Case Study 3

"This instrument has the uniqueness of a combined high spatial and spectral resolution, offering new prospects in emission monitoring from HAPs and GEO"

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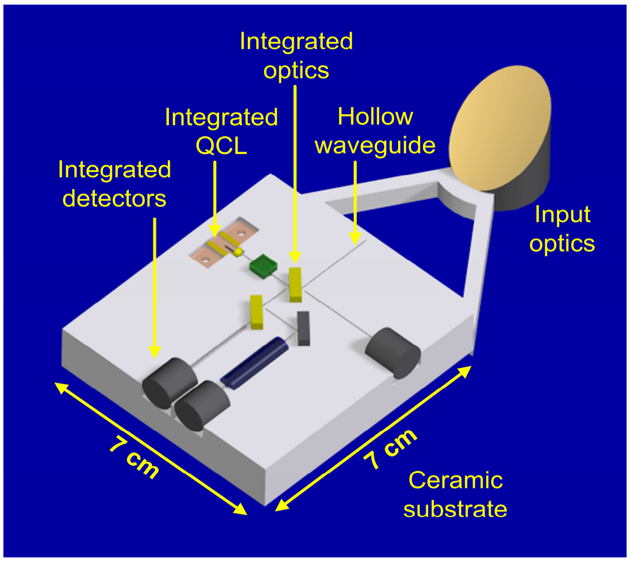
Ultra-high resolution spectroscopy leads to better quality remote sensing measurements of atmospheric composition

Industry
Vapour remote monitoring for environmental, security & defence and industrial applications
Challenges
Provision of high spectral and spatial resolution atmospheric monitoring, with high sensitivity for detection of minute amounts of atmospheric constituents
Solution
Unique high spatial resolution due to coherent detection
Altitudinal information from the high spectral resolution
Benefits
Global emission monitoring from space
Accurate assessment of emission sources
High resolution mapping of pollutant transport

Summary
This Laser Heterodyne Radiometer (LHR) is able to provide a unique combination of high sensitivity, high spatial resolution and high spectral resolution in a very compact package. It was one of the original projects to be spun out of the Centre for Earth Observation Instrumentation (CEOI), when it was created in 2007.

This passive thermal infrared radiometer uses a low-power, highly stable quantum cascade laser to down convert the spectral information of the incoming optical beam. Using the thermal infrared region of the spectrum, where a large number of molecular constituents exhibit very strong signatures, boosts the sensitivity of the detection and ensures very high spatial resolution of the coherent detection technique. The instrument can also benefit from the application of new hollow waveguide (HWG) technology.

The CEOI's vision is to develop and strengthen UK expertise and capabilities in EO instruments by developing key capabilities through the teaming of scientists and industrialists. Created as a result of joint support from the Natural Environment Research Council (NERC), the Technology Strategy Board (TSB) and industry, it is funded through the UK Space Agency. Space instrumentation makes valuable contributions in air quality monitoring, which is a vital goal for human health and for our understanding of climate change.



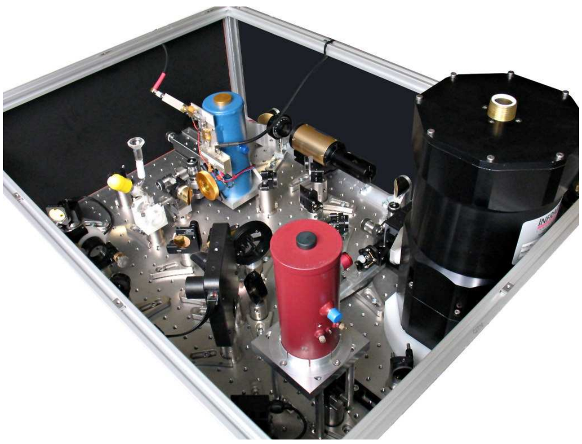
Challenge
A key challenge is to be able to undertake remote sensing from distant locations while keeping a very small field of view in order to cover a large Earth surface area with high spatial resolution**.** The LHR can achieve this from a variety of platforms, including sub-city scale observation from space or street scale observation from high altitude platforms (HAPs). This project also aimed to miniaturise the optical system by applying hollow waveguide (HWG) technology to the instrument to favour deployment on unmanned aerial vehicle (UAV) and/or microsatellites.

Solution

The seedcorn project for LHR was completed in March 2010. A key research and development achievement was the development of a hollow waveguide board for heterodyne mixing using QinetiQ's innovative approach to optical systems manufacture which is the optical equivalent to the electronic printed circuit board. Other technical milestones included the assessment of mixing performance using quantum cascade lasers and the implementation and demonstration of a full laser heterodyne spectro-radiometer based on a hollow waveguide mixing board.

A key breakthrough was the ability of the hollow waveguide to purify the mode structure of the QCL radiation and to virtually eliminate optical feedback to the laser. Additionally, the implementation of the hollow waveguide mixing board to the instrument has demonstrated superior stability and elimination of alignment problems. These are important outputs which ensure optimum sensitivity is maintained even if the instrument operates in harsh environments. The success of these outcomes has also laid foundations for the development of a miniature, fully integrated instrument suitable for deployment on small satellites, unmanned aerial vehicles and high altitude platforms. Additionally, beyond LHR, the technology has also potential applications in the wider field of quantum cascade laser based chemical sensors.

These technical milestones enabled the successful demonstration of heterodyne detection of gaseous absorption and emission using the hollow waveguide mixer. The first ever heterodyne measurements using the combination of a room-temperature laser and mid infrared detector were achieved.



Breadboard of the first generation of LHR

The LHR can undertake remote sensing from distant locations while keeping a very small field of view. So it is ideal from geo-stationary platforms for constant monitoring of the same location with spatial resolution on the ground of about 1 km squared.

Additionally, the LHR's potential for a uniquely narrow field of vision could be used for the monitoring of precise locations, to enforce CO_2 emission levels, for instance. Besides the spatial resolution, another advantage when monitoring a highly localised area is the instruments ability to focus on emissions release points before the plume disperses, which enhances detectibility and quantification accuracy.

Benefits

The LHR's sensitivity is approaching the ultimate detection limit of an optical instrument. Its high spectral resolution has the advantage of being able to identify the vertical atmospheric profile of atmospheric constituents. Because of this high resolution, the signals of the molecules coming from high pressure and those coming from low pressure can be discriminated.

The LHR project has successfully demonstrated an instrument that can provide real data, both in the lab and on the ground. It has also helped to demonstrate the usefulness of the HWG technique and there are plans to fully integrate the LHR into HWG, following further work on the miniaturisation aspects

An active version of this instrument is also being developed for the security and defence areas. Higher sensitivity is achieved in the region of below 100 parts per billion for remote sensing at a medium range (1-3 km). A recent atmospheric campaign showed the instrument is able to detect several molecules when using high frequency agility quantum cascade lasers.

Contact point for further information:

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