Science & Technology Facilities Council

Centre for EO Instrumentation

Technology Market Case Study No. 3 (Update 1)

Laser Heterodyne Radiometer

The Idea

Earth Observation has an ongoing need for technologies and instruments that are smaller, lower powered and cheaper, but with ever better performance. These requirements are difficult to reconcile unless radical new approaches are taken. The Laser Heterodyne Radiometer (LHR) is one such radical approach. It is a relatively new spectro-radiometer concept, being a passive sounder which uses a low-power solid-state laser as a local oscillator, and observes the unique spectral signatures of atmospheric constituents and pollutants in the mid infrared. The LHR has the performance advantages of high sensitivity, high spectral resolution, and high spatial resolution combined with relatively low complexity. The technology has potential for extreme miniaturisation, enabling it to compete with, and in some cases, exceed the performance of the costly, heavy and bulky Fourier Transform Spectrometers normally used in these applications and wavelength domains.

Support from CEOI

In order to help turn this idea into reality, CEOI provided funding to a team led by RAL-Space (part of the Science and Technology Facilities Council) to take the technology from TRL 2 to TRL 5-7. The work included:

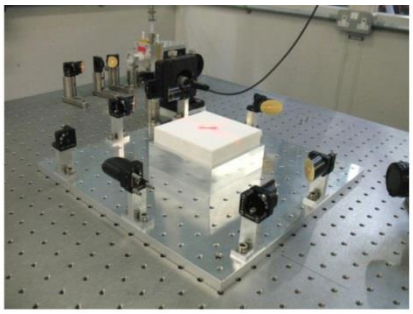
- Initial performance / technology improvement and the first proof of concept with the core instrument implemented in a hollow waveguide;
- Fibre, detector and active component integration in the hollow waveguide to create a fully encapsulated miniature LHR for EO;
- Development of instrument simulator, analysis of performance, and mission aspects;
- Experiments with a CO_2 specific LHR in solar occultation mode to show science benefits.

The Result

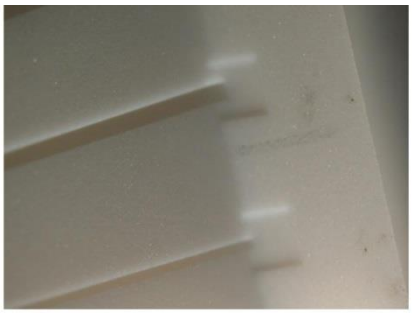
The results have clearly established that the LHR technology holds the promise of highly miniaturised instruments for airborne and space deployments, and is highly suitable for atmospheric analysis, planetary exploration, and astronomy. Six refereed journal papers and 22 conference papers have been published, 1 CASE studentship undertaken, and 5 postdoctoral students trained in the research and development associated to LHR.

Wider Deployment

The Laser Heterodyne Radiometer provides a core sensing technology for the ESP-MACCS mission, selected by ESA as a Scout Mission. The main scientific objective is to understand and quantify processes in the Upper Troposphere and Stratosphere (UTS), study its variability and contribute to trend analysis on its composition and its effect on climate. ESP-MACCS focuses on the observation of the tropical and sub-tropical



A hollow waveguide integrated beam mixer under studies in the lab



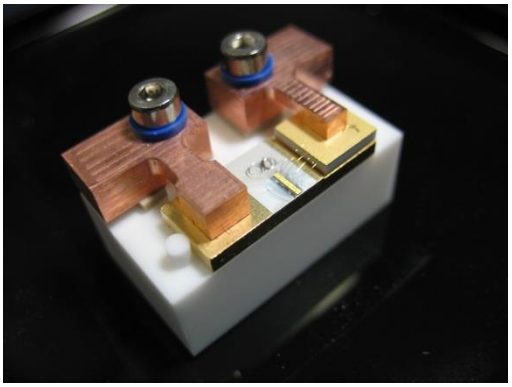
Zoom on squared hollow waveguides

latitudes, so as to observe key radiatively important gases (H_2O, CO_2, CH_4, O_3, N_2O) as well as aerosol and air mass.

ESP-MACCS aims to provide the specific observational capability of a limb-sounding mission required to address a number of highly relevant scientific questions, namely:

- how water vapour in the UTS responds to and interacts with climate change
- how the chemical composition in the UTS responds to increasing emissions
- how estimates of surface greenhouse gas (GHG) emissions can be improved through better knowledge of GHG and ozone in the UTS
- how climate change affects stratospheric ozone and its recovery.

The space segment consists of a constellation of three 12U cubesats, each carrying three Thermal InfraRed (TIR) spectrometers (HIROS) as the primary payload and a Visible Near IR (VNIR) Hyperspectral Solar Disk Imager (HSDI) as secondary instrument payload.



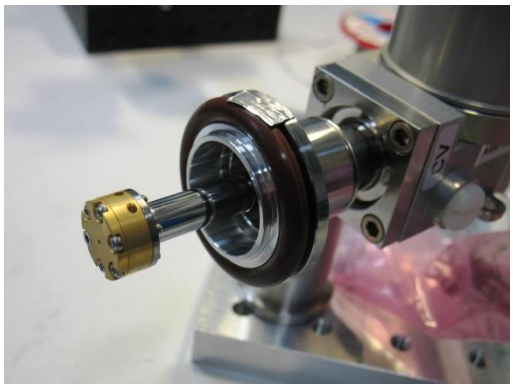
Quantum cascade laser local oscillator at the core of the LHR. The laser dimension are 0.5x0.3x3 mm3

The Future

A smallsat mission for in orbit demonstration, and airborne deployment in advance of larger operational missions are the key steps to mature the technologies. Considering wider exploitation, an SME has been created for exploitation of LHR IP (Mirico Ltd). MIRICO is currently working on two laser sensing products adressing medical, industrial and environmental markets. Development of the LHR technologies has also led to the concept mid infrared hyper spectral heterodyne lidar, currently exploited in the field of security and defence via an IP license to a UK SME.

CEOI

The Centre for Earth Observation Instrumentation (CEOI) works with UK organisations, both academic and industry. Its objective is to develop a world leading, internationally competitive, national Earth Observation (EO) instrument and technology R&D capability through the teaming of scientists and industrialists. The CEOI is funded by the UK Space Agency with parallel technology investment from industry.



Miniature 80K blackbody cavity mounted on a tactical close cycle cooler for LHR emission experiments.

Further information about this technology and others funded by the CEOI can be found at www.ceoi.ac.uk. You can also contact the CEOI Director, Dr Chris Brownsword, Tel: +44 (0)7825762527, Email: cbrownsword@qinetiq.com.