Technology Market Case Study No. 6

Terahertz Multichannel Radiometer Using Stabilised 3.5-THz Quantum-Cascade Laser Local Oscillators and Schottky Diode Technology

The Idea

Advances in satellite remote-sensing measurements of the constituents of the atmosphere have substantially increased our knowledge of atmospheric composition over the last decade. For instance, relatively localized measurements of the mesosphere and lower thermosphere (MLT) region of the Earth's atmosphere from sensors on sounding rockets provide an important indicator of global climate change. Nonetheless very limited global measurements of key atmospheric species have been made directly by previous satellite missions.

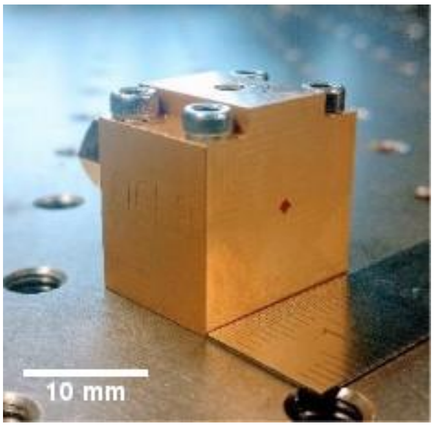
These global measurements with high spectral resolution of the important MLT atmospheric species, particularly atomic oxygen and hydroxyl radicals are highly challenging. The LOCUS mission concept (**L**inking **O**bservations of **C**limate, the **U**pper-Atmosphere and **S**pace-Weather) uses a novel and breakthrough limb sounding, multi-channel radiometer operating in the terahertz (THz) spectral range (0.8 – 5 THz) that addresses this challenge. However, significant improvements in the stability of the THz radiometers are required for the instrumentation to achieve the technical performance necessary for future space mission opportunities. Frequency stability of the quantum-cascade lasers (QCL), which are used as precision local oscillators (LO) in the instruments, is the factor that currently limits the resolution of the spectra that can be acquired. Improving this stability will give much better specificity of the measurements (i.e. ability to distinguish between different gas species), and better frequency-noise performance.

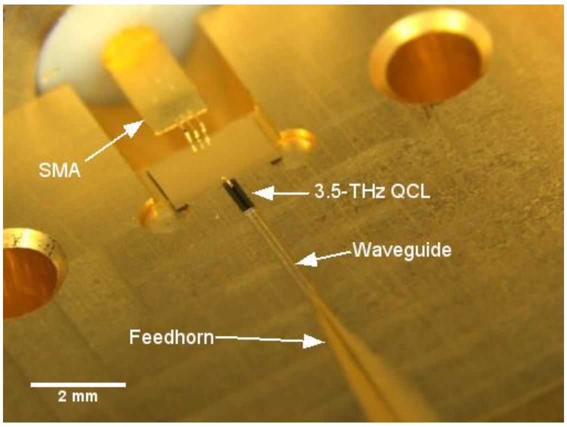
Support from CEOI

Developments of the LOCUS radiometer to take it to a higher technology readiness level (TRL) were funded by CEOI, resulting in a breadboard optics and support infrastructure payload (in a representative thermal environment) with data simulation models. Most recently, CEOI has funded a project led by the University of Leeds to stabilise the 3.5-THz quantum-cascade laser (QCL) local oscillators (LOs) using Schottky diode technology. This project is a key element in preparing the radiometer for flight readiness. Further work is being evaluated to stabilise the 4.7-THz channel and add a power modulator/stabiliser to give a big stability/noise-performance boost.

The Result

The photographs show: (left) the 3.5-THz QCL LO mounted into a ~cm^3 sized enclosure, containing a precision micro-machined waveguide, diagonal feedhorn and electronic / thermal interfaces: (right) the interior view of the block, showing the key components.





To achieve its technical goal of the first space-compatible (compact, integrated, robust and low-power) subsystem for stabilising the frequency of a compact 3.5-THz laser source, the project constructed a harmonic mixer based on Schottky diode technology, and coupled this to a ~500-GHz LO. The project also developed a precisely tunable 3.5-THz quantum-cascade laser and, in collaboration with UKRI–STFC RAL Space, integrated the LO/mixer system with a stabilisation and control loop to lock the QCL emission frequency to < 1 part-per-million precision.

Wider Deployment

Stable THz technologies have a wide range of future applications in diverse disciplines including planetary science, astronomy, spectroscopy, security and communications. Examples include:

Technology	Applications	Customers
THz diodes, components and receivers.	Remote sensing, short range comms, medical sensing, non-destructive imaging	Military and civil last-km telecoms, local area networks, NHS, auto-industry, agri-sensing.
THz sources (QCL and harmonic)	Remote sensing, short range comms, medical sensing, non-destructive imaging	Military and civil last-km telecoms, local area networks, NHS, auto-industry, agri-sensing.
THz Systems	Remote sensing, short range comms, medical sensing, non-destructive imaging. EO, astronomy, space weather and climate monitoring.	Military and civil last-km telecoms, local area networks, NHS, auto-industry, agri-sensing, academic, meteorological organisations.

The Future

By exploiting cutting-edge UK THz heterodyne receiver and spectrometer technology, the LOCUS limb sounder could provide, for the first time, global height-resolved atomic oxygen distributions over several years to examine inter-annual variability as well as seasonal variations. This will significantly enhance our understanding of the upper atmosphere. In addition, LOCUS will measure nitric oxide (NO), produced by charged particles in the lower thermosphere and an indicator of space weather; the hydroxyl radical (OH), which is central to mesospheric chemistry; CO, an excellent tracer of mesospheric transport; molecular oxygen (O_2) and ozone (O_3); humidity (H_2O); and temperature down to the stratosphere.

LOCUS will provide the most powerful suite of observations with which to investigate chemical, radiative and dynamical processes controlling the composition and thermodynamics of the upper atmosphere and links to the middle/lower atmosphere and climate. Achievement of this will place the UK in a position of scientific and technical leadership with respect to MLT climate studies and in the development of world leading THz technologies for a wide range of applications.

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. The CEOI is funded by the UK Space Agency with parallel technology investment from industry. Its key aim is to develop UK capabilities in future space instrumentation for EO through the teaming of scientists and industrialists.

Further information about this technology and others funded by the CEOI can be found at ceoi.ac.uk. You can also contact the CEOI Director, Professor Mick Johnson: Tel: +44 (0)1438 774421 or email: mick.johnson@airbus.com.