(Towards) On-Chip Mid-Infrared Spectroscopy

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Selective sensing in the mid-infrared (MIR) region is pivotal across diverse applications such as process control, environmental monitoring, and healthcare diagnostics. However, the widespread adoption of MIR technology is often hindered by its high cost and bulky instrumentation. To address these challenges, there is a growing interest in developing on-chip spectrometer solutions that offer compactness, cost-effectiveness, and portability while maintaining high performance.

We investigate novel approaches to on-chip MIR spectroscopy, aiming to bridge the gap between conventional bulky systems and emerging miniaturized solutions. Our research is motivated by the need to expand access to MIR spectroscopic capabilities and enhance their utility across a range of industries and scientific disciplines.

Modification of the heterostructure of quantum cascade lasers (QCLs) facilitates the creation of bi-functional devices capable of both lasing and detection functionalities [1]. By engineering the QCL heterostructure, we aim to develop compact on-chip spectrometers that are capable of high-resolution spectral analysis within the MIR range [2,3]. The integration of surface plasmon polaritons with bi-functional QCLD devices enables enhanced sensing capabilities, particularly in the realm of liquid sensing.

In our efforts to miniaturize on-chip spectroscopic systems, we utilize interband cascade lasers (ICLs) to access smaller wavelengths and reduce power consumption. This is crucial for creating compact and energy-efficient devices suitable for portable applications. By integrating ICLs, we expand spectral coverage while ensuring optimal power efficiency, advancing the development of practical on-chip MIR spectroscopy solutions.

We explore alternative approaches for achieving large spectral coverage in on-chip spectrometers. The utilization of frequency comb technology offers the advantage of high-speed, broadband spectral measurements without the need for moving parts. Recent advancements in frequency comb technology have led to the development of free-running solitons within ring lasers, presenting a monolithic electrically driven platform for direct soliton generation. This innovation holds promise for further miniaturization and integration of on-chip spectroscopic systems, paving the way for compact and portable MIR sensing devices with unprecedented performance [4].

In addition to liquid sensing, our research extends to gas sensing applications, wherein we are pioneering novel methods for on-chip light guiding and detection. By harnessing the principles of integrated photonics, we aim to develop on-chip gas sensors with enhanced sensitivity, selectivity, and robustness, suitable for deployment in industrial, environmental, and medical settings [5].

References

[1] B. Schwarz et al., Nat. Commun **5**, 4085 (2014).
[2] R. Szedlak et al., ACS Photonics, **3**, 1794 (2016).
[3] F. Pilat et al., Lab Chip, **23**, 1816 (2023).
[4] N. Opacak et al., Nature **625**, 685 (2024).
[5] B. Baumgartner et al., Sens. Actuators B Chem., **302**, 127194 (2020).