A Method to Extend the Absorption Length for Optical Fiber Gas Sensor

Kuanglu YU[1, 2, 3], Chongqing WU*[2], Yao ZHAO[1], Chao LU[3], Chaonan PAN[2], and Zhi WANG[2]

1. Institute of Information Science, Beijing Jiaotong University, Beijing 100044, China.
2. Key Lab of Luminescence and Optical Information, Ministry of Education; Institute of Optical Information, Beijing Jiaotong University, Beijing 100044, China,
3. Photonics Research Center, Department of Electronic and Information Engineering, the Hong Kong Polytechnic University, Hong Kong.
**cqwu@bjtu.edu.cn*

Abstract: The Dual Loop Optical Buffer was explored in sensing. Not only could each probe's absorption length, hence its sensitivity, be flexibly adjusted and boosted, but also the probes' numbers can be changed according to needs.

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Introduction

The absorption spectrum method is a very important technique for the fiber optics gas sensors. The key to improve the detection sensitivity is to extend the absorption length of the probe. Ordinary methods extend the absorption length by the utilizations of White-Cavity, Herriot-Cavity or the Cavity Ring-Down Spectroscopy Method. For White-Cavity and Herriot-Cavity methods, it is necessary that two perfect reflect optical mirrors must be precisely aligned, it is, however, very difficult to achieve and even harder to maintain technically. For the Cavity Ring-Down method, although precisely alignment is not needed, the cycles of ring-down is relatively restricted because of the large coupling lose or the loop lose. To the authors' knowledge, for those usual fiber optics gas sensors available, the detection sensitivities are fixed corresponding to the gas gap in the cell. However, in order to get a larger dynamic range, people may want to change the sensitivity of the probe accordingly from time to time, which would be quite complicated or rather not possible,

In the past decade, the Dual Loop Optical Buffer (DLOB) based on collinear 3x3 fiber coupler was proposed and is now being developed intensively, whose buffering cycles could be more than sixty [1]. The DOLB's characteristics indicate it may be a nice candidate to solve the problems mentioned in the previous paragraph. In this manuscript, a new method based on the DLOB to flexibly extend the absorption length of gas sensor is proposed. Firstly, the principle of DLOB is introduced. And then the method to increase the buffering cycles is proposed, by which the absorption length is greatly lengthened for dozens of times, which could also be adjusted according to needs. Finally, the test result of buffering the signal in the DLOB was given.

Gas sensor with the Dual Loop Optical Buffer

The Dual Loop Optical Buffer (DLOB) concept and experiments were initially carried out by Wu and et al [2-4]. The DLOBs, which have advantages such as, compact, inherently stable, and are capable of buffering double wavelength lights for one up to dozens of loops at the user's will, are composed of a Semiconductor Optical Amplifiers (SOA), one paralleled arranged 3×3 couplers, two Wavelength Division Multiplexers (WDM), and a couple of Polarization Controllers (PC). The typical configuration of the DLOB is shown in Fig. 1.

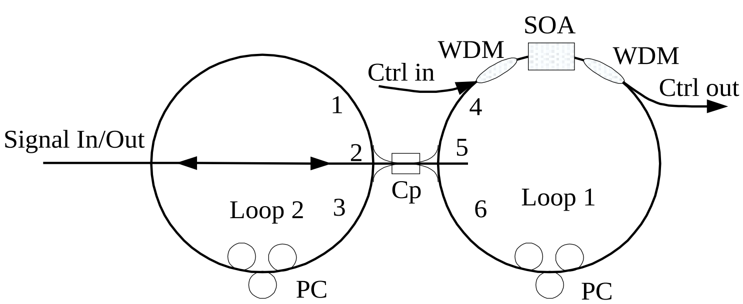


Fig. 1: Configuration of Double-Loop Optical Buffer.

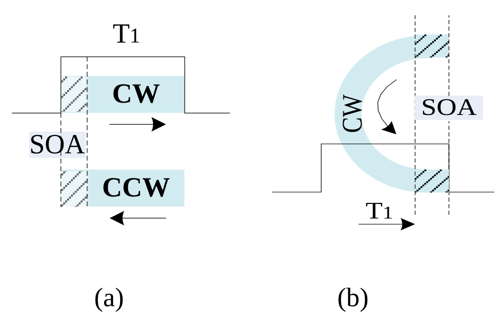


Fig. 2: Schematic drawing of signal frame in SOA.

