Single-end-access configuration for POF-based touch sensing

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Introduction

Fiber-optic sensors are expected to play a significant role in solving social problems in our modern world. They can be divided into two categories: (i) distributed sensors, which are often based on Rayleigh, Brillouin, and Raman scattering phenomena [1], and (ii) single-point or multiplexed sensors, which include fiber Bragg grating (FBG) sensors [2]. Herein, we will focus on the latter, which have relatively high measurement accuracy.

FBGs have been used to measure various physical quantities, such as temperature [3], strain [3], and refractive index [4], among others. FBGs inscribed in silica single-mode fibers (SMFs) are widely used, but they easily break under relatively small strains of several percent. To address this issue, FBGs inscribed in plastic optical fibers (POFs) using femtosecond laser irradiation have gained significant attention. POFs made of poly (methyl methacrylate) (PMMA) are commonly used, but we are focusing on FBGs inscribed in perfluorinated graded-index (PFGI-) POFs, which have relatively low propagation loss at telecom wavelengths.

Three methods for inscribing PFGI-POF-FBGs have been developed: point-by-point, line-by-line, and plane-by-plane. These methods have been shown to have different sensing performances compared to those of silica SMF-FBGs and PMMA-POF-FBGs. One unique potential of POF-FBGs is touch sensing, in which the transmitted optical power changes significantly depending on the distance between the FBG and external objects (such as metal or rubber) [5]. However, POF-FBG-based touch sensing has only been demonstrated in a transmissive configuration, which is not practical for many applications, and the use of a supercontinuum (SC) source has made the system costly.

In this work, we demonstrate the basic operation of a single-end-access configuration of POF-FBG-based touch sensing using an amplified spontaneous emission (ASE) source.

Experimental Setup and Conditions

We used an FBG inscribed line-by-line in a PFGI-POF (GigaPOF-50SR, Chromis Fiberoptics) with a length of ~0.4 m. It consists of three layers: a core (diameter: 50 µm, refractive index: ~1.35), a cladding (diameter: 70 µm, refractive index: ~1.34), and an overcladding (diameter: 490 µm). The core and cladding are made of doped and undoped amorphous fluoropolymer (CYTOP®), respectively, and the overcladding is made of polycarbonate. The FBG was inscribed directly in the middle of the PFGI-POF using a femtosecond laser system (LASEA S.A.), without removing the overcladding.

The experimental setup of the reflectometric configuration of POF-FBG-based touch sensing is depicted in Fig. 1. In this setup, the output from an ASE source was injected into one end of the PFGI-POF via an optical circulator, and the reflected light spectrum was observed using an optical spectrum analyzer (OSA). It is worth noting that using an SC source is not ideal in this case due to the wavelength-dependent loss of the optical circulator. To study the touch sensing characteristics, the reflected spectra were first measured when a rubber object (20x20x50 mm) approached the FBG. The same measurement was then performed when the rubber object was touched at three different positions on the POF: (A) 5 cm in front of the FBG, (B) on the FBG, and (C) 5 cm behind the FBG (as shown in Fig. 1).

Results

Figure 2 shows the measured dependence of the reflected light spectrum (1520–1620 nm) on the distance between the FBG and the object. The observed peaks and dips may be caused by modal interference in the multimode PFGI-POF, although its influence should be small compared to the transmissive configuration. As the object approached the FBG, the spectral power started to decrease, and when the object touched the FBG, a relatively large decrease in power was observed in most wavelength ranges.

Figure 3(a) shows the spectra around 1570 nm when the object touched points (A), (B), and (C) (along with the reference curve when the object was not touched). The spectral power decreased in some wavelength ranges only when the object touched point (B), i.e., the FBG-inscribed part. This is clearly seen in the magnified view around 1566.5 nm in Fig. 3(b); the power change at 1566.5 nm was >1.1 dB when the object touched the FBG, while it was <0.2 dB when the object touched the other points. This result strongly suggests that POF-FBG-based touch sensing can be performed on the basis of the power at this wavelength using a one-end-access configuration.

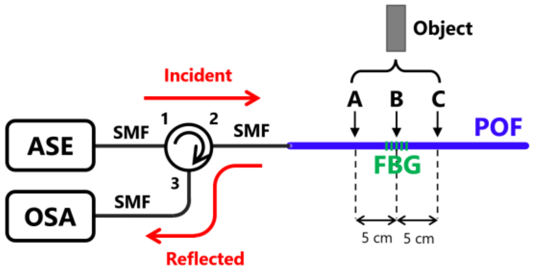

Fig. 1 Schematic setup for reflectometric POF-FBG-based touch sensing. ASE: amplified spontaneous emission, OSA: optical spectrum analyzer, SMF: single-mode fiber.

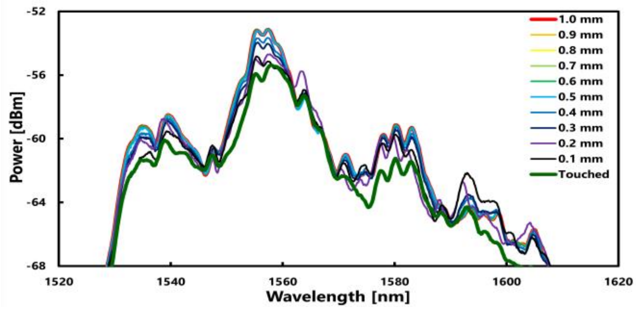

Fig. 2 Measured spectral change in relation to the distance between the FBG and a rubber object.

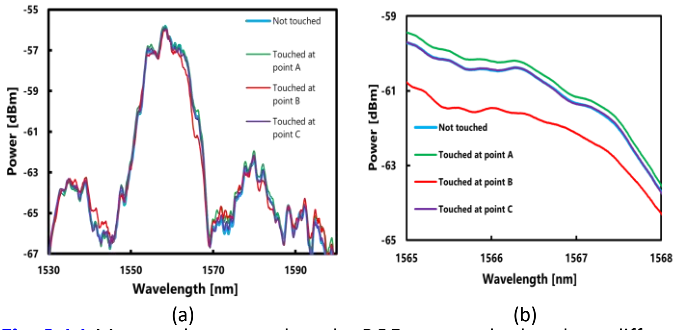

Fig. 3 (a) Measured spectra when the POF was touched at three different positions. **(b)** Magnified view around 1566.5 nm.

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