Karlsruhe Institute of Technology

PhD Thesis at KIT, Karlsruhe, Germany: Luminescence of Single Lanthanide Molecular Complexes

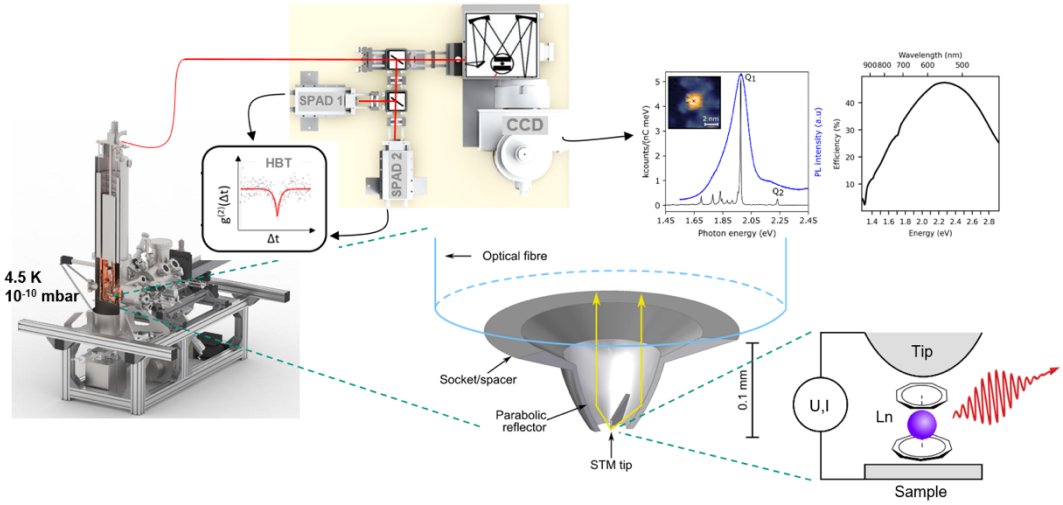
Materials based on rare-earth metals are important for our modern high-tech society and rare-earth element molecules are promising candidates for future low-energy lighting and electrically driven single-photon sources, because they combine very sharp emission lines with the possibility to functionalize the ligands in order to maximize the coupling to the photon field and thus the emission efficiency.

Scanning tunneling microscopy induced luminescence (STML) provides an experimental pathway to combine photon spectroscopy with the high lateral and energy resolution of scanning tunneling microscopy (STM). In order to study the light-emitting properties of individual molecules, we have developed a low-temperature STM that allows to collect light emitted from the tunnel junction. The collected light is then guided into a spectrometer or photon counting diodes via an optical fiber. The setup has recently been extended by a Hanbury Brown-Twiss (HBT) interferometer in order to characterize the nature of the light emitted from individual molecules in the STM junction.

In this PhD thesis, tailor-made molecules will be studied in detail using STML in ultra-high vacuum and cryogenic temperatures. STM will be used to verify if the complexes survive the deposition, identify the adsorption geometries and charge states of the molecules on the surfaces. Laterally resolved tunneling spectroscopy reveals the energy and shape of the molecular. The electroluminescence of the molecules will be studied and compared with photoluminescence data of the molecule in solution and in gas phase. The molecules will be characterized in terms of quantum efficiency for electron to photon conversion as well as the lifetimes of the involved states. Furthermore, using the HBT interferometer, the statistic nature of the light will be studied recording the time correlation of individual photons emitted from molecules. This includes possible higher order effects that are analogous to up- and down- conversion, i.e. the emission of single photons as the result of two stepwise electronic excitations triggered by tunneling electrons, and the emission of two photons in a cascade after a single electronic excitation to a high energy level.

This PhD thesis is part of the new SFB *4f for Future* (*https://www.materials.kit.edu/927.php*) established at KIT which comprises an Integrated Research Training Group for doctoral researchers, connecting training and research aspects.

The position is open from first of January 2023. Application should be addressed to Prof. Wulf Wulfhekel (wulf.wulfhekel@kit.edu). A Master degree in physics or related disciplines is required. Prior experience in STM, molecular electronics or single molecule luminescence are welcome.



Schematics of the STML setup to study emission spectra and time correlation ($g^{(2)}$) of the light emitted from single 4f molecular complexes.