SIMULTANEOUS IDENTIFICATION AND QUANTIFICATION OF METHANE AT STAND-OFF DISTANCE BASED ON HYPERSPECTRAL MIR IMAGER

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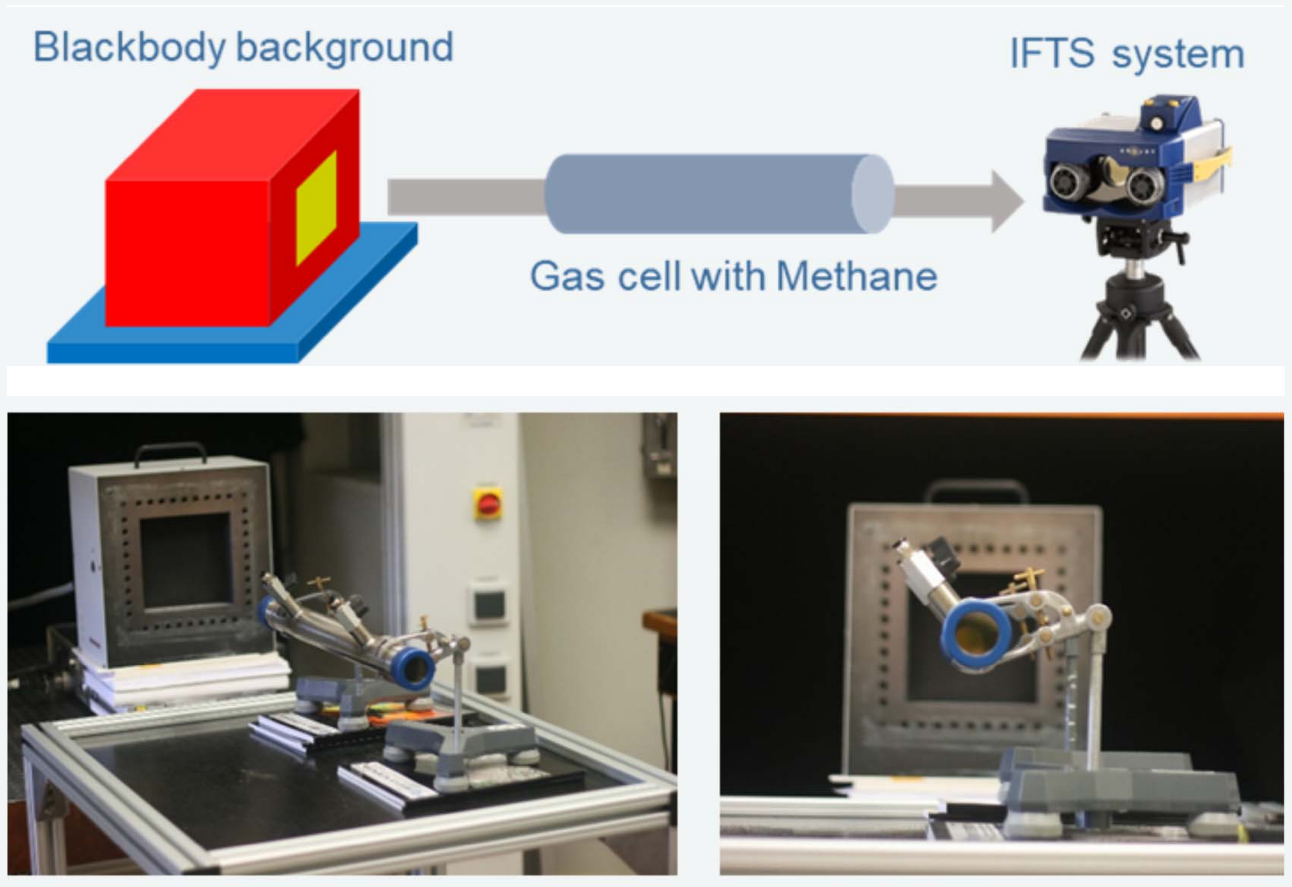
ABSTRACT