The clockwise (CW) light and the count-clockwise (CCW) light in the right hand side loop are modulated in the SOA in the DLOB, and by the Cross Phase Modulation (XPM) in the SOA, the phase of the two lights are change from 0 to π (see Fig. 2), and the signal lights are trapped in the DLOB for designated loops until another control light comes in to change the phase differences back to 0.

By adding a sensitive component into the left loop, i.e. the gas cell in our case, a test point could be formed. The gas gap of the probe could thus be lengthened for designated times. A gas sensing network can be built with DLOBs as shown in Fig. 3.Outputs of DFB 1 and 2 act as the detection and reference light, while the light from DFB 3 is the control light. By correctly setting the loop lengths and controlling the lights from different test points from overlapping, the gas concentrations of the points under surveillance could be found out. With this system, the sensitivity of each test point could be modified individually by changing the related control lights, and combing the possibility of buffering the signal light for dozens of times, the system could detect both high and low concentration gases as needed.

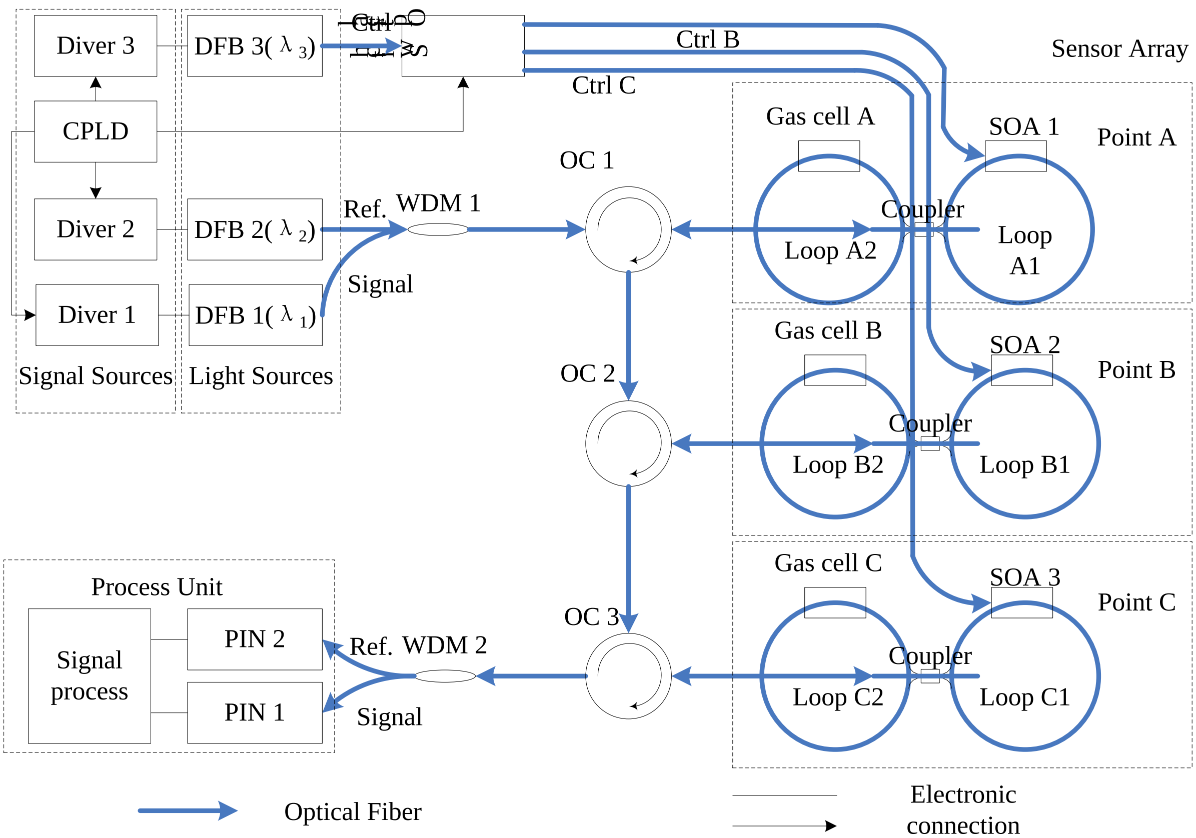
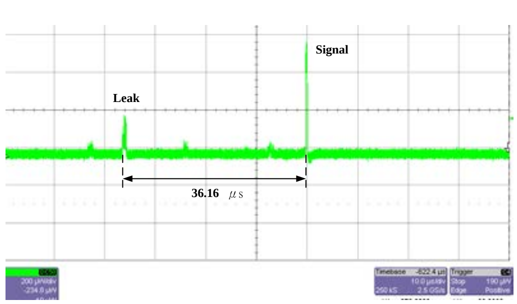
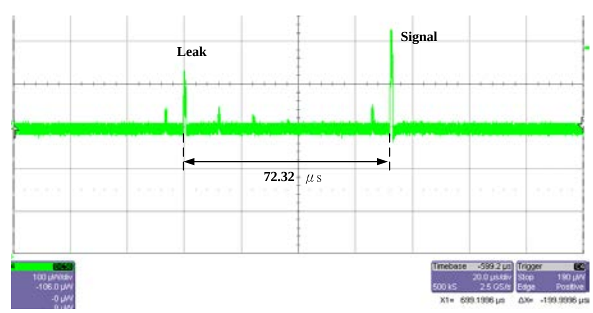


