Unveiling the Secrets of Gases: Laser Spectroscopy for a Greener, Healthier and Safer World

Laser spectroscopy of gases has emerged as a transformative technology with far-reaching implications for various fields, from environmental protection to healthcare and monitoring industrial processes. In the pursuit of a greener, healthier, and safer world, researchers worldwide are on a mission to develop sensitive and selective gas sensors. The combination of precision optics, lasers and the photothermal effects shows great potential for the development of miniaturised and versatile detectors for real-world applications. The pioneering research on new laser-based gas sensors could be achieved only with joint financing and the collaboration of two leading research Groups, each having expertise in dissimilar academic disciplines.

Project Goal: Miniaturized Marvels

The primary objective of the project is to develop new gas sensors based on the photothermal effects. Photothermal spectroscopy (PTS) of gases has proven to provide sensitivity and selectivity comparable with other state-of-the-art gas detection techniques, while maintaining a small footprint and miniscule sample volume. The research will focus on gas sensors based on miniature fiber Fabry-Perot cavities (FFPC), which have proven to provide the required passive stability and refractive index (RI) modulation redout sensitivity required for implementation in PTS.

Research Plan

The research plan is divided between two Universities taking part in the project. University of Bonn (UoB) will be responsible for the development of FFPCs specifically designed for implementation in photothermal gas sensing. This includes providing FFPC configurations capable of working in the telecom wavelength region (1550 nm), which is fundamental for the future development of inexpensive and robust sensors. Wroclaw University of Science and Technology (WUST) will be responsible for designing several new configurations of gas sensors relying on the PTS principle, which will integrate the FFPCs. Based on the WUST feedback, UoB will tailor the parameters and performance of the FFPCs to maximise the sensitivity and passive stability of the sensors. During the project we will design, build and optimise several new configurations of FFPC-based PTS gas sensors and compare the performance with commonly used techniques, e.g. multi-pass-cell-based gas spectrometers or quartz-enhanced photoacoustic spectroscopy. The long-term performance and stability evaluation of the developed sensors will be included in the realisation of the project.

Why Laser Spectroscopy Matters

Laser spectroscopy's importance is underscored by its diverse applications across various sectors. In medicine, laser spectroscopy enables the analysis of exhaled breath. This technology promises noninvasive disease diagnosis and monitoring by detecting trace gas biomarkers, which are “fingerprints” for various health conditions, for example, cancer, diabetes, or respiratory disorders. Laser spectroscopy plays a pivotal role in environmental protection by aiding in the analysis and precise localisation of air pollutant sources. The development of laser-based gas sensors is a game-changer for control in industrial processes, where enhancement of the efficiency and safety of industrial operations is key to ensuring a smoother and cleaner future for manufacturing. However, out-of-lab deployment of laser spectrometers is a complex task, which in most cases requires compromise between the sensor footprint, sensitivity and versatility. Our preliminary experimental results on FFPC-based PTS sensors show, that aided with further development, a new era of miniaturised, multi-gas sensors is on the verge of a breakthrough.

The Path Forward: Promising Results

By combining the knowledge and expertise of two interdisciplinary Groups from Europe, cutting-edge research on now laser-based gas detectors will be conducted. By implementing miniaturised and robust FFPCs we will refine the photothermal gas detection technique, paving the way for the development of a new branch of sensitive, selective and versatile gas sensors. The results of the project will include deepening the knowledge about the PTS gas detection technique, construction of innovative laser-based gas sensors, and miniaturization of these devices for future widespread deployment. During the project, the versatility of the proposed gas detection technique will be experimentally verified and compared with other laser-based gas detection techniques.

Beyond its scientific contributions, laser spectroscopy exemplifies the synergy between cutting-edge research and real-world impact. It paves the way for a cleaner and healthier planet, improves the quality of healthcare, and enhances safer industrial operations worldwide.