Ultra-broadband infrared gas sensor for pollution detection

TRIAGE

TRIAGE project newsletter #1

Nov-2021

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Welcome to the first TRIAGE project newsletter!

Despite the COVID-19 restrictions, it has been a busy time in the opening months of the TRIAGE project. In this first newsletter we report on the following items of activity:

- Establishing ECREAM: a cluster of related EU projects on environmental monitoring
- Assessing the TRIAGE detection limits at Radboud University
- Thermally joining optical fibres made from highly dissimilar glasses at NORBLIS
- Modification of the FLAIR system for 24/7 operation at CSEM
- TRIAGE vacancy!! Postdoc position at LiU

More information is available on the project website https://triage-project.info

Introducing ECREAM

As part of its dissemination and communication strategy, TRIAGE has formed the European Cluster of Research projects for Environmental and Agri-food Monitoring (ECREAM). This cluster will work together to coordinate research, share data and disseminate results. It currently consists of fourteen EU projects, listed opposite (with hyperlinks to the respective websites for further information). Discussions are already underway for joint exhibition booths, workshops and conferences in 2022, and regular web meetings are held to plan events and present on project results.

More information can be found on the TRIAGE ECREAM webpage:

https://triage-project.info/links/ecream

ECREAM

European Cluster of Research projects for Environmental and Agri-food Monitoring

AEOLUS	MOLOKO
AQ_WATCH	MONPLAS
GRACED	PASSPORTOUT
EXHAUSTION	PHOTONFOOD
h-ALO	TRIAGE
MappingAir	TUBE
MAX-FRESH	ULISSES

Consortium

DTU, VIGO System, CSEM, NKT Photonics, Senseair, NORBLIS, Radboud University, Linköping University, Vivid Components

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PHOTONICS PUBLIC PRIVATE PARTNERSHIP

TRIAGE is an initiative of the Photonics Public Private Partnership.

https://triage-project.info

Establishing the TRIAGE detection limits

In this first period, Radboud University (RU) researchers have been assessing the detection limit of its in-house sensor for different species relevant for TRIAGE. Its broadband Fourier transform spectrometer (FTS) is capable of recording the spectra of multiple species simultaneously, so it can potentially retrieve the concentration of various gases from the measured spectra. However, atmospheric water vapour (H_2O) and carbon dioxide (CO_2) have relatively high concentrations compared with other species under study in TRIAGE. This makes it more difficult to detect those whose absorption spectra overlap with H_2O or CO_2 spectral features. Therefore, RU has been evaluating the proper wavelength range for each particular species to obtain the minimum spectral interference with these two interfering compounds. This can potentially affect the detection limit for some species, especially in the case where their strongest absorption lines (bands) may not be considered in the spectral fitting and concentration retrieval routine due to this spectral interference.

