Master thesis: **Double resonant hBN-Gold heterostructures for mid-IR frequency upconversion**

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Project type: Master thesis or Internship
Start date: Fall 2026 or sooner
Deliverables: Thesis or final report and defense or presentation

Overview

The mid infrared frequency range of the electromagnetic spectrum (10 THz-100 THz) holds great technological and scientific promise, as in this frequency range lay for example the vibrational frequencies of organic molecules and their functional groups, yet this frequency range is still challenging to exploit. While for frequencies above (the near infrared and visible) and below (radiofrequencies), efficient, commercially available and compact detectors exist, for the mid-infrared range detectors typically are bulky and require cryogenic temperatures. One approach to overcome the detector issue is to shift the frequency of the mid-IR light to near-IR light by a nonlinear process called sum frequency upconversion (SFG). This approach has been developed within LQNO and is used routinely in the group to study molecular spectra by relying on the field enhancement of metal antennas [2,3], see also the figure below.

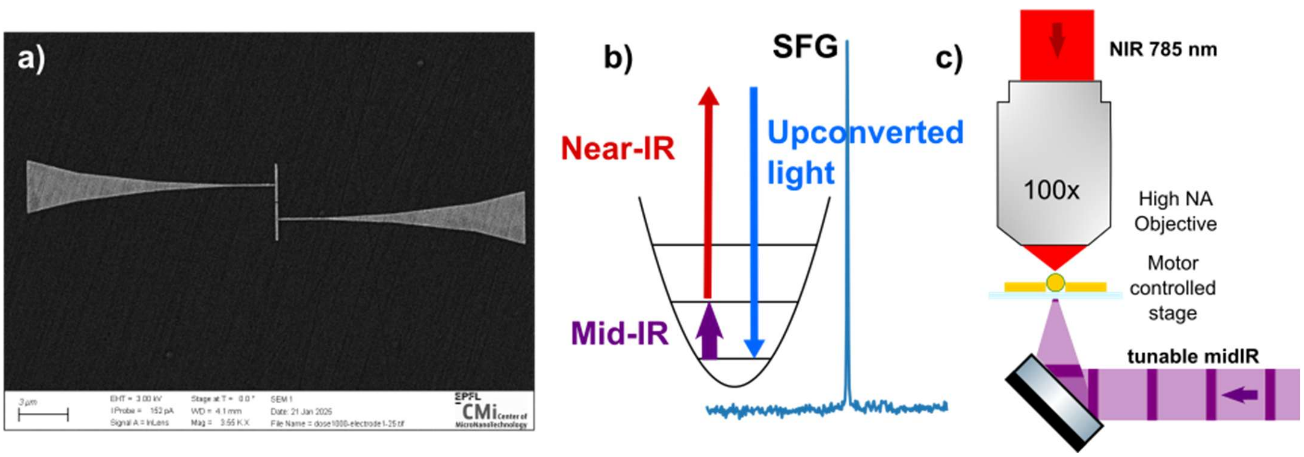

Figure 1a) SEM image of a resonant antenna fabricated in the CMI cleanroom. b) Sketch of the sum frequency process: Incoming mid-Ir light (purple) combines with a pump near infrared light (red) to give rise light at visible frequencies (blue). A typical SFG spectrum is shown in blue. C) Sketch of the setup for measuring SFG.

Within the master thesis we would like to explore a new material, hexagonal boron nitride (hBN), for sum frequency upconversion. hBN is a so called 2D material and has been shown to allow SFG in a technologically interesting range [4]. In the project we would like to increase the efficiency of the upconversion process by embedding the material within gold antennas such as shown in Figure 1a).

Tasks

During his Master thesis the student will design and fabricate these structures using the facilities of CMI cleanroom such as ebeam-lithography, etching or thin film deposition subsequently he will measure the SFG yield of the fabricated structures using the optical setups found in our labs.

We are looking for motivated students with a background in the areas of physics, chemistry, material science, engineering or similar. Previous experience with clean room equipment or optical measurements is a plus but not mandatory.

If you are interested in the project and you want to know more please do not hesitate to contact us. We are looking forward to hearing from you.

[1] Roelli, Philippe, et al. "Molecular Platform for Frequency Upconversion at the Single-Photon Level." *Physical Review X* 10, no. 3 (2020): 31057. https://doi.org/10.1103/PhysRevX.10.031057.

[2] Chen, Wen, et al. "Continuous-Wave Frequency Upconversion with a Molecular Optomechanical Nanocavity." *Science* 374, no. 6572 (2021): 1264–67. https://doi.org/10.1126/science.abk3106.

[3] Xie, Zhiyuan et al. "Continuous-Wave, High-Resolution, Ultrabroadband Mid-Infrared Nonlinear Spectroscopy with Tunable Plasmonic Nanocavities." *ACS Photonics*, ahead of print, March 23, 2026. https://doi.org/10.1021/acsphotonics.6c00123.

[4] Mueller, Niclas S., Alexander P. Fellows, Ben John, et al. "Full Crystallographic Imaging of Hexagonal Boron Nitride Monolayers with Phonon-Enhanced Sum-Frequency Microscopy." arXiv:2504.15939. Preprint, arXiv, April 23, 2025. https://doi.org/10.48550/arXiv.2504.15939.