

Transversely loaded Bragg grating pressure transducer with mechanically enhancing the sensitivity

Tsutomu Yamate⁽¹⁾, Rogerio T. Ramos⁽²⁾, Robert J. Schroeder⁽²⁾, Raghu Madhavan⁽³⁾,
Stephen C. Balkunas⁽²⁾ and Eric Udd⁽⁴⁾

Schlumberger-Doll Research
Schlumberger Oilfield Services
Ridgefield, CT USA

(1) Schlumberger K.K, 2-2-1 Fuchinobe Sagamihara, Kanagawa, 229-0006 JAPAN
Tel: 81 42 759 5377, Fax: 81 42 759 3492

(2) Schlumberger-Doll Research, Old Quarry Road, Ridgefield, CT 06470 USA
Tel: 1 203 431 5000, Fax: 1 203 438 3819

(3) Sugar Land Product Center, 110 Schlumberger Dr., Sugar Land, TX 77478 USA
Tel: 1 281 285 8913, Fax: 1 281 285 8999

(4) Eric Udd, Blue Road Research, 255 NE 205th Avenue, Fairview, Oregon 97024 USA
Tel: 1 503 667 7772, Fax: 1 503 667 7880

Introduction

Fiber optic sensors and systems in the oil and gas industry have potentially significant advantages compared to conventional sensor systems, particularly for downhole permanent monitoring applications. The typical environmental requirements in well bore applications are 20kpsi and 175 degree C and measurements in these hostile environments need much higher pressure and temperature capability [1]. Fiber optics sensors are electrically passive and do not require downhole electronics, resulting in potential operations at high temperatures with high reliability [2].

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 [3-5], as well as longitudinal strain and temperature [6-8]. Schlumberger demonstrated a Bragg grating pressure sensor with a single mode side-hole fiber [9] and superior pressure response with low temperature sensitivity up to 300 degree C compared to the Bragg grating written onto conventional single mode optical fiber [10]. The transverse load is applied to the core by the air holes in the fiber cladding under high pressure, resulting in stress induced birefringence and a dual peak spectral output. The peak to peak separation is sensitive to pressure, and very insensitive to temperature.

In this paper, we describe a transversely loaded Bragg grating pressure transducer with mechanically enhanced the sensitivity utilizing fiber Bragg gratings written onto a single mode fiber [11], and demonstrate pressure sensitivity up to 5k psi with low temperature sensitivity.

Transducer structure and experimental results

Figure 1 shows a schematic view of the transducer structure. The transducer and an optical fiber are set in an atmospheric chamber, and transverse stress is applied to the optical fiber by a piston. The force applied to the fiber is proportional to the area of the piston; therefore, the transverse load can be adjusted by changing the area. Two optical fibers without coating material are set between two quartz plates, one with a FBG, and a dummy fiber, added to keep the symmetry and alignment of the plates. The balance of the transverse load between the FBG and the dummy fiber depends on the position of the fibers; therefore, the pressure sensitivity of the transducer changes slightly depending on assembly conditions. The surfaces of these plates are optically flat in order to apply uniform transverse load to the optical fibers. Isolation from the high pressure is provided by an O-ring sealing and a thin diaphragm made of stainless steel. Since

the fiber is not under high pressure, fiber feed-through design is simplified. A prototype with ¼” piston was designed and built.

A broad band 1550nm light source was used to illuminate the FBGs through an optical coupler, and the reflected signal at the Bragg wavelength was fed back to a detection system. A Fabry-Perot (FP) tunable filter system was used to measure the peak wavelength. Pressure was controlled by a hand pump, and monitored by a quartz pressure gauge.

Figure 2 shows the dynamic measurement from the fiber optic transducer compared to a Qz pressure gauge. Three pressure cycles between 2300 psi and 2600 psi were applied, with the fiber optic transducer signal closely following the quartz pressure gauge.

Figure 3 shows the relation between peak separation and pressure. The solid line is the pressure response according to the theory [12] and the dots represent test results. The pressure response of peak separation was ~ 0.33 pm/psi, which is close to the expectation and 10 times higher than the pressure sensitivity of unenhanced standard FBGs (~ 0.03 pm / psi) under hydrostatic pressure condition. Since the minimum detectable peak separation of a FP detector is ~ 400 pm, the detectable low pressure was ~ 1200 psi. Therefore, the pressure response was measured from 2000 psi.

Figure 4 shows the peak separation versus pressure at different temperatures. There is a linear relation between peak separation and pressure over the temperature range, and the peak separation has little sensitivity to temperature over the range. The residual temperature sensitivity can be compensated for by measuring the temperature using the absolute value of each peak wavelength.

Conclusions

A transversely loaded Bragg grating pressure transducer with mechanically enhanced sensitivity was developed utilizing fiber Bragg gratings written onto a single mode fiber. We demonstrated that the pressure sensitivity was 0.33 pm/psi, which is 10 times superior to fiber Bragg gratings written onto a standard single mode fiber with small temperature sensitivity. Transversely loaded Bragg grating pressure transducer with mechanical sensitivity enhancement can be used for a multi-point pressure measurement system under a hostile downhole environment.

