MSc Thesis / BSc Thesis / HiWi: Rydberg excitons in cuprous oxide – towards an integrated and scalable solid state quantum device

From atomic physics we know that an electron can be excited to a state with large principal quantum number, forming a so-called Rydberg atom. The giant size of Rydberg atoms – about several hundreds of Å – leads to huge interaction effects from which one gains insight into atomic physics on the single quantum level.

An exciton is an excited state of the crystal, in which an electron and a hole form a quasiparticle bound by Coulomb interaction. If an exciton is in a state with large principal quantum number, it is termed Rydberg exciton. In covalent crystals, such as cuprous oxide (Cu_2O), excitons are delocalized, the electron-hole pair is loosely bound, and the orbits are large with macroscopic dimensions of up to µm-size. Excitonic effects are decisive for the optical properties of semiconductors, among which cuprous oxide is unique in crystal quality. Furthermore, in contrast to Rydberg atoms, highly excited excitons with µm-size extensions are of interest because they can be placed and moved in a crystal with high precision using macroscopic energy potential landscapes. Similar to Rydberg atoms, they are capable of sensing elementary excitations in its surrounding on a quantum level. This means that Rydberg excitons in cuprite are of great research interest as they make a well-controllable, macroscopic quantum system.

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S. O. Krüger and S. Scheel, "Waveguides for Rydberg excitons in Cu_2O from strain traps," Phys. Rev. B **97**, 205208 (2018).

V. Walther et al., "Interactions between Rydberg excitons in Cu_2O," Phys. Rev. B **98**, 165201 (2018).

A. Konzelmann, S.O. Krüger, and H. Giessen, „Interaction of orbital angular momentum light with Rydberg excitons: Modifying dipole selection rules," Phys. Rev. B **100**, 115308 (2019).

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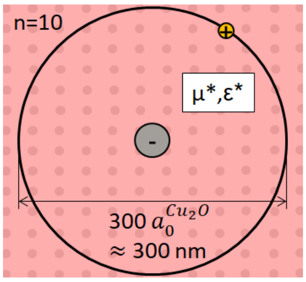
Your task:

Your task is to align a pump-probe laser setup for spectroscopy measurements on cuprous oxide excitons. You will assemble a *solid state quantum device* by attaching an optical fiber with 3D-printed micro-optics to a cuprous oxide crystal flake. By inserting crystal and fiber into a cryostat at 1.4 K, you will perform highly accurate, integrated reflection measurements of Rydberg excitons in cuprous oxide. This will create the first fiber-coupled solid-state Rydberg quantum device.



Required skills:

- Interest in optics, semiconductor, and low-temperature physics
- Interest in experiment-computer interaction
- Hands-on and practical attitude

You gain:

- Laser alignment skills
- Handling of ultra-cold liquid nitrogen and helium
- Know-how about Rydberg excitons in semiconductors

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