FIBRE OPTICAL SENSOR FOR C_2H_2 GAS USING PERMANENTLY SEALED GAS FILLED PBGF REFERENCE CELL

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Introduction

It is of great importance to develop gas sensing techniques which are selective, quantitative, fast-acting and not susceptible to poisoning. Spectroscopic optical gas sensors, especially those capable of remote sensing over optical fibres, are highly attractive for fast real-time detection and measurement of many gases [1]. One highly selective optical gas sensing method is correlation spectroscopy (CS) [2], in which a reference sample of target gas is held fixed within the interrogation system to act as a spectral reference, and is then compared with the spectrum of the test gas to obtain the measurement. We have suggested that a Photonic Bandgap Fibre (PBGF), filled with the target gas, provides a very effective and compact reference, with a clear advantage over traditional linear cells, which are bulky, intricate, fragile, difficult to align and expensive [3].

In our previous work the PBGF was held in custom gas-tight holders, which allowed filling by free diffusion from the fibre endfaces, as well as free space input and output optical coupling. For the first time in this sensing configuration, we now report an improved and more compact reference cell, in which both ends are arc fusion spliced to standard SMF-28 after filling with the target gas. We present results from our CS sensor for C_2H_2 (acetylene), measure its sensitivity to C_2H_2 and its cross-sensitivity to CO_2.

Method

We have fabricated three reference cells, each at atmospheric pressure, of 15cm, 40cm, and 1m length. As C_2H_2 gas has convenient P and R branch absorption bands in the region 1510-1550nm (Figure 1), our sensor was constructed from standard telecommunications components, as shown in Figure 2. Our light source was broadband ASE from an erbium-doped fibre, pumped with a 100mW 980nm laser diode. This light was alternately switched between two arms, one containing our spliced reference cell (referenced arm), the second containing no reference cell (non-referenced arm). The resulting arms were then mixed using a 3dB fibre coupler. One output branch from the coupler was directed to a monitor photo-diode, whilst the second output (the ‘probe light’) was directed through our measurement cell (standard bulk linear cell of 14cm path length), which provided interaction with test gases. Measurements were made by computing the ‘arm transmission ratio’, i.e. the ratio between the probe light transmitted through the measurement cell when the referenced and non-referenced arm was selected. This is an improvement on our previous CS work, which required on-line adjustment of the source power to balance the probe power from both arms.

Results

We have measured the response of our system to C_2H_2 (Figure 3) and have measured its noise limited sensitivity to be 100ppm, using our 4s averaging time (at 1000ppm C_2H_2 concentration). This is a 17x improvement compared with our previous work[3]. For the first time, we have measured the cross-sensitivity of our sensor to CO_2, (which has absorption lines overlapping with our source output spectrum, Figure 1), to be equivalent to 150ppm C_2H_2 for 100% CO_2. Using the same source and optics to make broadband absorption measurements (i.e. without CS), we measured a 450ppm cross-sensitivity to 100% CO_2, nearly three times worse than the CS value. Our results compare favourably with theory.

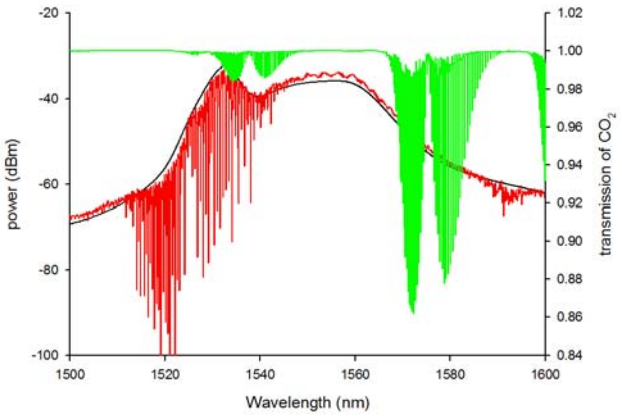

Figure 1 Useful spectra: probe light spectrum with non-referenced arm selected, measured, 10pm resolution (black line), probe light spectrum, referenced arm selected, measured, 1m reference cell selected, 10pm resolution (red line) and CO_2 transmission, 1m path length, atmospheric pressure, 25ºC, modelled, 94ppm resolution (green line).

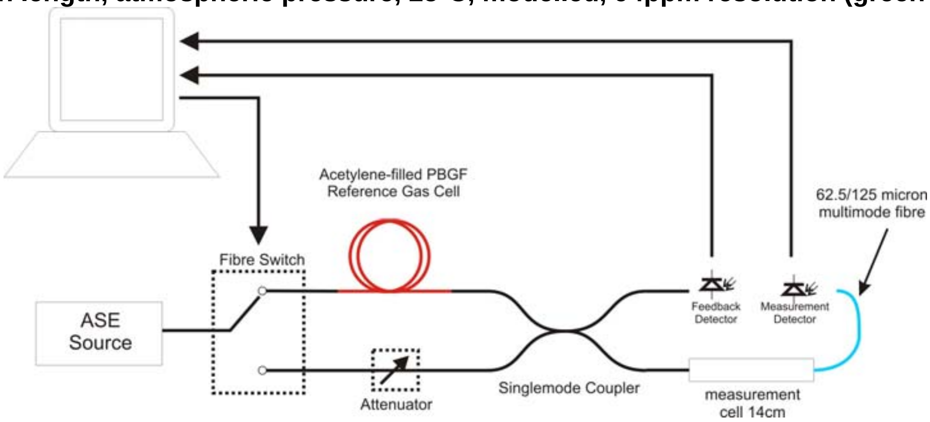

Figure 2 CS sensor schematic using PBGF reference cell

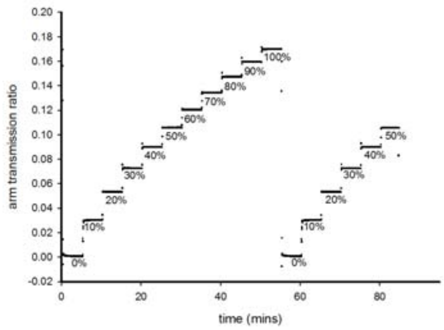

Figure 3 Arm transmission ratio, logged as various concentrations of C_2H_2 were directed through the measurement cell. (4s averaging time, 1m reference cell selected)

1. Moseley, P.T., J.O.W. Norris, and D.E. Williams, *Techniques and Mechanisms in Gas Sensing*. 1991: IOP publishing.
2. Dakin, J.P. and H.O. Edwards, *Progress in fibre-remoted gas correlation spectrometry.* Opt eng, 1992. **31**: p. 1616-1620.
3. Brakel, A.v., et al. *Correlation spectroscopy gas sensor with photonic band-gap fibre reference cell*. in *Europtrode VIII*. 2006. Tubingen.