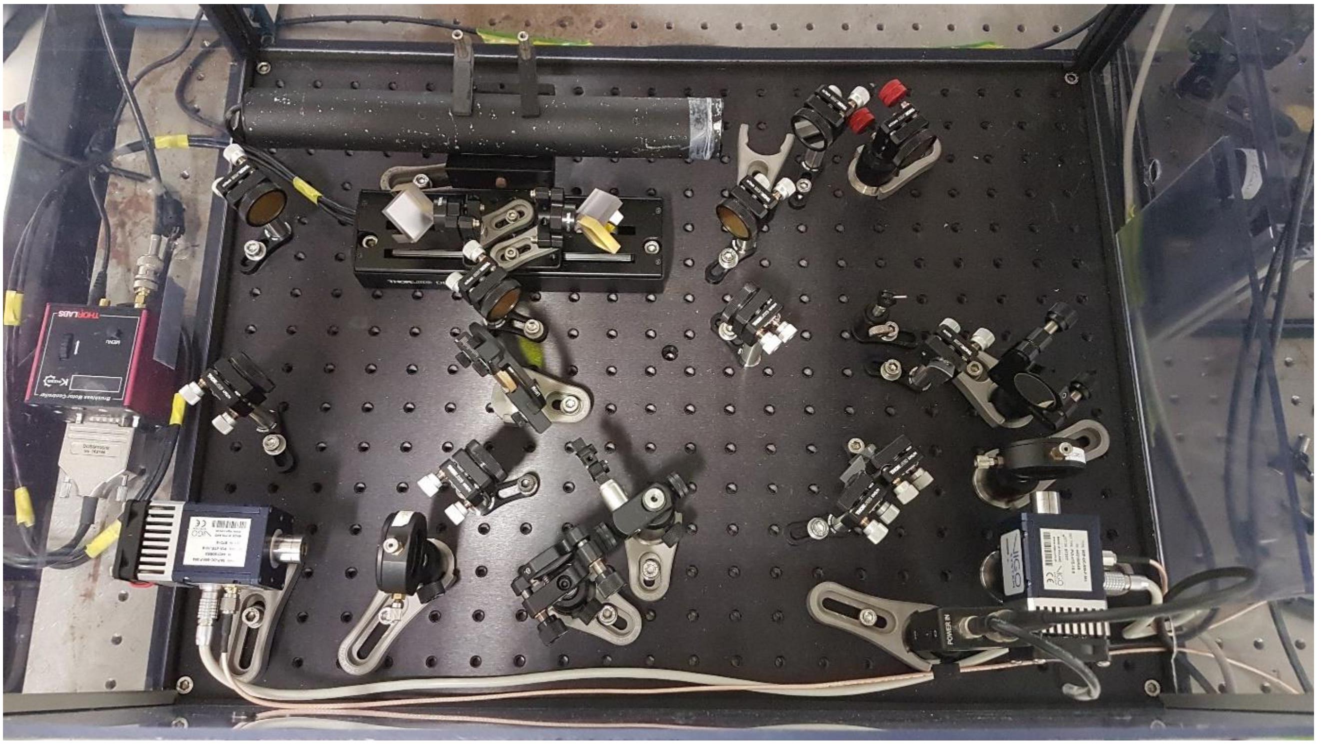

Fig. 1: Prototype lab-based FTS set-up at Radboud University

In addition, the power spectral density (PSD) of the supercontinuum (SC) source as well as its relative intensity noise (RIN) define further limitations to the minimum detection limit achievable for different species. The SC RIN is currently the main source of noise in the system, and dictates the sensitivity (detection limit) of the spectrometer for different species (aside from the spectral interference). Therefore, it is crucial to consider the PSD and RIN of the SC for estimating the detection limits. At RU the researchers are utilising a similar mid-infrared SC source that was developed by DTU in the framework of the FLAIR project to perform laboratory measurements. The measurement results are used for checking the validity of the chosen wavelength range for spectral fitting of each particular species of interest (including consideration of the spectral interference from H_2O and CO_2). Following standard practice, the minimum detection limit is then calculated as three times the standard deviation of the noise equivalent absorption for each species. The retrieved detection limits can be used as a starting point for studying the potential use cases of the complete system which will be developed later in the project. This will also help to identify the most appropriate potential use cases, which align with the sensor capabilities.

