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Multi-point optical fiber pressure sensor

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ABSTRACT

This paper reports on a multi-point optical fiber pressure sensor using fiber Bragg gratings (FBGs) written on an exposed core optical fiber (ECF) by femtosecond laser. The pressure sensing elements were constructed as Fabry-Perot (FP) interferometers of different cavity lengths using pairs of FBGs with identical resonant wavelength. In this fashion an interference pattern was formed within the FBG bandwidth with much narrower fringes, leading to better detection limit. Fast Fourier transform (FFT) was used to calculate the phase change of the FP interference pattern with respect to applied pressure. The pressure sensitivity was proportional to the cavity FP cavity length, and reached -0.672 rad/MPa for the case of FP with 9 mm cavity length. The proposed sensor has potential to measure pressure at very high temperature thanks to its single material configuration.

Keywords: Fiber Bragg gratings, optical fiber sensor, pressure sensing, high temperature

1. INTRODUCTION

Fiber optic pressure sensors are of interested due to their characteristics of small size, light weight, rigidity, immunity to electromagnetic interference, long-distance measurements, and multiplexing capability [1]. To date, most optical fiber pressure sensors have been proposed either based on fiber gratings and/or interferometers [2]. Among them, fiber Bragg gratings (FBGs) [3] have a unique advantage as it allows dense distribution of sensors thanks to its very small size and wavelength division multiplexing. However, FBG based pressure sensors are known to have low sensitivity, particularly for single mode fiber [2]. This can be improved with the use of novel specialty fiber design such as photonic crystal fiber, but the FBG sensitivity is still orders of magnitude smaller than its interferometer counterparts. Improving FBG-based pressure sensors in terms of sensitivity in specialty fiber is therefore desirable.

One of the niche areas for fiber optic pressure sensor is the measurement of pressure under extremely harsh environment, particularly high temperature. In such conditions, the use of single-material microstructured optical fibers can be of particular advantage thanks to its ability to withstand high temperature as dopant diffusion is avoided.

In the paper we propose a multi-point pressure fiber sensor using FP interferometer in an ECF, formed by pairs of FBGs with identical resonant wavelengths for high temperature pressure sensing applications.

2. MULTI-POINT PRESSURE SENSOR

Two pairs of FBGs with identical resonant wavelength were written using a point-by-point fs-laser ablation technique on the core of a single in-house fabricated pure-silica ECF. The fabricated sensors were then packaged in an Inconel tube and placed in a sealed pressure chamber to measure the sensor pressure response (Fig. 1(a)). The cavity lengths for sensor FP1 and FP2 were 9 and 7 mm, respectively, leading to free spectral ranges (FSR) of FP1 and FP2 to be 0.10 and 0.13 nm, as shown in Fig. 1(b). FFT was applied with a fixed window on the main peak of each FP sensor, as shown in Fig. 1(b) and the phase change at the most dominant spatial frequency was calculated as different pressure was applied on the sensors. The results in Fig. 1(c) demonstrates that the phase change is linearly proportional to the applied pressure, with sensors of different cavity lengths exhibiting different sensitivity, -0.504 rad/MPa and -0.672 rad/MPa for FP2 and FP1, respectively.

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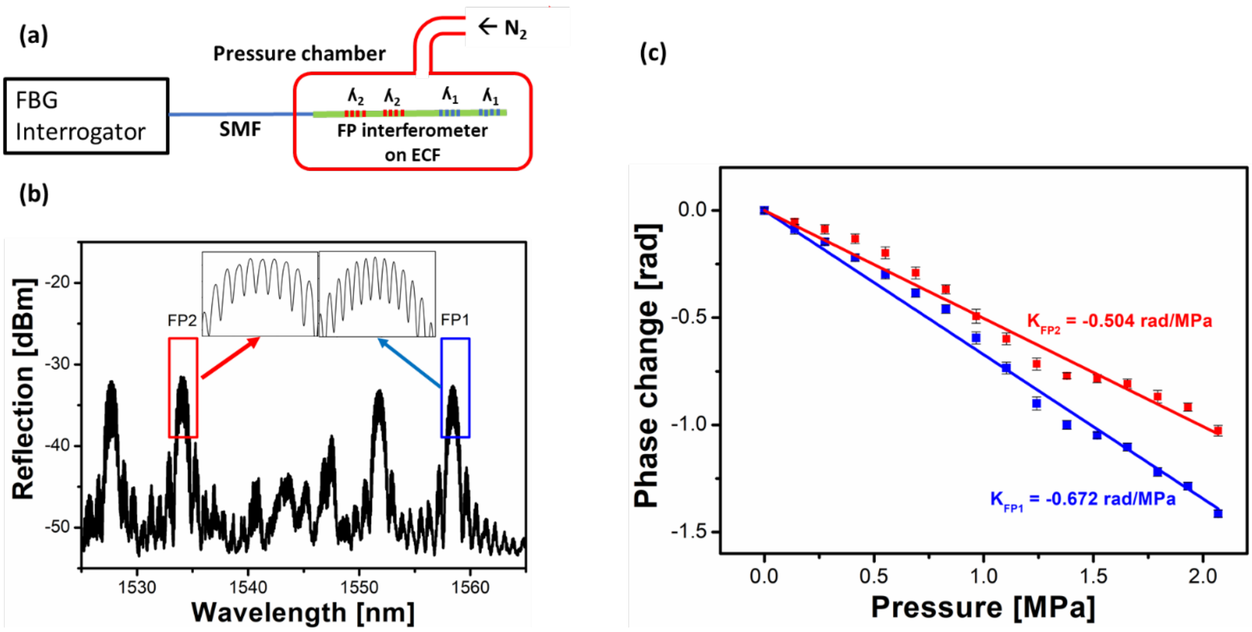

Figure 1. (a) Schematic diagram of 2-point optical fiber pressure sensor. (b) Reflection spectrum showing the FP interferences. (c) Phase change of FP interferences with respect to pressure variation.

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