Gas sensing with integrating spheres

Use of integrating spheres as long pass gas cells

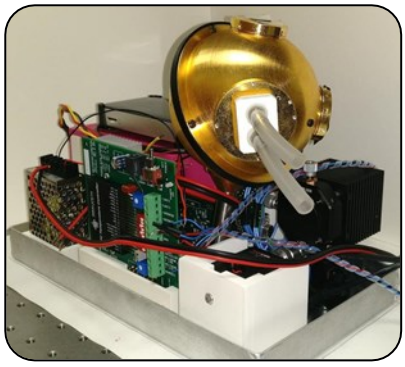
- High sensitivity gas measurements often use long path, multipass gas cells, which can be difficult to align and require careful engineering to maintain alignment in field conditions.
- Integrating spheres have a diffusely reflective inner surface, which scatters the light over multiple random paths within the cell. This provides robustness against misalignment caused by vibration, g-loading or thermal expansion.
- Engineering photonics has been developing integrating spheres as potential gas cells for use in challenging environments.

Our approach

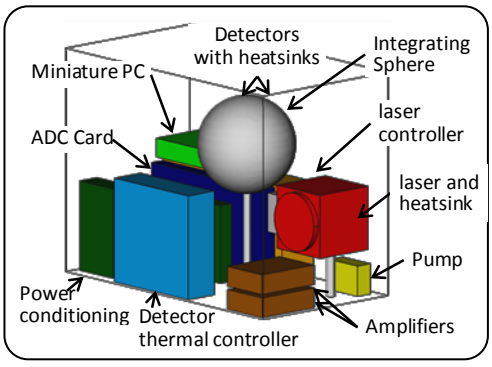
We have solved a series of technical hurdles for this technology:

- Minimised laser speckle noise and laser feedback, both of which can be performance limiting [1].
- Accurate mean effective pathlength and analytical expression for the nonlinearity in pathlength at high gas concentrations, allowing accurate calibration [2].
- The mean pathlength depends critically on the internal reflectivity, so calibration can be affected if the sphere becomes dirty in use. We have developed in-situ calibration techniques that avoid this problem [3,4].

Implementation



(a)



(b)

(c)

(a) Sub ppm methane detector using a mid IR laser and integrating sphere. (b) 3D model of instrument. (c) Installation on a Scottish Aviation Bulldog (owned and operated by Cranfield University) for atmospheric measurements.

Further information:

[1] D Masiyano, J Hodgkinson and R P Tatam, "Gas cells for tunable diode laser absorption spectroscopy employing optical diffusers. Part 2: Integrating spheres", *Applied Physics B*, **100** , pp. 303-312, 2010.

[2] J Hodgkinson, D Masiyano and R P Tatam, "Using integrating spheres as absorption cells: pathlength distribution and application of Beer's Law", *Applied Optics* **48**, pp. 5748-5758, 2009.

[3] S Bergin, J Hodgkinson, D Francis and R P Tatam, "Integrating cavity based gas cells: a multibeam compensation scheme for pathlength variation", *Optics Express* **24**, pp. 13647- 13664, 2016.

[4] S Bergin, J Hodgkinson, D Francis and R P Tatam, "In-situ pathlength calibration for integrating cavities", UK patent application GB1506609.5, 2015.

Centre for Engineering Photonics

Centre for Engineering Photonics

About Cranfield University

Cranfield is an exclusively postgraduate university that is a global leader for transformational research in technology. Cranfield is focussed on the specialist themes of aerospace, defence and security, energy and power, environment and agrifood, manufacturing, transport systems, and water.

Cranfield has the largest number of engineering and technology postgraduates in the UK, awards over five percent of the UK's engineering and technology PhDs each year and currently works with over 1,500 companies and organisations worldwide.

Cranfield is ranked in the top five of UK universities for commercial research income, with 81% of Cranfield's research classed as world-leading or internationally excellent by REF (Research Excellence Framework, 2014). Cranfield University was formed in 1946 as the College of Aeronautics, the first postgraduate college of its kind.

The Centre for Engineering Photonics

Engineering Photonics at Cranfield is recognised internationally as a leading centre for optical sensing and instrumentation, which, since its inception in 1989, has been led by Professor Ralph Tatam. Engineering Photonics undertakes research ranging from blue skies concepts to the development of prototype instrumentation that is used by us and our academic and industrial collaborators in real environments. Further information about the Centre and a full list of publications and links can be found at openoptics.info.

Research areas

Engineering Photonics applies advanced photonic technologies to solve challenging measurement problems. Our research underpins measurements across a wide range of industrially important areas such as: aerospace, healthcare, manufacturing, transport, automotive, environment and agrifoods. We work in collaboration with academia, SMEs and major international companies both nationally and internationally.

Technologies

Optical interferometry; optical fibre sensor technology including interferometry, FBGs and LPGs; optical imaging and image processing; optical gas sensing; speckle interferometry and metrology.

Contact:

Professor R. P. Tatam
E: r.p.tatam@cranfield.ac.uk
Centre for Engineering Photonics
Cranfield University
Cranfield, MK43 0AL, UK
www.cranfield.ac.uk/centres/engineering-photonics-centre

Centre for
Engineering Photonics