INTERNSHIPS AT LIFE SCIENCE TRACE DETECTION LABORATORY (TDLab)

Research in the TDLab focuses on the detection of species in the gas phase in complex mixtures at trace levels. For this, we use various laboratory instruments such as high-resolution mass spectrometry, and we also develop new laser-based spectroscopic instruments (e.g. using Fourier transform spectroscopy) for specific applications. These applications include agri-food industry, air pollution monitoring, bio-medical and disease detection, emission/exposure measurement, and much more.

Currently, we are specifically looking for students for the following projects:

- Master internship in multispecies open-path molecular absorption spectroscopy
- In-situ spectroscopy of plasmas
- Modelling of emission fluxes from spectroscopic data
- Bachelor internship project – Mass spectrometry: Detecting VOCs from faecal and caecal samples in relation to poultry intestinal health
- Master internship project – Mass spectrometry: Development of a mass spectrometry strategy for detecting formaldehyde in exhaled breath
- Master internship project – Mass spectrometry: Monitoring of SO2 using thermal desorption – gas chromatography – mass spectrometry (TD-GC-MS)
- Master internship project – Mass spectrometry: Development of a real-time detection strategy for monitoring the highly reactive hydrazine molecule
- Microcantilevers for chemical detection

Master internship in multispecies open-path molecular absorption spectroscopy

Are you an enthusiastic student in Physics and Astronomy, Molecular Sciences, or related fields who is looking for a Master's internship? Are you keen on developing or working with novel scientific instruments? Would you like to learn new concepts of laser spectroscopy and use them in real-life research? Then you have a part to play as an intern in our research group. Join us, learn how things work in laser spectroscopy, and gain hands-on experience in the lab and in the field!

In this project, we develop a transportable laser-based sensor for detection of trace gas species in an open-path configuration. The sensing principle is based on molecular absorption and the technology is based on supercontinuum laser sources and Fourier transform spectroscopy (FTS). In the open-path configuration, the laser beam is sent out from the source over a free distance (outside of the lab) and is reflected back towards the spectrometer, where the absorption spectrum is recorded. Different gas species absorb light at different wavelengths, thus by analyzing the spectrum we can determine the gases and their concentrations.

What is this position about?

You will join a team of senior and junior researchers working on the project and will learn about FTS, laser beam propagation, open-path beam stirring, analysis of absorption spectrum, and much more. The team members are actively developing and updating different hardware and software parts of this system, as well as performing measurements in the field for open-path monitoring of pollutants/greenhouse gases, and analyzing the data. Therefore, you can expect to gain a lot of new experiences in different disciplines.

What expertise is needed?

Prior basic knowledge of laser physics, absorption spectroscopy, and MATLAB is preferred but is not mandatory.

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In-situ spectroscopy of plasmas

Electrical discharges or plasmas of gas mixtures are a beautiful way to create chemical conversions of molecules without unnecessary side products or a high carbon footprint. For example, greenhouse gases like methane or carbon dioxide can be converted in a plasma to bigger, more valuable molecules like acetylene, syngas or formaldehyde [1].

In this project, a novel instrument, a supercontinuum-based Fourier transform spectrometer, which has been developed in our group [2], will be used to do mid-infrared absorption spectroscopy and observe the molecules and their behavior inside the plasma. The plasma is generated in a tube, in which the plasma is generated by applying a high voltage. The aim will be to optimize the spectroscopic setup, perform measurements inside the plasma tube, find the optimal parameters for plasma generation, and obtain data on the molecules formed during the process.

[1] Krebbers, R. et al. Mid-infrared supercontinuum-based Fourier transform spectroscopy for plasma analysis. Scientific Reports vol. 12 (2022). DOI:10.1038/s41598-022-13787-w.

[2] Abbas, M. A. et al. Fourier transform spectrometer based on high-repetition-rate mid-infrared supercontinuum sources for trace gas detection. Optics Express vol. 29 22315 (2021). DOI:10.1364/OE.425995

Modelling of emission fluxes from spectroscopic data

Emissions of “nitrogen” species, such as ammonia or nitrogen oxides, or emissions of greenhouse gases, such as carbon dioxide, methane, or nitrous oxide: it is an extremely relevant and hot topic which pops up in the news almost daily. However, substantial data of the actual deposition or emission of these gases in/from an area remain challenging to this data. Within our group, we have worked on a novel system, with which we can measure the concentration of such gases in an open, outdoor area. The system is based on a laser which is sent over a free, outdoor path. The absorption of light can be used to acquire information on the concentration of the molecules in the air, in that area, at that specific moment. While that is a known and proven method for quantifying concentrations in the air, the translation of this data to emission fluxes from an area (so the rate of emission of a certain gas in for example kg/hour) remains challenging. In this project, we will use data acquired by our group at a waste-water facility (see figure) to calculate the emissions of nitrogen gases and greenhouse gases from the plant. Part of the internship could be to find and try out different methods and models for these calculations, such as inverse dispersion modelling, total mass balance calculations, and more.

