Thermally Insensitive Pressure Measurements up to 300 degree C Using Fiber Bragg Gratings Written onto Side Hole Single Mode Fiber

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Abstract

A thermally insensitive pressure measurement up to 300 degree C was demonstrated utilizing fiber Bragg gratings written onto a side-hole single mode fiber. The resulting temperature sensitivity is about 300 times lower than normal FBGs.

Introduction

Fiber optic systems are passive and intrinsically safe and can be used in the oil field industry to monitor a number of wells from a single surface electronics package [1]. The fiber optics system is attractive for high temperature applications because of passive measurement, no downhole electronics, and potentially high reliability for high temperature operation. The typical environmental conditions in well bore applications are 20kpsi and 175 degree C. Measurements in these hostile environments need much higher pressure and temperature capability [2]. The scientific drilling programs also require sensors that can operate at high temperatures such as 300 degree C [3].

Fiber Bragg gratings (FBGs) can operate at high temperatures, and are candidates for multifunctional and multi-point sensors for well and reservoir monitoring. Fiber optic Bragg grating sensors have been used to measure longitudinal and transverse strain [4-6], as well as longitudinal strain and temperature [7-9]. One of the problems of conventional FBG sensors is high temperature and pressur cross sensitivity. Schlumberger demonstrated a Bragg grating pressure sensor with a single mode side-hole fiber and superior pressure response with low temperature sensitivity up to 100 degree C compared to the Bragg grating written onto conventional single mode optical fiber [10]. The birefringence is introduced by the air holes in the fiber cladding under high pressure, resulting in a dual peak spectral output. The peak to peak separation is sensitive to pressure, but much less sensitive to temperature.

In this paper, we describe the higher temperature performance of the side-hole pressure sensor, and demonstrate the pressure sensor operation up to 300 degree C and 12kpsi with low temperature sensitivity.

Experimental Results

The pressure sensor in our experiments consists of a side-hole fiber with two 35 μm diameter air holes (side-holes) on opposite sides of the core, and a FBG with 1557 nm Bragg wavelength was written on the core. The side hole fiber was spliced onto a SMF -28 fiber to seal the air holes, preventing fluid

from entering the side holes. The SMF–28 fiber extends the total fiber length to enable the fiber to connect the FBGs on the side-hole fiber to the measurement system through the high pressure tube and the high pressure fiber feedthrough. The fibers were placed inside of a pressure tube filled with lubricating oil, and the pressure was controlled by a dead weight tester. Tests were made from 8 to 12kpsi and 33 to 300 degree C.

For the measurement system, a broad band 1550nm light source was used to illuminate the FBGs through an optical coupler, and the reflected signal with the Bragg wavelength was fed back to a detection system. An Optical Spectrum Analyzer (OSA) or Fabry-Perot (FP) tunable filter system was used to measure the peak wavelength.

Figure 1 shows the temperature sensitivity of the peak to peak separation from 33 degree C to 300 degree C at 8kpsi, 10kpsi and 12kpsi. The peak to peak separation has low sensitivity to temperature up to 300 degree C over the pressure range although the each peak position changes widely. The pressure sensitivity of the peak to peak separation is a constant of ~ 0.06 pm /psi over the pressure and temperature range.

Figure 2 shows the peak to peak separation change from 33 degree C to 145 degree C at 12kpsi. About 3 pm of the peak to peak separation change was measured by the temperature change of 112 degree C. The temperature sensitivity of peak to peak separation was - 0.03 pm / degree C, which is ~ 300 time better than that of the spectral response of a fiber grating written into conventional single mode fiber (~ 10 pm / degree C). This reduces the need of a separated temperature measurement and allows monitoring pressure in wells under unstable thermal conditions.

Figure 3 shows the pressure response of peak to peak separation at 300 degree C from 8kpsi to 12kpsi. The peak to peak separation follows the pressure change linearly, and the pressure sensor with side-hole fiber is operational at 300 degree C

Since the sensing element of the side-hole fiber is very small (125 μm diameter, ~ 10mm length), the pressure sensor can be miniaturized, resulting in small packaging and potentially better time response to pressure with low temperature sensitivity.

Conclusions

The side-hole fiber grating-based pressure sensor is operational at 300 degree C and 12kpsi. The low temperature sensitivity of the side-hole pressure sensor has been demonstrated up to 300 degree C. We demonstrated that the temperature sensitivity of the pressure sensor was –0.03 pm/ degree C at 12kpsi, which has ~ 300 times superior temperature insensitivity to fiber Bragg gratings written onto a conventional single mode fiber. The side-hole fiber Bragg grating based pressure sensor can be used for a multi-point pressure measurement system under a hostile downhole environment.