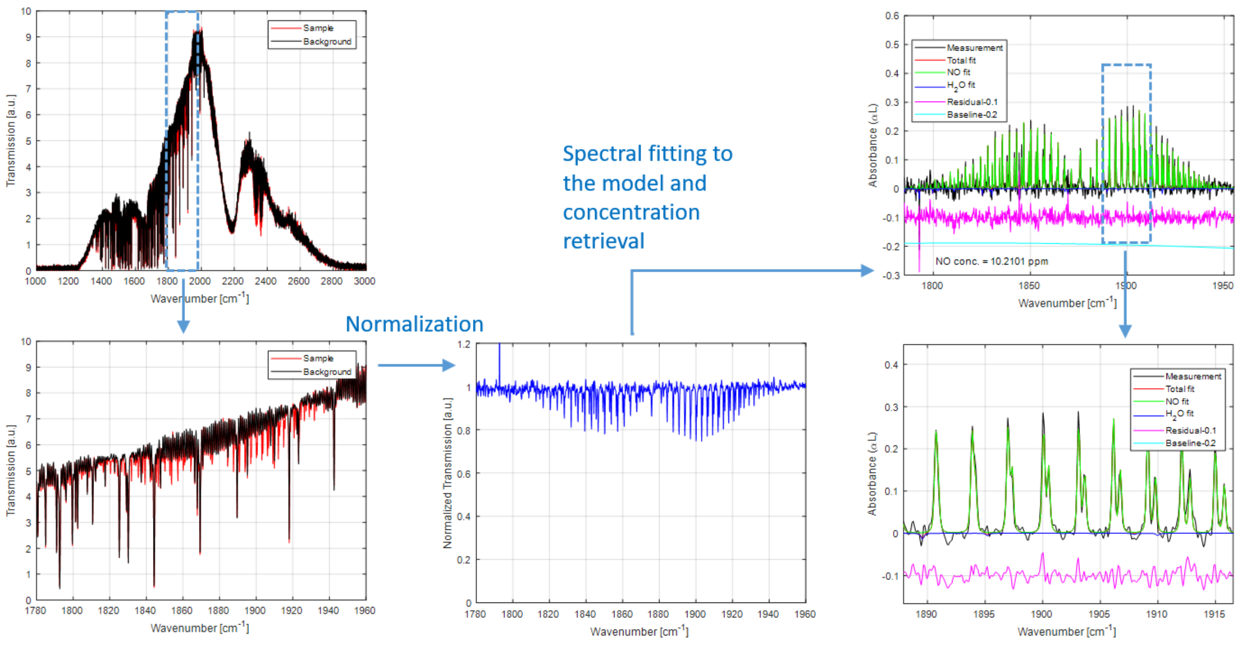

Fig. 2: Schematic showing the steps from spectrum to concentration

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Thermally joining optical fibres made from highly dissimilar glasses

NORBLIS
Nordic Broadband Light Solutions

The task of NORBLIS within the TRIAGE project is to deliver supercontinuum lasers that span from 2-10 μm in wavelength. To cover such a wide band in a practical and efficient manner, NORBLIS is using a series of optical fibres made from different materials that each transmit in a different part of the spectrum. This introduces the challenge of coupling between these dissimilar optical fibres with sufficient efficiency and robustness, and NORBLIS is solving this through a thermal joining process. The difficulty in joining these dissimilar materials comes from the different thermo-mechanical properties of the glasses. As an example, fluoride glasses start to soften at around 250-300 °C, while for fused silica this limit is ~1200 °C. Such an extreme contrast in thermal properties means that normal fusion splicing processes will not work.

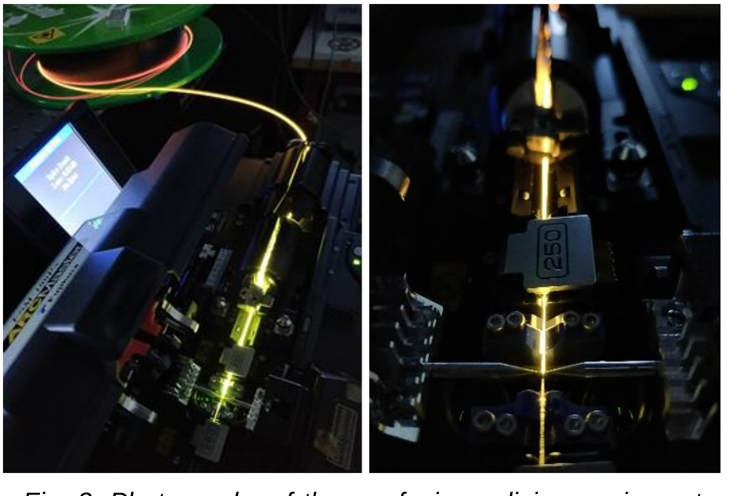

Fig. 3: Photographs of the arc fusion splicing equipment used for thermally joining dissimilar optical fibres at NORBLIS. The colours are fluorescence emissions from a rare-earth doped fluoride optical fibre.