Bachelor internship project – Mass spectrometry: Detecting VOCs from faecal and caecal samples in relation to poultry intestinal health

Start: Q2, Q3 or Q4

Intestinal diseases in poultry are one of the most prevalent and costly problems in poultry production. One of the most prevalent infections is coccidiosis, which is caused by *Eimeria* parasites [1]. Previous studies have shown that volatile organic compounds (VOCs) from air samples can detect and quantify Eimeria *parasites* in broilers. Also, it is thought that VOCs from manure samples can be of aid to identify specific biomarkers associated with shifts in the gut microbiota [2,3]. During this project, faecal and caecal samples will be analyzed with proton transfer reaction – time-of-flight – mass spectrometry (PTR-ToF-MS) and thermal desorption – gas chromatography – mass spectrometry (TD-GC-MS). The aim of these analysis is to identify potential biomarker candidates related to 1) microbiome shift and 2) *Eimeria* infection.

References

1. ter Veen, C., de Bruijn, N. D., Dijkman, R. & de Wit, J. J. Prevalence of histopathological intestinal lesions and enteric pathogens in Dutch commercial broilers with time. Avian Pathol. 46, 95–105 (2017).
2. Borgonovo, F. et al. A Data-Driven Prediction Method for an Early Warning of Coccidiosis in Intensive Livestock Systems: A Preliminary Study. Animals 10, 747 (2020).
3. Grilli, G. et al. A pilot study to detect coccidiosis in poultry farms at early stage from air analysis. Biosyst. Eng. 173, 64–70 (2018).

Master internship project – Mass spectrometry: Development of a mass spectrometry strategy for detecting formaldehyde in exhaled breath

Start date: Any time

Formaldehyde exposure is a major problem for human health. Many consumer products as cosmetics, clothing, and furniture are sources of formaldehyde. Studies have shown that longitudinal exposure causes nose cancer and potentially leukaemia. Furthermore, it has been shown in a rat study that formaldehyde can be adsorbed through the skin. However, formaldehyde is a tricky molecule to measure as it is very reactive and can potentially form dimers in biological systems. Current methods for formaldehyde In this project, the aim is to investigate the use of selective reagent ion – time-of-flight – mass spectrometry (SRI-ToF-MS) for detection of formaldehyde in exhaled breath as a non-invasive alternative. During this project, the following questions need to be answered:

- Develop a feasible strategy for formaldehyde detection in exhaled breath
- Determine the detection limit of formaldehyde in exhaled breath
- Establish background levels of formaldehyde in the air

Relevant literature:

Bartnik, F. G., Gloxhuber, C. & Zimmermann, V. Percutaneous absorption of formaldehyde in rats. *Toxicol. Lett.* **25**, 167–172 (1985).

Riess, U. *et al.* Experimental setup and analytical methods for the non-invasive determination of volatile organic compounds, formaldehyde and NO in exhaled human breath. *Anal. Chim. Acta* **669**, 53–62 (2010).

Winkowski, M. & Stacewicz, T. Optical detection of formaldehyde in air in the 3.6 μm range. *Biomed. Opt. Express* **11**, 7019 (2020).

Master internship project – Mass spectrometry: Monitoring of SO_2 using thermal desorption – gas chromatography – mass spectrometry (TD-GC-MS)

Start date: Any time

Sulphur dioxide (SO_2) is a common air pollutant originating from e.g. electricity generation, industrial boilers, and diesel engines. Even at very low concentrations (low part-per-billions), SO_2 is known to have a detrimental effect on optical systems [1]. Therefore, regular monitoring of SO_2 is of the essence to minimise downtime of optical instruments. During this project, the aim is to 1) Identify a strategy for capturing and analysis of SO_2 based on literature search and 2) Validate a TD-GC-MS method for detecting SO_2 at low part-per-billion (ppb) level.

References

1. H. Fontaine, G. Demenet, V. Enyedi, S. Cetre, M. W. Montgomery, W. Maurer, Eds. (2010; http://proceedings.spiedigitallibrary.org/proceeding.aspx?doi=10.1117/12.864268), p. 782328.