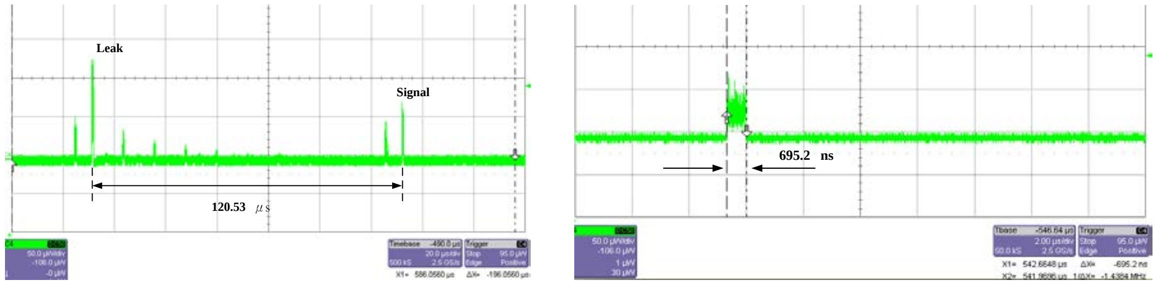
Fig. 3: Configuration of sensing network using DLOBs.



(a)



(b)



(c) (d)

Fig. 4. Output of the signal after it was buffered for (a) 3 loops, (b) 6 loops, and (c) 10 loops, (d) is the detail of the output signal for (c).

Test Results

The buffering results of the test signal were given in Fig. 4. The loop length is 2410.72 m corresponding to a round trip time of 12.0563 μs. Here the signal light was 695 ns while the control light was 1190.4 ns and can fully cover the signal light when in SOA[5], and the time intervals of the so-called write and read control pulses are respectively (a) 3, (b) 6 times, and (c) 10 times of the signal's round trip time in the buffer. The pulses before the signal output were actually the leakage of light sneak from the process of the light going into the 3 by 3 coupler. And the first peak, that is the leak, could be used to as a mark of the start of the buffering and a reference of the output power. Fig. 4(d) is the details of the output signal after travelling through the gas cell for 10 times. The round-trip loss for the signal light was 1.745 dB, with the Beer-Lambert Law, the gas concentration could be figured out.

Summary

In this manuscript, a proper method of lengthen the gas gap of the optical gas sensor with DLOBs was proposed, and recent experiments showed the gaps could be ten times of its original. This value could be further increased potentially [1], and altered with needs for sensitivity which would be rather hard for other gas sensors. An fiber optics gas sensing network based on DLOBs was put forward and the test results would be a useful reference in the upcoming experiments.

Acknowledgements

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