

Topic for a Master's Thesis

„ Tuning of SEIRA with different PCMs “

Nanophotonics is a discipline in physics which deals with the **emission, detection and transformation** of light at length scales well below the employed wavelength (usually nanoscale). Ideally, nanophotonic optical components are freely adaptable and programmable in their functions.

Infrared spectroscopy enables the investigation of organic compounds in chemistry, biology and pharmacy. Most of the characteristic molecular vibrations lie in the infrared spectral range and provide information about the molecular bonds and compositions. This is contrasted by the small absorption cross-section of molecules in the range of 10^{-20} – 10^{-30} cm². To detect small amounts of them nevertheless, plasmonic nanostructures are used in **surface enhanced infrared absorption (SEIRA)**. The enhanced near-fields at certain points of the nanostructure, so-called hotspots, enable the measurement of even small amounts of organic molecules placed inside these hotspots due to enhanced absorption there¹.

Phase-change materials (PCMs) have been found to be optimal candidates for tuning antenna resonances. They have a high optical contrast between their amorphous and crystalline structural phases which originates from a newly discovered binding mechanism called “metavalent” bonding. Normally, PCMs can only be switched between two dielectric phases in the mid-infrared spectral range.

Recently, our group introduced the next-generation PCM **In₃Sb₁Te₂ (IST)**, which can be switched between dielectric and metallic optical behavior, to infrared nanophotonics. IST can be classified in a new material class of **non-volatile, switchable “bad metals”**.

With a **home-built laser switching setup**, we could already demonstrate the direct writing and erasing of plasmonic IST nanoantennas into a thin film of amorphous IST without need for cumbersome nanofabrication methods like electron beam lithography². This **new technology** now allows for the rapid prototyping of metallic nanophotonic components.

In the next step, the methods of enhanced molecular absorption can be merged with antenna resonance tuning by PCMs. A previous Master's Thesis already showed the problem of positioning the molecules only on top of the antennas and not directly in the hotspots. In a first experiment, the amorphous IST layer shall be prepatterned with Focused Ion Beam milling (FIB) to create small trenches inside the material. Molecules can be placed inside these trenches to be directly positioned in the hotspot of dimer antennas. In addition, the tuning of SEIRA effects with metal nanoantennas and an underlying **dielectric PCM** such as Ge₃Sb₂Te₆ (GST) can be studied. By changing the dielectric surrounding of the underlying material, the antenna resonances can be tuned to over a broad wavelength range. Therefore, the antennas enable an on- and off-resonant detection of molecules placed in the hotspots of the antennas. The tuning mechanism offers locally addressing of the antennas for selective biomolecule sensing.

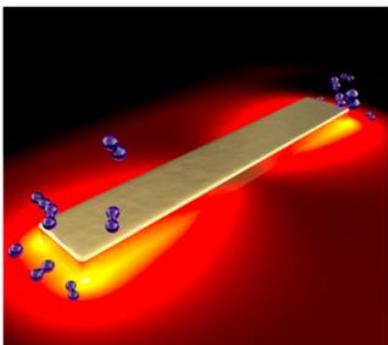


Figure 1: Placing the molecules in the hotspots of a resonantly excited nanoantenna leads to an enhanced molecular absorption. Image taken from [1].

Contact:

Lukas Conrads M. Sc.

✉ conrads@physik.rwth-aachen.de

📍 26 A 105 📞 0241 / 80 20268

¹ Neubrech et al. *Chemical Reviews* **117**, 7 (2017)

² Heßler et al. *Nature Communications* **12**, 924 (2021)