In an effort to reduce the human footprint on Earth's atmosphere on account of the world massive industrialisation, several renowned organisations as WHO have established air quality guidelines to control the emission values of air pollutants. One of the main greenhouse gases that contributes to global warming is methane, and an effective and reliable measurement method that allows simultaneous identification and quantification of this gas may have considerable interest for both industrial sectors and environmental authorities. One of the objectives of the EMPIR project 16ENV08 IMPRESS 2 is to develop hyperspectral measurement methods for the determination of emissions from biomass combustion sources in the pursuit of innovative on-line techniques which can be the basis of a forthcoming and unambiguous European regulation. Hyperspectral imaging techniques have come up as an interesting gas measurement method due to its many advantages like simultaneous large area information and quantification at safe distances from the pollutant source. These features turn these techniques into an outstanding option to precisely measure the emissions of real combustion systems like the previously mentioned biomass plants. In this poster, a measurement procedure to identify and quantify methane at stand-off distance is presented. The straightforward laboratory setup is described, as well as the obtained signature infrared spectrums which would be the foundation to concentration measurements, by using a transmittance fitting algorithm applied to spectra measured by an imaging FTIR system. The main advantage of the FTIR imaging is its high spectral resolution that allows to differentiate methane from other hydrocarbons whose MIR (mid-infrared) spectra are located in the same spectral range, as well as the spatial resolution that makes possible to image the pollutant clouds. The initial tests will use a gas cell with a defined path at room temperature, with the aim of extending measurements to high temperature leaks typical of anthropogenic methane sources.

MEASUREMENT SYSTEM—HYPERSPECTRAL IR IMAGER

The core of the measurement system to identify and quantify methane is an Imaging Fourier Transform Spectrometer (IFTS) that operates in the extended mid-infrared range (1.5 µm to 5.5 µm). This device has two main parts: A Michelson interferometer and an In-Sb array of detectors of size 320 x 256 pixels. As a result, an image with both spatial as well as spectral (up to 0.25 cm^{-1}) resolution can be obtained. The simple experimental setup for indoor laboratory measurements is shown next:



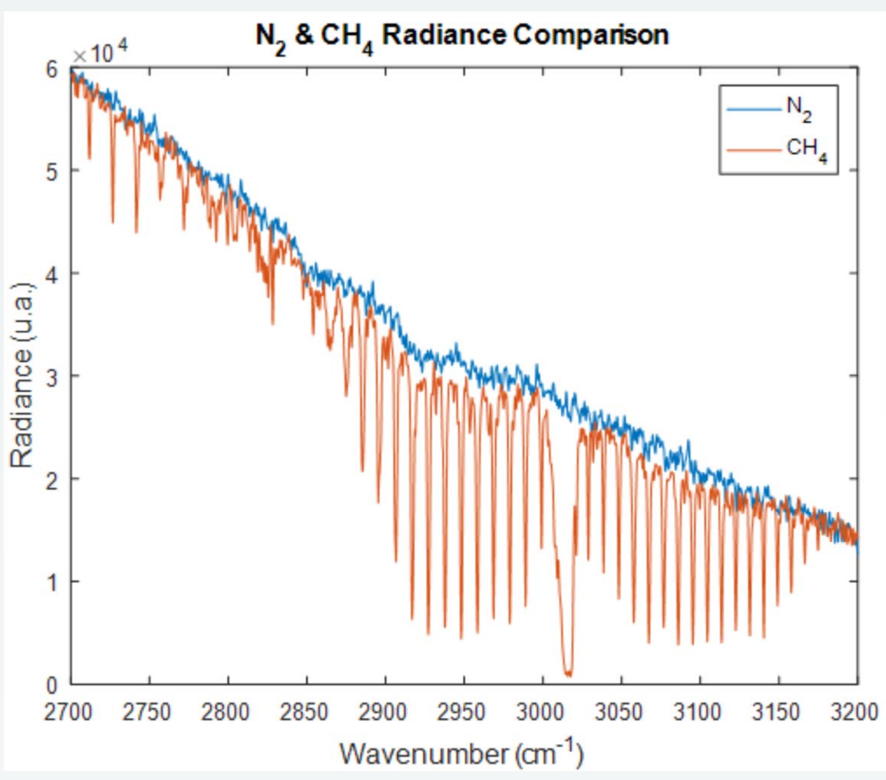
The radiometric model applied to the laboratory measurements takes the background radiation into consideration, i.e. the absorption (or active) mode is chosen. To acquire the information coming from the gas under test (mainly, identification and quantification) it is necessary to know the effect of such gas plume on the background radiation that passes through it. A similar measurement without gas plume provides the path transmittance, which is a quantity very sensitive to concentration changes of the target gas (methane, in this case) allowing to reduce possible error sources in this procedure like instrumental effects.

