FLAIR - Flying ultra-broadband single-shot InfraRed Sensor

At A Glance: FLAIR

Flying ultra-broadband single-shot InfraRed Sensor

Project Coordinator

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Partners:

- TEKEVER AS (PT)
- Senseair (SE)
- NKT Photonics (DK)
- New Infrared Technologies (ES)
- Radboud University Nijmegen (NL)
- Denmark Technical University (DK)
- EMPA (CH)
- CSEM (CH)

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FLAIR aims at developing an airborne, compact and cost-effective air quality sampling sensor for sensitive and selective detection of molecular fingerprints in the 2-5 µm and 8-12 µm infrared absorption windows. Mounted on an adapted and optimized UAV (drone), the sensor will enable pervasive sensing on large scales outside urban environments where air quality monitoring remains challenging.

Main Objectives

- **O1: Sensor prototype development** for cost effective, compact, highly sensitive and selective ultra-broadband real-time molecular trace gas detection of several species simultaneously in a complex mixture from their infrared (IR) absorption fingerprints.
- **O2: FLAIR sensor mounted on a UAV** for pervasive (large area covering) sensing.
- **O3: Airborne detection of relevant molecular gases and fine particles** emitted into the atmosphere by human activities as well as natural processes by flying the sensor mounted on the modified UAV along well-defined trajectories.

Expected achievements and innovations

- Development/Optimisation and testing of a compact and cost-effective mid-IR supercontinuum sources against FLAIR requirements covering 2-5 mm and 8-12 mm wavelength
- Development/Optimisation of uncooled PbSe detector arrays and testing of microbolometer detector arrays
- Design, development and testing of spectrometer optics (multi-pass absorption cell, 2D spectrometer and imaging optics) adapted to the detector format, an air/gas handling system for integrated and real time measurements and dedicated control electronics.
- Adaptation/Optimization of a specific data processing algorithm for the extraction of relevant spectroscopic information
- Modifications of an UAV to fit the specifically designed sensor
- Flight tests of the integrated UAV/sensor system.
- Airborne selective detection of at least two molecular species emitted by known artificial sources
- Airborne detection of molecular species and fine particles under real-world conditions

Technical Approach

The sensor system proposed in FLAIR consists of an innovative 2D spectrometer system embarked on an UAV for pervasive air quality monitoring. A block diagram of the overall system is depicted in Figure 1.

The general working principle is the following: a broad spectrum generated by a specifically designed supercontinuum laser (A) will propagate through a multip ass cell (D) filled with air samples via a dedicated gas handling (pump) system (E). The pressure within the multipass cell will be maintained at a reduced pressure between 50-100 mbar, using pressure reduction valves, to be independent of the UAV altitude and keep a stable and reduced pressure broadening of the absorption lines and thus minimize spectral overlap with interfering gases. Two super-continuum sources will be developed within the FLAIR project, covering one of the two spectral windows, i.e. 2-5 µm and 8-12 µm, respectively:

- The first supercontinuum source, covering the 2-5 µm wavelength range, will be developed by NKT. The detection will be implemented using NIT's 2D PbSe array detectors. As both technologies will be developed for FLAIR based on already commercialized technology, the risk for this development is low. The expected detection sensitivity does respect current air quality regulations and guidelines.
- The second supercontinuum source aims at covering the 8-12 µm wavelength range and will be developed by DTU based on current advances in infrared fibre technology. Here, the detection will rely on 2D microbolometer arrays that are already commercially available as off-the-shelf components. While this development is substantially more risky than its 2-5 µm counterpart, this effort is motivated by the potential additional benefit that can be expected for FLAIR for certain molecules of interest in case of success.

The output spectrum with absorption features from different interrogated species is dispersed by a 2D spectrometer (C) based on the combination of a Virtually Imaged Phased Array (VIPA) and a conventional grating. The resulting 2D absorption spectrum will be imaged onto the detector array. The spectrometer optics (C) and deconvolution algorithms (F) will optimize the signal contrast either for a full spectrum (~2-5 µm bandwidth) or for a smaller spectral window with higher resolution. The respective trace gas absorption spectrum can be recorded in a single shot by reading the detector array. From the obtained absorption spectrum, a data processing algorithm (F) will provide information on the levels of pollutants present in front of the UAV.

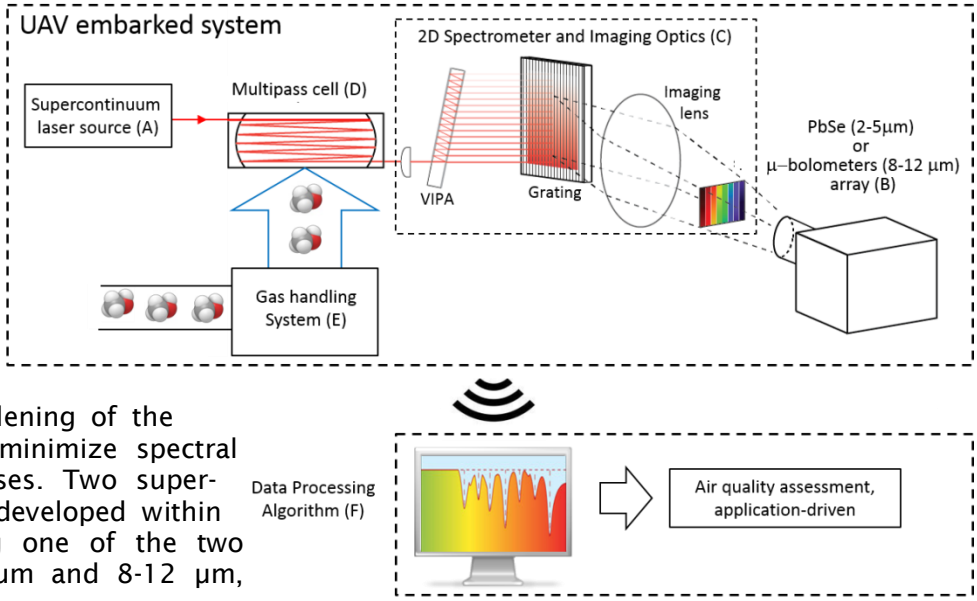

Figure 1 - Simplified block-diagram of the overall sensor system. Labels correspond to subsystems descriptions

Expected Impacts

Better and pervasive environmental sensing and a safer environment

- FLAIR is a breakthrough instrument and concept for broadband infrared spectroscopy with unprecedented combination of sensitivity, selectivity as well as short acquisition time at 1 second scale
- FLAIR will pave the road towards manufacturing similar instruments at highly competitive cost and hence for widespread application
- FLAIR allows for monitoring of air pollution (including fine particles) along highways and leak detection along pipelines over more than 150 km of length as well as above and around industrial facilities and oil platforms.

Secured and reinforced industrial leadership in sensing applications for the environment

- FLAIR ties into several of the breaking megatrends where drone carried sensors allow for the collection of unprecedented amounts of data to be fed into the internet of things and analyzed by big data processing to enable better monitoring thereby optimisation efficiency in a wide range of applications.