High Sensitivity Gas Sensing Using Hollow Core Photonic Bandgap Fibres Designed for Operation at mid-IR Wavelengths

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High sensitivity gas detection is of great interest in the fields of security, medical diagnostics, and environmental and industrial monitoring. Optical absorption methods are well established and the use of fibre based devices has advantages in terms of small footprint, relatively low cost, immunity to electromagnetic interference and potential for distributed sensing; however, they generally suffer from poor sensitivity due to the difficulty of achieving an efficient spatial overlap with gas analytes. The use of Hollow Core Photonic Bandgap Fibres (HC-PBGFs), i.e. a special type of optical fibres that guide light in a hollow core through bandgap effects, enables an extremely efficient sensing platform due to close to 100% overlap between the light and gas in the hollow core and the possibility for long interaction lengths. Furthermore, HC-PBGFs can be designed to operate at mid-IR wavelengths, where conventional fibres cannot operate. We recently demonstrated HC-PBGFs with loss as low as 0.05dB/m at 3.3µm and more than 100nm 3dB transmission bandwidth [1]. The capability of accessing the mid-IR wavelengths is critical for gas sensing, as the fundamental vibrational transitions of many gas molecules (for instance those containing C-H, O-H, N-H groups) fall in this spectral region. By detecting the fundamental absorption bands as opposed to their much weaker overtones in the near IR often targeted by fibre based sensor systems, substantially higher sensitivity can be achieved [2]. Additionally, mid-IR HC-PBGFs have relative large core diameters (~50 µm), which is beneficial in allowing a comparatively faster gas filling and evacuation.

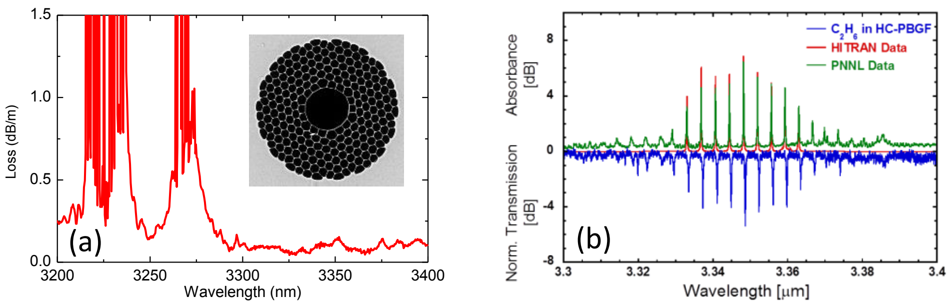

Figure 1: (a) The loss spectrum of a typical mid-IR HC-PBGF (Inset shows a SEM image of the fibre), (b) Normalized transmittance of a 5.7m long section of fibre, filled with 50 ppm C_2H_6 in N_2, compared to HITRAN and PNNL data.

In this work we present recent gas sensing results obtained using newly developed mid-IR HC-PBGFs. A high intensity, ultra-broad mid-IR supercontinuum laser and an optical spectrum analyser were used to probe the gas absorption lines achieving values of wavelength resolution and signal to noise ratio unprecedented for a fibre based system [2]. Here we report measurements of Acetylene at 3µm, Methane at 3.25µm and Ethane at 3.35µm (Fig 1(b)). We obtained as high as 0.9ppmV sensitivity limit using a relatively simple interrogation arrangement, with very substantial scope for improvement. The results show the potential of the proposed approach for high sensitivity gas sensing and its suitability for a range of real life application is being evaluated.

1. N. V. Wheeler, et al. "Low-loss and low-bend-sensitivity mid-infrared guidance in a hollow-core-photonic-bandgap fiber," Opt. Lett., vol. 39, no. 2, pp. 295–8, Jan. 2014.
2. M. N. Petrovich, et al. "High sensitivity methane and ethane detection using low-loss mid-IR hollow-core photonic bandgap fibers,"Proc. SPIE 9157, 23rd International Conference on Optical Fibre Sensors, 91573P