TRANSMITTANCE SPECTRA FOR METHANE

If the methane that is going to be measured is at room temperature and in active mode configuration (with high temperature IR sources as background like blackbodies) a transmittance value may be established based on measurements with and without methane plume through the optical path. The experimental transmittance value is the ratio of these two measurements subtracting the internal radiation coming from the IFTS, indicated as $B_{off}(v)$

$$\tau_g^{exp}(v) \equiv \frac{S_{g,abs}^{exp}(v) - B_{off}(v)}{S_{ref}^{exp}(v) - B_{off}(v)}$$

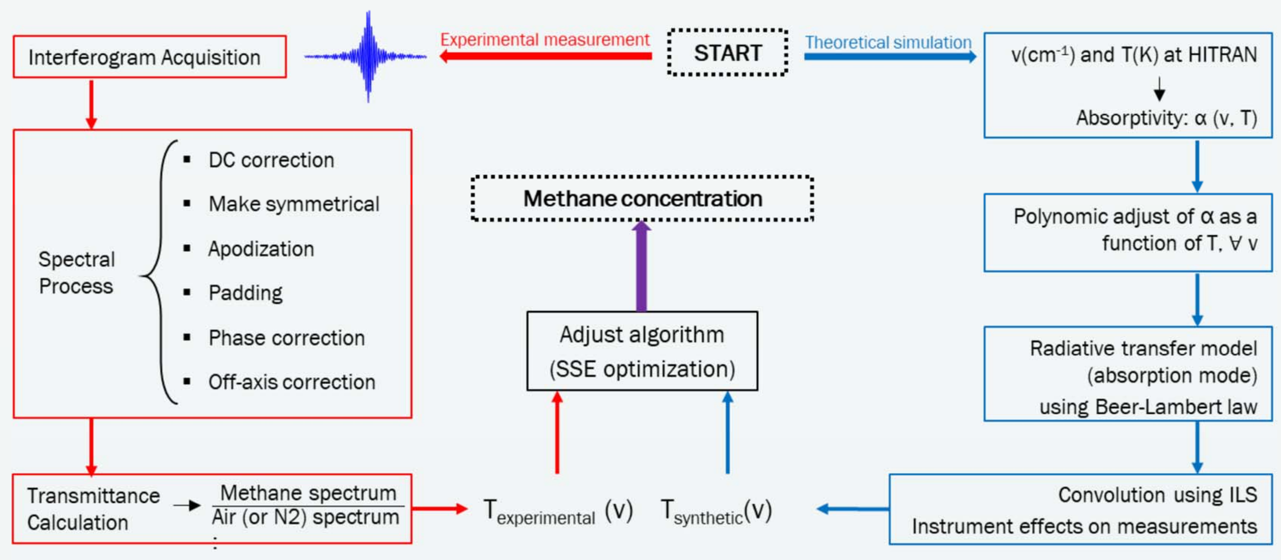
In order to successfully get the methane identification, it is important to know the spectral range where this gas has IR absorption. This range is located between 2700 cm^{-1} and 3200 cm^{-1} as it can be appreciated in the next figure where it is shown a comparison between two measurements with the same setup: One of them with N_2 at 100% and other with CH_4 at 15% carried out at LIR-UC3M facilities.



METHANE MEASUREMENTS AT LABORATORY

It is worth to outline the simplicity of the setup that includes: An extended high temperature blackbody as background surface, a long optical path gas cell (40 cm), two Zn-Se windows that allow a properly transmission in the target IR range and the previously mentioned IFTS with the adequate configuration to carry out a high-resolution measurement.