References

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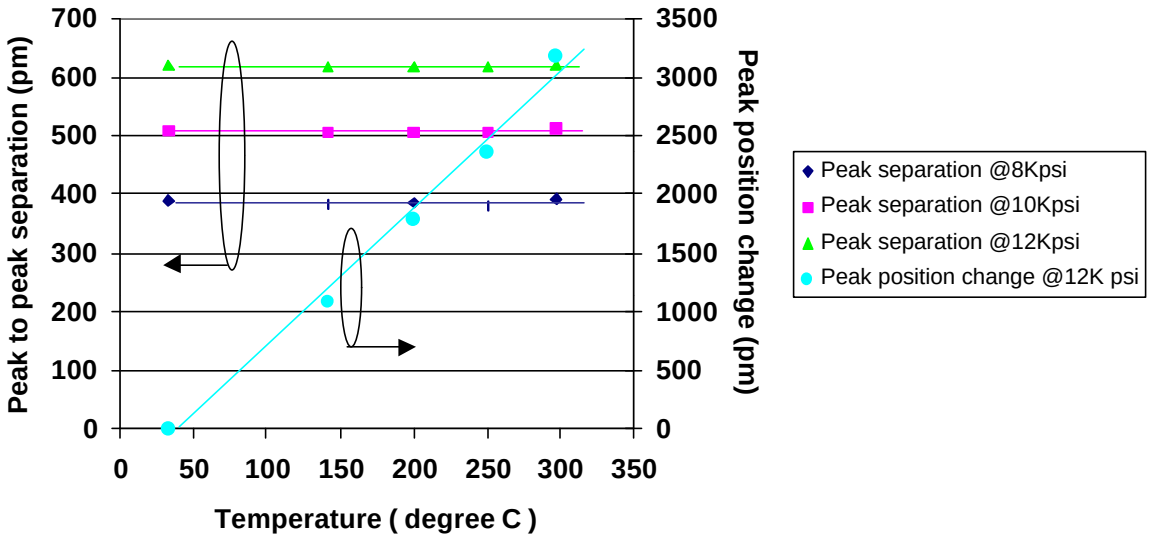

Figure 1 Response of peak to peak separation and peak position change with pressure and temperature

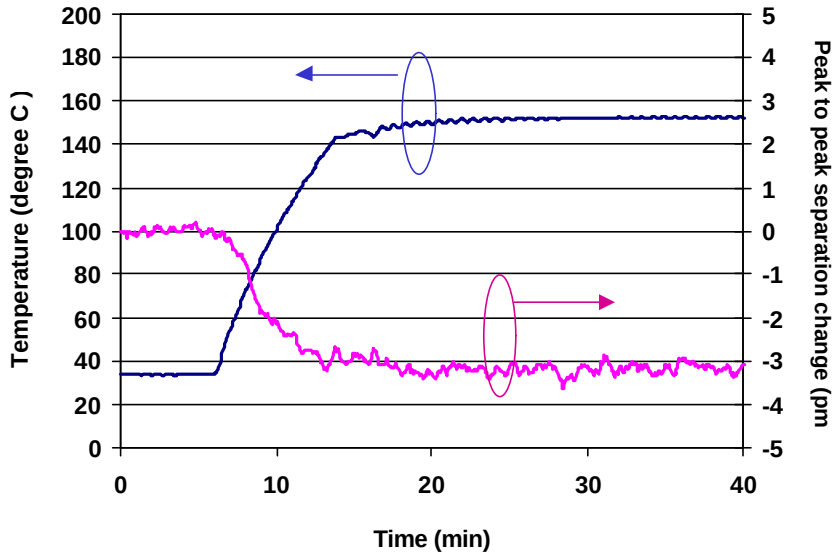

Figure 2 Response of peak to peak separation change with temperature at 12kpsi

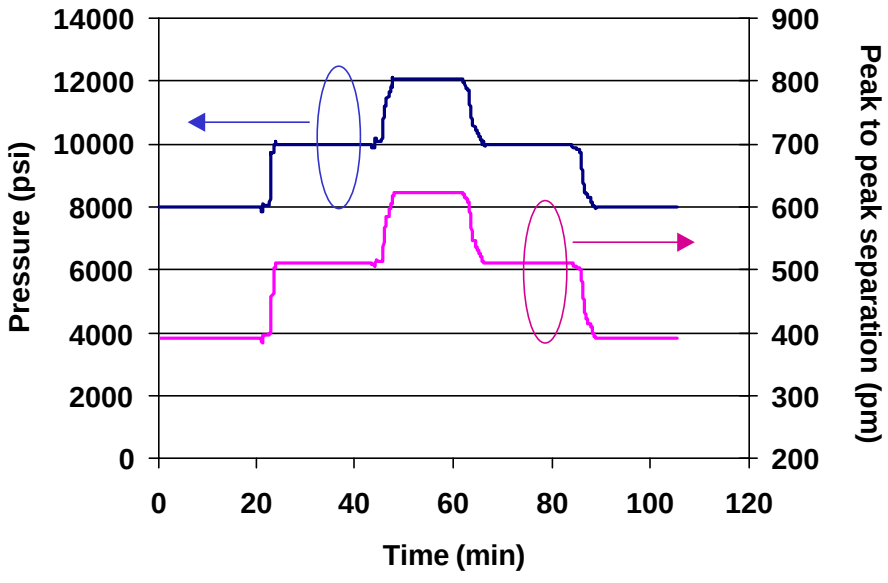

Figure 3 Pressure response of side-hole FBGs at 300 degree C