Master internship project – Mass spectrometry: Development of a real-time detection strategy for monitoring the highly reactive hydrazine molecule

Start: Any time from Q2

Hydrazine is an extremely reactive molecule with commercial relevance, used in the pharmaceutical industry, as rocket fuel, blowing agent, to polymerize molecules and many more applications. Hydrazine is currently produced in the chemical industry. However, it is also a key intermediate in the energy metabolism of anaerobic ammonium oxidizing (anammox) bacteria, which are applied in wastewater treatment plants (WWTPs) for the efficient, low-energy and environmentally-friendly removal of toxic nitrogen compounds, i.e. ammonium. The enzyme that converts ammonium and nitric oxide to hydrazine in anammox bacteria is called hydrazine synthase. Currently, we are investigating whether the isolated hydrazine synthase enzyme can be used for the production of hydrazine. However, to examine the feasibility of this biological hydrazine production approach, we need a direct, and preferable online, method to detect hydrazine. To this day, there are several detection methods for hydrazine and derived molecules, which are all based on offline derivatization of hydrazine with other chemicals for its detection. Although sensitive, derivatization methods will always rely on the chemical reactions performed being efficient and unhampered. Preliminary results showed that we were able to detect hydrazine using selective reagent ion – time-of-flight – mass spectrometry (SRI-ToF-MS). The next step is to determine the detection limit of the methodology and apply the developed method on a real world sample.

Outline:

- Finalise and analytically validate the SRI-ToF-MS strategy for real-time hydrazine detection.
- Monitor hydrazine production in an anammox bioreactor

Relevant literature

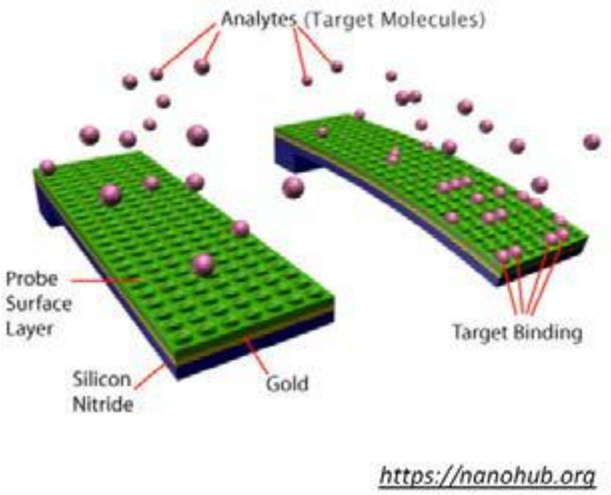
Meurs, J., Sakkoula, E., & Cristescu, S. (2022). Real-time non-invasive monitoring of short-chain fatty acids in exhaled breath. Frontiers in Chemistry, 0, 424. https://doi.org/10.3389/FCHEM.2022.853541

Dietl A, Ferousi C, Maalcke WJ, Menzel A, de Vries S, Keltjens JT, Jetten MSM, Kartal B, Barends TRM (2015) The inner workings of the hydrazine synthase multiprotein complex. Nature 527: 394–397. https://www.nature.com/articles/nature15517

Microcantilevers for chemical detection

Miniaturized sensors have been in particular interest in the recent years, thanks to the advancement of technology in miniaturization of optical, electrical and mechanical systems.

One of the popular miniaturized platforms for sensing is a microcantilever (MCL). A MCL is a miniaturized beam constrained at one end with the other end extending freely outwards. An external stimulus causes the MCL to bend or oscillate in a static or a dynamic mode, respectively. In the static mode, the displacement of the MCL due to a load or intrinsic stress generated on or within the MCL is measured. In the dynamic mode, an external actuation (piezoelectric, magnetic, or electrostatic actuator) causes the MCL to oscillate at its natural (resonant) frequency. Any change in the load or mass of the MCL results in a change in frequency that is subsequently measured.



To allow chemical sensing, the MCL surface is coated with a probe coating (functionalized surface). Specific analytes are then adsorbed by specific coatings. The amount of target material is measured by monitoring a change in the MCL's natural frequency. For example, as more target analyte attaches to the surfaces, the MCL gain mass and its resonant frequency decreases. The higher the frequency shift, the greater the amount of accumulated mass. The data is then processed and the concentration of analyte is determined.

For this project, we are looking for an enthusiastic Msc student from Physics/ Physical Chemistry/ Science/ who likes to work in the lab. in testing and validation of a basic MCL sensor in a proof-of-principle experiment. This includes the external oscillation of a MCL with an activated surface with and without adsorbing a specific analyte. The main goal is to gain insights in how the MCL technology works for biosensing (i.e. detection of relevant biomarkers (in the gas or liquid phase) and potentially bacteria and viruses).

In our group we have a starting kit with several MCLs from commercial suppliers and simple electrical readouts. You will do this research at the Life Science Trace Detection Laboratory (TDLab, www.ru.nl/TDLab), Dept of Analytical Chemistry & Chemometrics (IMM, FNWI). This research is a collaboration between the TDLab and the Saxion Hogeschool (Enshede, Applied Nanotechnology).

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