Instead, joining of optical fibres made from silica and fluoride glasses must rely on the mechanical bonding achieved by the soft fluoride glass wrapping around the rigid silica glass (Figure 4). Since the two glasses are not fused together, the bond is more fragile than normal fusion splices. However, if done correctly, the joint can withstand pulling force of about 0.5 N. In the first few months of the TRIAGE project, NORBLIS has continued to develop its recipes and has optimised the performance. Figure 5 shows the measured joint pulling strength of fourteen silica-fluoride joints made using slightly different recipes.

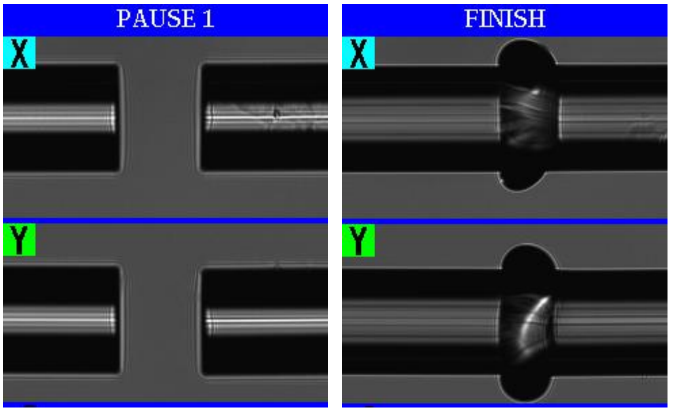

Fig. 4: Microscope images showing the silica (left) and fluoride (right) fibres before and after thermal joining.

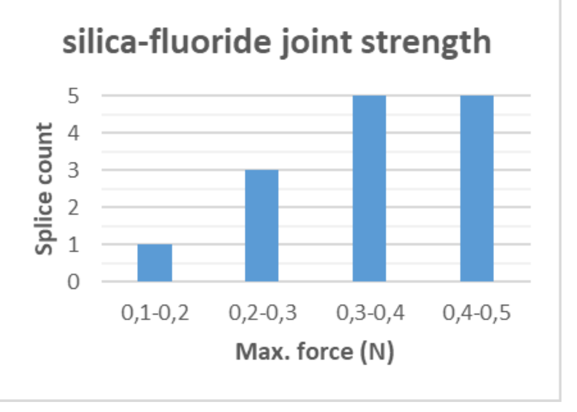

Fig. 5: Strength of fourteen joints made using a variety of splice recipes.

Mechanical optical connectors using metal or ceramic ferrules are known to be a very robust solution for joining optical fibres. However, the NORBLIS thermal joining process has a distinct advantage over connectors when it comes to the efficiency of coupling light from one fibre to the other. Since the exotic optical fibres that are needed to cover the extremely broad bandwidth of the NORBLIS SC laser have larger-than-standard tolerances on the core/cladding diameter and the core offset, perfect overlap between the cores of the two fibres is not guaranteed when using connectors, resulting in excess coupling loss. Through the thermal joining approach, the two fibres can be aligned precisely to optimise the transmission before the joint is established.

Another source of loss in a chain of dissimilar fibres based on optical connectors is that caused by microscopic air gaps and surface roughness introduced by polishing the end-face of the fibre after connectorisation. Polishing of fluoride and chalcogenide glasses can be challenging, and often results in a surface quality that is inferior to a precision cleaved surface. By thermally joining two dissimilar glasses, the air-gaps and scratches between the two fibres are filled-out, reducing the loss from Fresnel reflections at the air-glass boundaries and scattering from surface roughness. Increasing the transmission and reducing the loss at the fibre joints is an essential step towards the goal of TRIAGE, and NORBLIS is already well on the way to ensuring a robust, compact, all-fibre SC laser.