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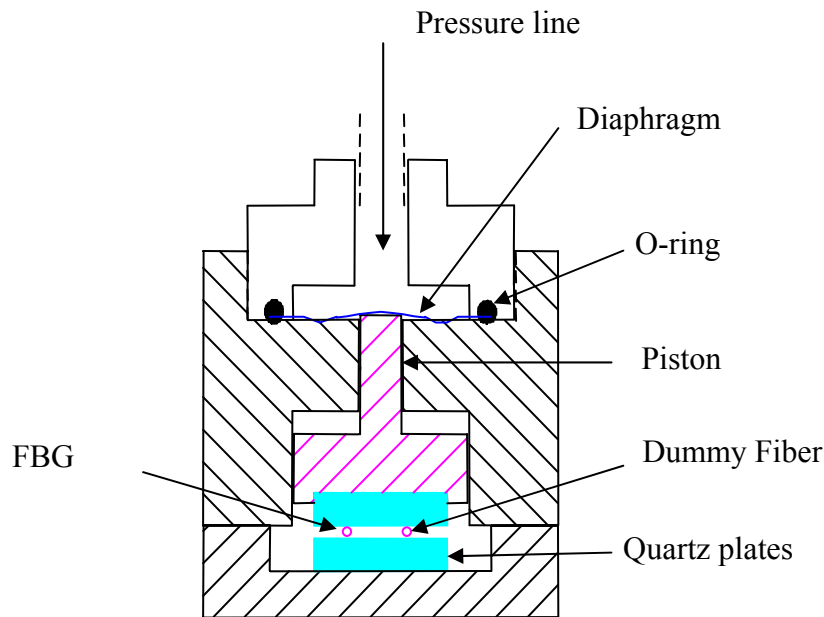


Figure 1 Structure of transversely loaded Bragg grating pressure transducer

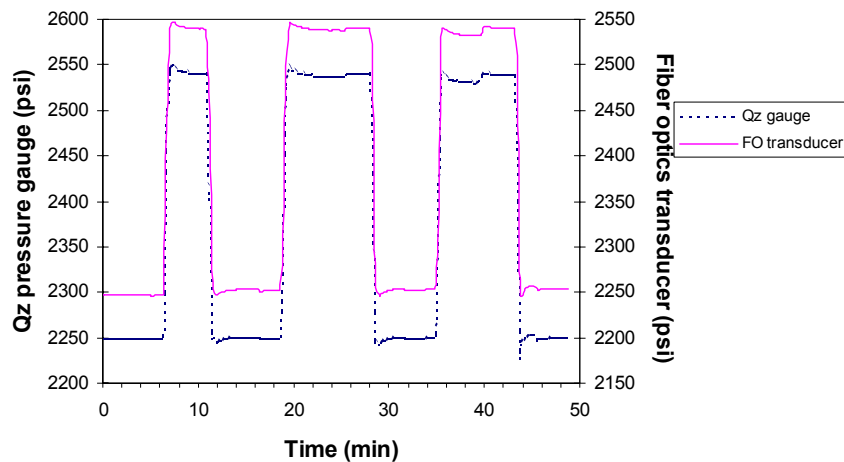


Figure 2 Dynamic measurement from the FO transducer compared to a quartz (Qz) pressure gauge

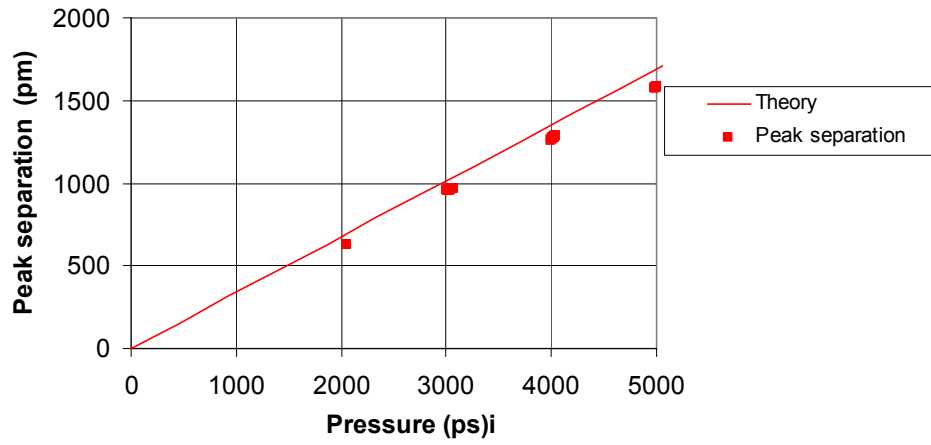


Figure 3 Peak separation versus pressure for the 1/4" piston transducer with standard fibers

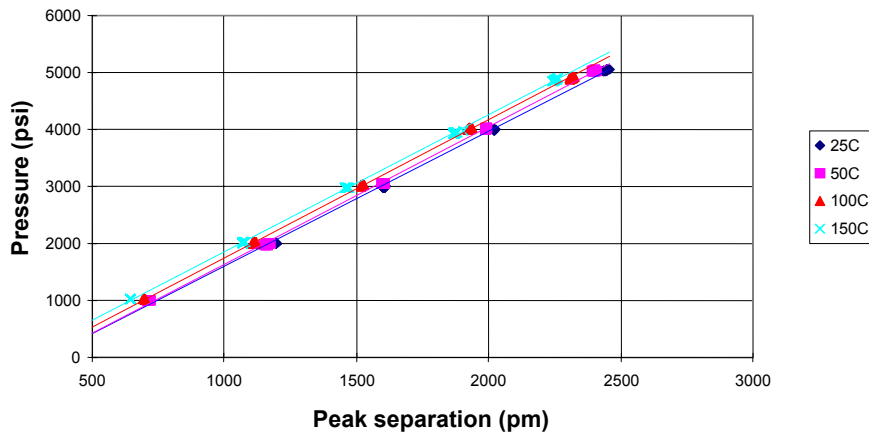


Figure 4 Peak separation versus pressure at different temperatures