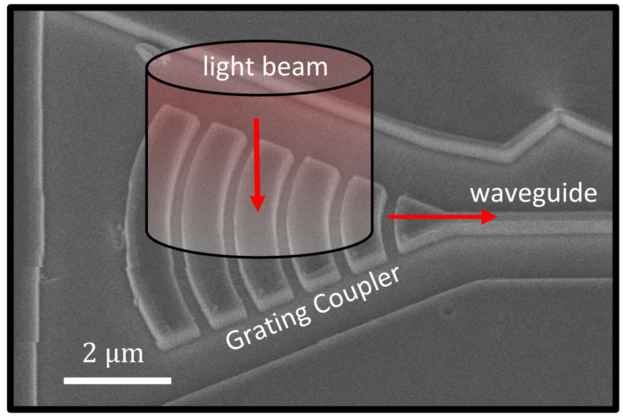
Master thesis on Nanophotonic Quantum Memories

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 in- and outcoupling of light. Therefore, Grating Couplers play a critical role for any on-chip photonic application, acting as the interface between laboratory and chip.

During the thesis you will start simulating the device design and building up a basic transmission setup for characterisation measurements. You will analyse the fabricated structure using tools like atomic force microscopy or scanning electron microscopy. After optimizing the Grating Couplers, we will use this platform to further study our waveguide cavity and the evanescent coupling between light in the waveguide and the rare-earth ions beneath.

Literature: Review of different Grating Coupler approaches [1]

[1] R. Marchetti, et. al, "Coupling strategies for silicon photonics integrated chips", Photonics Research 7, 2, 201-239 (2019)

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]

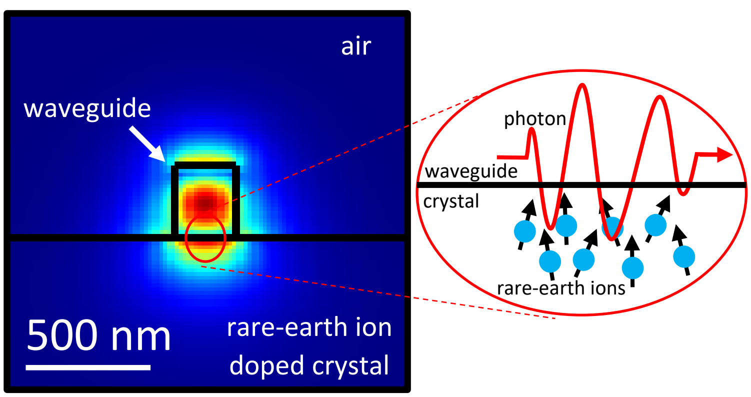
The goal of the project is the development of a nanophotonic quantum memory, where a quibit is stored-into an ensemble of rare-earth ions. For this purpose we developed an integrated photonic circuit using numerical simulations and e-beam lithography. This platform allows us to guide the light on-chip 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 grating couplers
- Spectroscopic techniques
- 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: November 2021