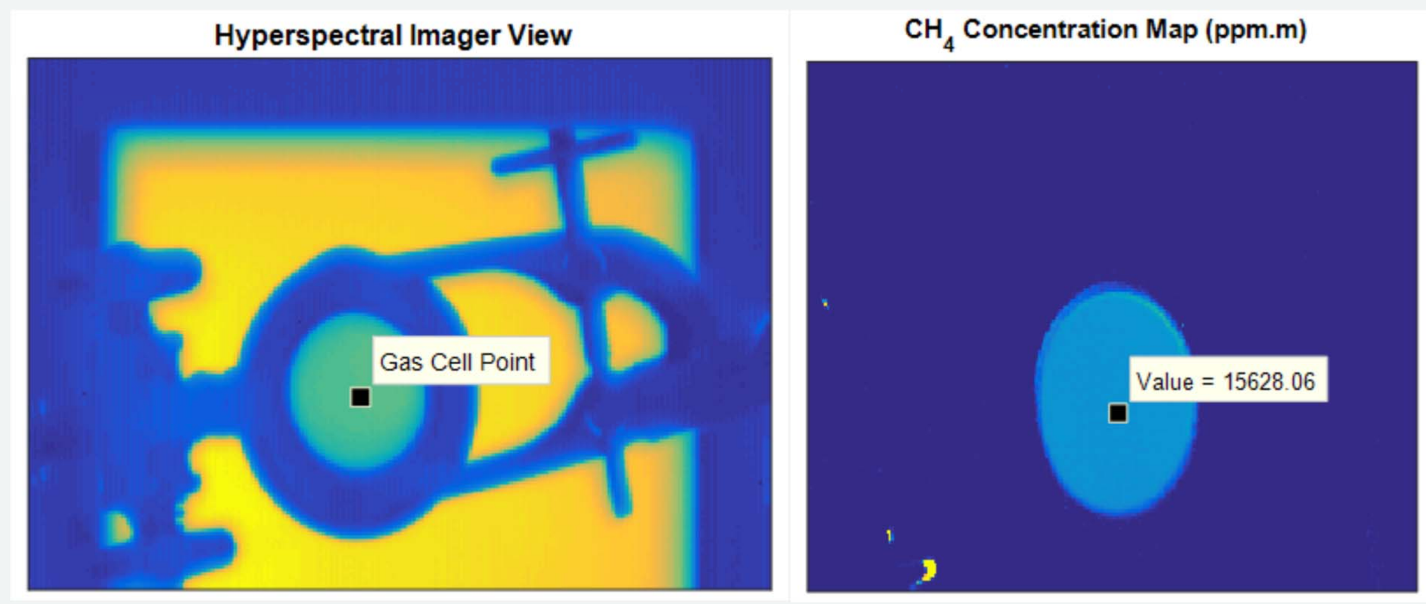
Once the whole measurement is completed, a series of processing stages are accomplished in order to determine methane quantification. The experimental measurement is compared with a theoretical transmittance spectra in such way that the concentration estimation could be estimated as precise as possible. A diagram of the procedure just described is illustrated next:



RESULTS — CONCENTRATION MAPS

Methane identification can be achieved by simple inspection of the spectrum in the region of the emission-absorption band, since these spectral features are highly specific (the so-called infrared fingerprint).

After the identification, gas concentration is going to be determined. The procedure indicated previously is conducted and as a result, values of column density (ppm.m) are obtained. These values can be related to methane concentration bearing in mind the optical path of the gas cell. Other physical property that can be retrieved with this procedure is temperature.



CONCLUSIONS AND FUTURE WORKS

- A high-performance procedure to retrieve methane concentrations at indoor facilities from MIR hyperspectral measurements has been developed. The information coming from the widely renowned HITRAN database has been a cornerstone in this retrieval from measured spectra.
- A simple measurement setup for methane at room temperature in absorption mode has been consolidated. The core of such setup is the IFTS, although in order to obtain accurate measurements a long and robust cell gas is very important as well as an extended and stable blackbody that ensure a high thermal contrast between the gas plume and the background.
- The information displayed on the obtained image shows the methane distribution on the measurement scene, which is very useful in cases where for instance a spatial analysis of the gas waste produced by a biomass plant is required. However, it is important to note that in real cases with methane at high temperatures, the radiometric model must be adjusted to a new case where the emission part of the gas plume has an important energy contribution.

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