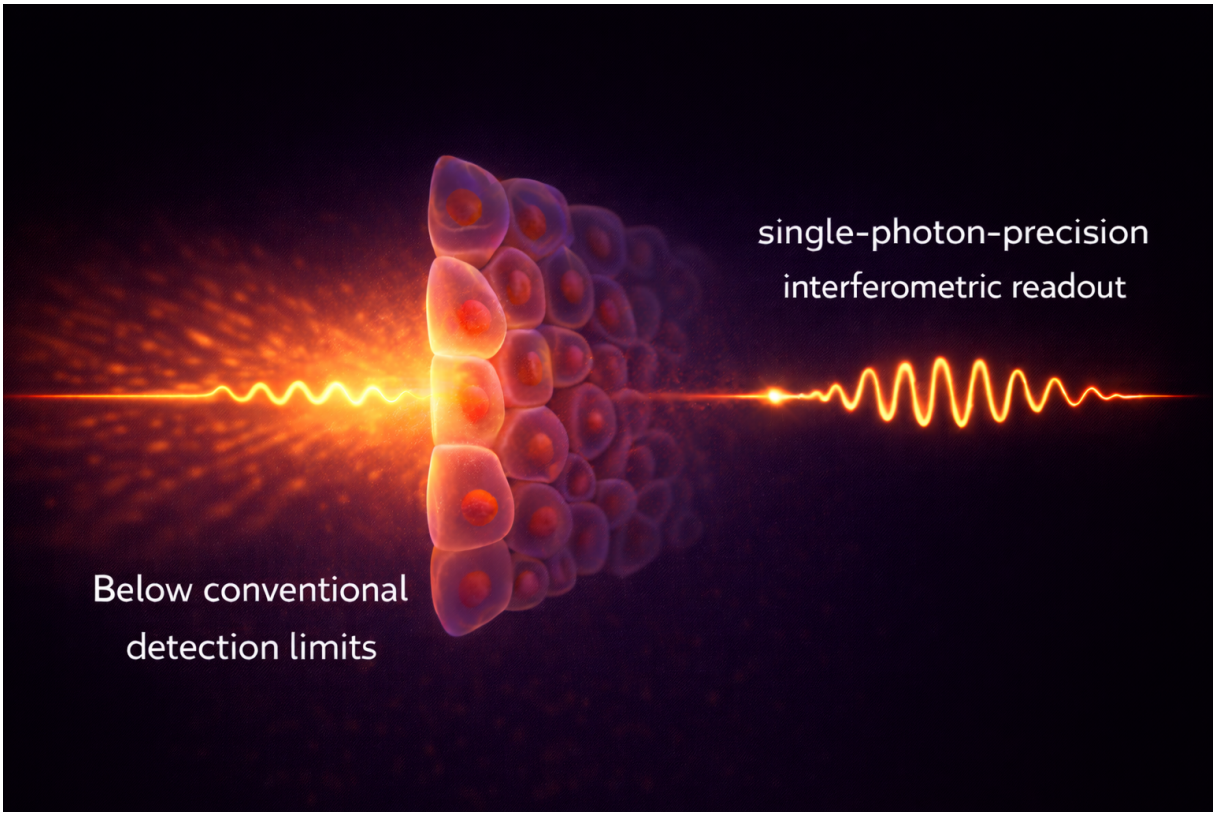
MSc Thesis at the Laboratory of Lightwave Metrology, Prof. Ioachim Pupeza

Mid-Infrared Interferometric Spectroscopy – Toward the Quantum Shot-Noise Limit



Mid-infrared molecular spectroscopy provides quantitative and specific fingerprints of complex biological samples, with high promise for applications in biology and medicine [1]. However, exploiting this potential requires pushing detection to the quantum-shot-noise limit. In this project, you will develop an interferometer based on a mid-infrared (-IR) quantum-cascade laser toward single-photon-level sensitivity for the detection of strongly attenuated signals, corresponding to deeply absorbing molecular fingerprint bands. Building on a concept previously demonstrated in our group with a continuous-wave near-IR source, you will transfer and extend this measurement strategy to the mid-IR regime, where many biologically relevant vibrational modes reside.

Your work will include optical design and interferometer alignment, as well as a quantitative noise analysis that disentangles technical noise from fundamental shot noise. You will perform proof-of-principle, ultrasensitive absorption measurements, and systematically compare the achieved sensitivity with predictions from digital-twin models. The topic is closely connected to our collaborative work with biology and medicine, aiming to extend the limits of current vibrational spectroscopy and to deliver more precise and faster diagnostic tools.

[1] I. Pupeza et al., “Field-resolved infrared spectroscopy of biological systems,” Nature 577, 52 (2020)

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