In the last years, rare-earth doped crystals have risen a strong interest for quantum technologies. This is due to their ability to present long-lived quantum states encoded both in their optical and spin transitions, an unmatched feature in the solid state. Recently, we measured these properties in rare-earth doped nanocrystals, demonstrating the longest lifetimes for any nanomaterial. These promising results open the way to new hybrid architectures combining, for instance, nanophotonic devices with rare-earth doped nanoparticles (Nano Lett. 2017, Nat. Commun. 2018, RSC Advances 2018). This research is currently pursued within the European Union funded quantum flagship project SQUARE (http://square.phi.kit.edu).

This project aims at developing new rare earth doped nanoparticles with enhanced properties and focuses on understanding the fundamental limitations of quantum state lifetimes at the nanoscale. For this, several combinations of host and dopants will be investigated to reveal the contributions of perturbations linked to e.g. paramagnetic impurities, charge noise, residual disorder. In particular, Yb ions will be studied as they recently emerged as a very promising system for a range of applications from quantum memories to microwave-optical quantum transducers (Nature Materials 2019).

Another goal of this project is to move beyond the current experiments on large ensemble of particles towards single object spectroscopy. This will allow us to evaluate the dispersion within a particular batch of particles, and establish relations between their structure and their quantum properties with an unprecedented accuracy. It will also enable accurate control of the quantum states opening the way to enhancing lifetimes by applying magnetic fields or series of excitations. This is currently a completely unexplored regime for nanomaterials and we expect it to provide essential elements for progress in quantum technologies.

Specific experimental techniques that will be used in the project are low temperature high resolution optical spectroscopy and optically detected spin resonance. A range of narrow linewidth lasers, covering the visible and near infrared range are available in the team, and will be used to adress the very narrow optical lines of rare earth ions. Single particle studies will empty a cryogenic confocal microscopy setup recently developed in the team. Other techniques that will be useful are absorption and emission optical spectroscopy, electron paramagnetic resonance, and structural characterisation techniques like electron microscopy and XRD. The nanoparticle will be either synthesized in the laboratory or obtained through collaborations.

More information about the research group can be found at www.cqsd.