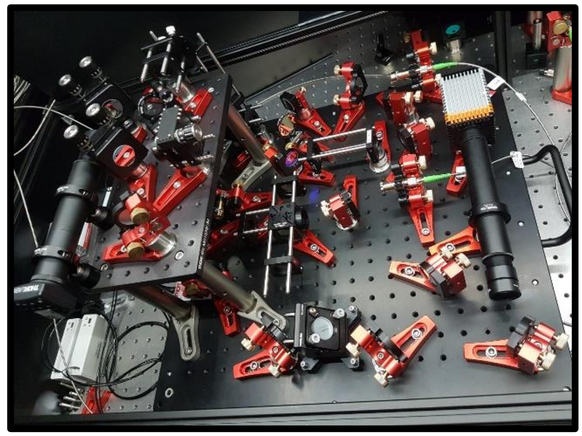
Master thesis on Nanophotonic Quantum Memories

Prof. Kai Mueller's group, Walter Schottky Institut



Topic

Investigate quantum optical behavior of rare-earth ion doped crystals for photonic Quantum Memory applications

Thesis Outlook

Rare-earth ions exhibit due to their orbital structue a unique optical and spin behavior. This leads to extremely long coherence and lifetimes of the system, making it to one of the most promising canditates for Quantum Memory applications. [1,2]

During the thesis you will get familiar with the level structure of our rare-earth ion doped crystals by taking basic photoluminescense measurements and resonant absorption measurements. Thereby, you will compare a well understood material system with a less prominent one. In addition, you will investigate the Zeeman splitting, photon echo and initiate hole bruning experiments. For this purpose one part of the thesis will also be, to extent the existing measurement setup with an double pass AOM (including alignment, software integration, reference measurements and optimization of performance).

[1] M. Afzelius, et. al, "Quantum memory for photons", Physics Today 68, 12, 42 (2015)

[2] C. W. Thiel, et. al, "Rare-earth-doped materials for applications in quantum information storage and signal processing ", Journal of Luminescence 131, 3, 353-361 (2011)

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. [3,4]

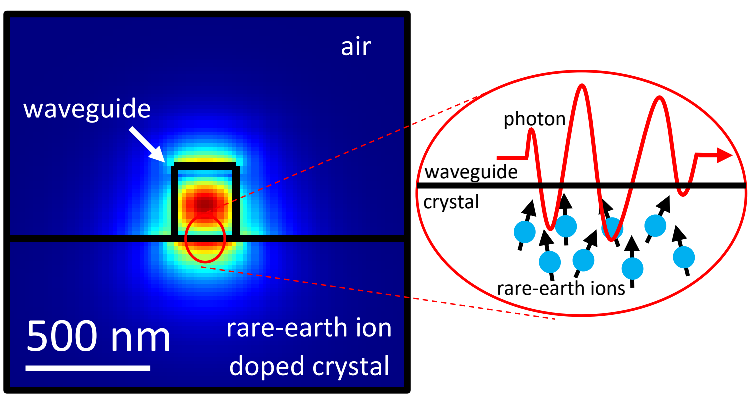
The goal of the project is the development of a nanophotonic quantum memory, where a quibit is stored-into an ensemble of rare-earth ions. For this purpose we developed an integrated photonic circuit using numerical simulations and e-beam lithography. This platform allows us to guide the light on-chip 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) [5]

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

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

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



Learning experiences (skills & knowledge)

- Spectroscopy techniques
- Rare-earth ions doped laser crystals
- Photonic Quantum Memories
- 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, electronics or programming 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