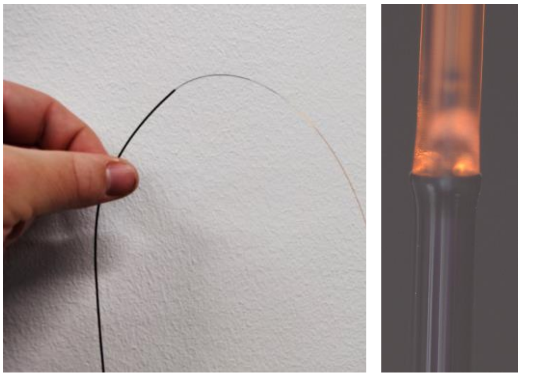

Fig. 6: (Left) Photograph of thermally joined chalcogenide fibres.

(Right) Image of the joint region under a microscope.

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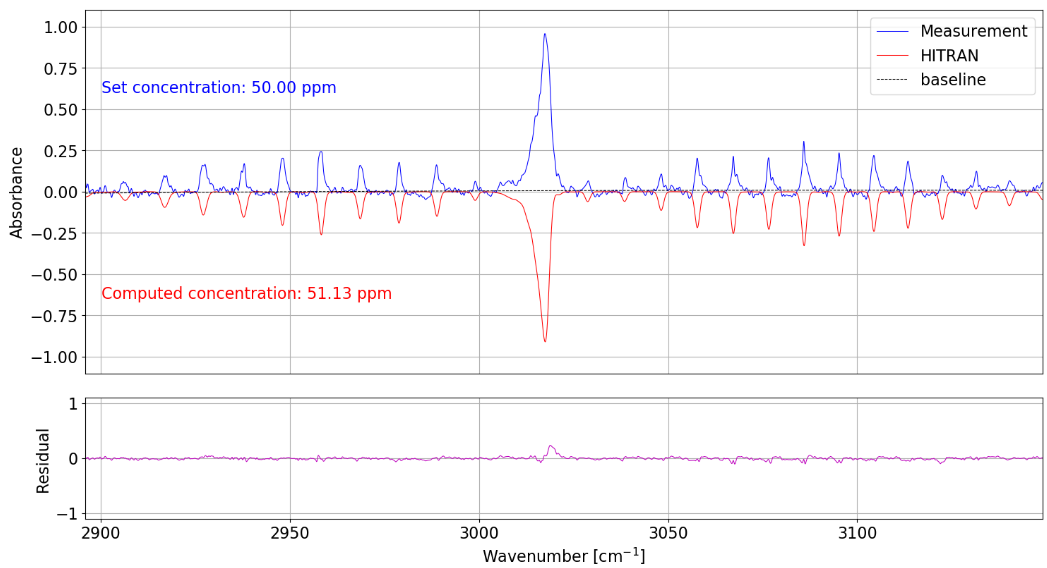
Modification of FLAIR system

In the H2020 FLAIR project, CSEM was responsible for the integration of an airborne spectrometer at system level. The project ended after the successful measurement campaign onboard a helicopter sampling more than 100 vessels over three days in the Kattegat channel, and detecting methane released in the fumes of liquefied natural gas (LNG) powered ships.

During the first months of TRIAGE, the FLAIR system has been modified for continuous 24/7 operation. The detection scheme has been upgraded for lock-in detection on the harmonics of the repetition rate of the 2-4 µm SC source at 200 kHz, rather than using a mechanical chopper at 123 Hz, providing a better usage of the available optical power.

Fig. 7: (Left) The FLAIR system
Fig. 8: (Below) Preliminary results



The firmware and user interface have been upgraded to adapt to the new usage of the prototype. Currently it is undergoing some validation tests and calibration against known gases, *e.g.* methane and water vapour. In the coming weeks, the system will start to broadcast absorption spectra continuously, which will be used to train and validate the machine learning algorithms, and to test and dimension the big data servers, transfer of data, API and widgets available on a dedicated web page. Stay tuned for more info!

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Vacancy!! Postdoc position at LiU!

LINKÖPING UNIVERSITY

As part of the TRIAGE project, Linkoping University is advertising for a Postdoc in Environmental Science, focusing on new instrumentation for measurements of air pollution and greenhouse gases. Please inform any colleagues who may be interested, or contact Prof. David Bastviken (david.bastviken@liu.se) directly.