Case Study 2

"This is a genuinely disruptive technology which can improve performance and reliability as well as cut manufacturing costs"

Prof. Mike Jenkins
Project Lead
QinetiQ

Hollow waveguide optical PCB technology provides new manufacturing solutions

Industries
Space, Manufacturing, Environmental, Health, Defence, Telecoms and Research sectors.

Challenges
To improve on conventional manufacturing processes which use multi-axial mounts and manual alignment techniques, leading to systems that are bulky, heavy, sensitive to misalignment and expensive to manufacture

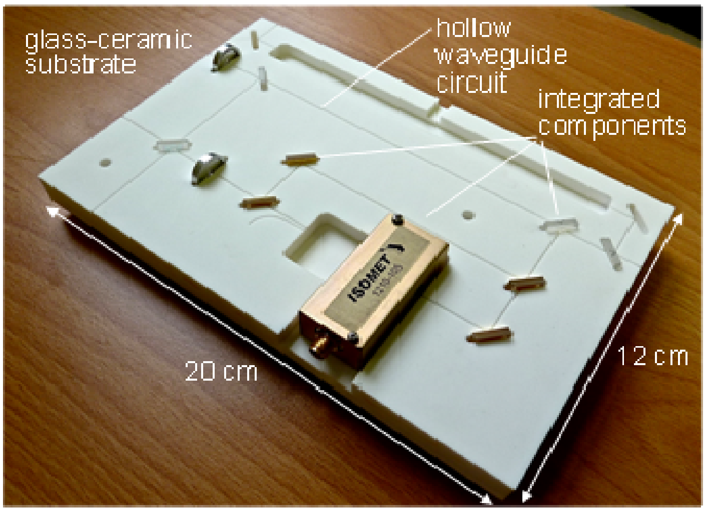
Solution
Optical printed circuit board (PCB) approach using hollow waveguides to guide radiation through circuits of optical components in precision alignment slots in a common motherboard.

Benefits
Reliable and durable Instruments that are more compact and rugged, have improved performance, are robust to misalignment and are cheap to manufacture

Summary
Hollow waveguide (HWG) based optical circuit board technology (the optical PCB) was invented by QinetiQ. In collaboration with the University of Leicester, University College London and the Centre for Terrestrial Carbon Dynamics, the technology was further developed to demonstrate a miniaturised differential absorption lidar (DIAL) subsystem for the measurement of atmospheric carbon dioxide.

The development work was funded by the Centre for Earth Observation Instrumentation (CEOI). CEOI has the goal of supporting and strengthening UK expertise and capabilities in Earth Observation (EO) instruments with the aim of better positioning UK's scientists and industrialists to win future international space programmes. Originally created with support from the Natural Environment Research Council (NERC) the Technology Strategy Board (TSB) and industry, CEOI is currently funded through the UK Space Agency.

Challenge
The manufacture of laser and electro-optic systems often relies on mounting each component in a multi-axial alignment mount and then using manual alignment techniques to achieve the desired performance. This leads to systems that are bulky, heavy, sensitive to optical misalignment and expensive to manufacture.



A high performance, compact, rugged, 2 µm DIAL subsystem for measurement of atmospheric CO_2 based on a HWG optical PCB approach.

The maintenance of optical alignment is also challenging in harsh vibrational and thermal environments.

Solution
The solution to the problem is the optical equivalent of the electronic printed circuit board. Hollow waveguides are formed in the surface of a dielectric substrate that provides the same function as the copper tracks on an electronic PCB in guiding light through a circuit of optical components, each of which is mounted in a precision alignment slot.

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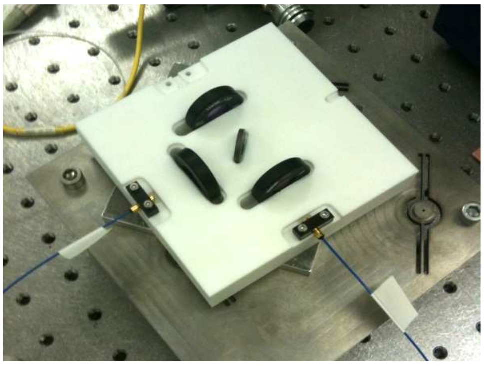
In one approach to the optical PCB, computer controlled milling techniques are used to create section alignment slots for the components and square channels for the hollow waveguide circuit. A lid caps the substrate forming the upper walls of all the waveguides. In an alternative approach, deep reactive ion etching (DRIE) in conjunction with silicon substrates facilitates the formation of much smaller cross-section hollow waveguide circuits and alignment features which are compatible with micro-optical components. In this manner a miniaturised version of the approach is feasible for producing optical PCBs the size of SIM cards.

In conjunction with automatic pick-and-place equipment, the approach will lead to high volume, low cost production of a very wide range of integrated optic laser and sensor systems. The use of hollow waveguides in the optical circuit board has a number of advantages compared with solid core waveguides. The hollow waveguides have very broad waveband transmission characteristics and can handle much higher powers than solid core waveguides. The fact that there is no refractive index step to bridge makes discrete component integration easy. The hollow core can also provide the basis of sample cells for the analysis of gases and liquids using absorption spectroscopy and interferometric techniques.

Hollow waveguide optical PCBs provide an integration platform for a very wide range of discrete optical and micro-optical components, including, beam splitters, lenses, wave plates, polarisers, lasers, amplifiers, detectors, and modulators. Additionally, fibre optic interfacing extends the range of component functionality and applicability.



An example of a fibre interfaced hollow waveguide coherent mixer subsystem for a 1.55 µm lidar currently being developed at QinetiQ under CEOI funding

This enables the realisation of compact, rugged, low cost sensors for a diverse range of applications in the fields of space, industrial, environmental, health, security and defence, including:

- Spectrometers, interferometers and laser heterodyne radiometers for earth science and planetary exploration
- Laser radars (including lidar-on-a-chip based on hollow silicon technology) for space, environmental, defence and homeland security applications
- Hollow waveguide lab-on-a-chip technology for portable gas and fluidic sensors for atmospheric and pollution monitoring, process control, in-vivo and diagnostics and drug discovery.
- Gas sensors for environmental and industrial monitoring and health care
- Fluidic sensors for pollution monitoring and health care
- Telecomms modules based on micro-optical components integrated together on fibre pig-tailed hollow waveguide optical circuit chips

Benefits

The HWG technology has been applied to a Laser Heterodyne Radiometer, with potential applications in Earth observation, space science and terrestrial sensing. It has been further developed to provide solutions to current optical circuit manufacturing techniques, overcoming problems of bulkiness, misalignment, and therefore reducing manufacturing costs.

The advantage of the hollow waveguide optical PCB is that it facilitates photonic and laser systems that are compact, rugged, have improved performance, are robust to misalignment in adverse environments and have improved reliability and durability. In this manner it provides an enabling technology that can underpin and stimulate growth in the UK's photonics and laser industries, particularly those related to space applications.

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