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Characteristics analysis of Fabry-Perot interferometer using chirped FBGs: Application to vibration measurement

チャープ FBG を用いたファブリ･ペロー干渉計の特性解析：振動計測への応用

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1. Introduction

Recently, there has been attracted much attention in application of optical fiber grating sensors for environmental monitoring, smart structures, smart manufacturing, and so on. Practical advantages of the fiber grating sensors are ease in multiplexed operation, compactness, simple structure, and semi-point sensing capability[1)] in addition to those attributed to conventional fiber sensors including high sensitivity, wide dynamic range, immunity to electromagnetic interference and remote sensing. We proposed until now various optical fiber Bragg grating (FBG) and long-period fiber grating (LPG) sensors based on the intensity modulation scheme in order to measure solid vibration and underwater sound[2-4)]. The sensitivity of the sensors with this scheme depends on the slope of the grating transmission/reflection spectrum and wavelength shift rate when an influence is applied. We have showed that a Fabry-Perot interferometer sensor with FBG reflectors has higher sensitivity since its transmission/reflection spectrum has larger slope than a single FBG[5)]. In this paper, we propose and examine a FPI sensor with chirped FBGs (CFBG) as reflectors. We expect higher performance by using this structure because with CFBG we may choose various wavelengths for the optical source and those may have different tendency in the movement of the free spectral range of a FPI.

2. CFBG-FPI

The fundamental structure of a CFBG is shown schematically in **Fig. 1**. A CFBG is a FBG whose grating period changes linearly along the length of the fiber. Because of the spatial variation in the grating period, the effective reflection point is different for each wavelength. The longer the wavelength is, in the case of Fig. 1, the farther the reflection point is. In a CFBG-FPI used for the experiment, CFBGs of same chirp rate (1.6 nm/mm) were arranged in symmetry and used as mirrors for a FPI. Two CFBGs are arranged so that a shorter period of the grating may be outside. The central wavelength and bandwidth of the CFBG are 1550 and 20 nm, respectively and the space between the CFBGs is 5 mm.

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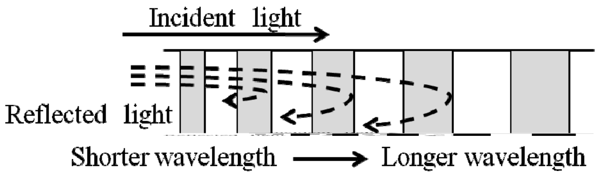
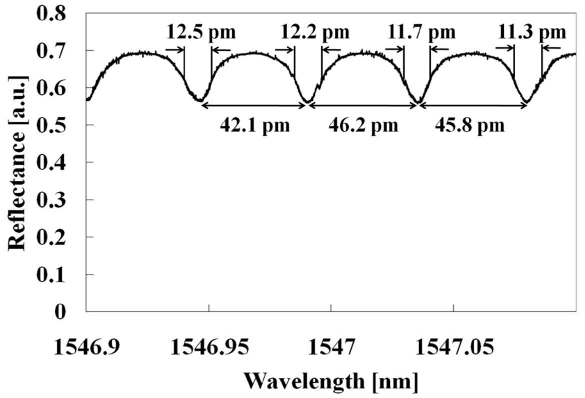


Fig. 1 CFBG and light reflection.

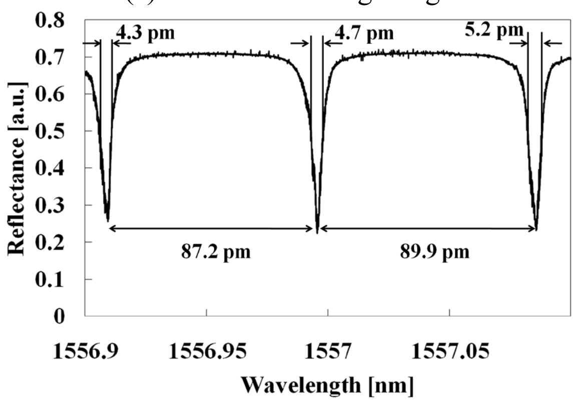
3. Experiments and Results

The spectrum of the CFBG-FPI was first measured by using an ASE light source (Mitsubishi Cable Industries LA155D-FB0-16FSS1) and an optical spectrum analyzer (OSA) with resolution of 10 pm (Advantest Q8384): the central wavelength was 1551 nm and bandwidth was 18 nm. Because of the limited spectral resolution of the OSA used in the experiment, fine structures of the CFBG-FPI spectrum could not be resolved and we then used a wavelength-tunable laser as an optical source (Koshin Kogaku LS-601A) instead. The wavelength of the source light was swept automatically with 1 pm/s, the reflected light was detected with a photodetector (PD; New Focus ν 2011), and the change in the photo current was recorded in PC with the data logger (Keyence NR-500). The wavelength was swept in two bands: from 1546.9 to 1547.1 nm and from 1556.9 to 1557.1 nm. The results are shown in **Fig. 2**(a) and (b), respectively. The free spectral range (FSR) and full width at half maximum (FWHM) are 44.7 and 11.9 pm in the shorter-wavelength region, respectively, and those in the longer-wavelength region were 88.6 and 4.7 pm, respectively.

The static strain characteristics of the transmission spectrum of the CFBG-FPI were measured. The one end of the optical fiber lead was glued to a fixed stage, and the other end was glued to a controllable displacement stage. Transmission spectrum was measured with the OSA and ASE light source, and the wavelength shift was determined. The measured transmission spectrum is shown in **Fig. 3** and the wavelength shifts in the shorter- and longer-wavelength regions are shown in **Fig. 4**, respectively. It is seen that the transmission spectrum shifts to the longer-wavelength side due to the applied static strain. The longer-wavelength region moves more than the shorter-wavelength and it is therefore understood that sensitivity is higher in the longer-wavelength region compared to the shorter-wavelength region.



(a) Shorter-wavelength region.



(b) Longer-wavelength region.
Fig. 2 Reflection spectrum of CFBG-FPI.

The vibration measurement with the intensity modulation scheme was done. An accumulating type piezoelectric transducer (PZT) was fixed directly to the CFBG-FPI and the vibration was applied. The sinusoidal wave of frequency 1 kHz was applied to PZT. The wavelength of the tunable laser source was tuned to the slope of the reflected spectrum. The reflected light was detected with PD. The results of the sensor output while changing the applied voltage to PZT are shown for the shorter- and longer-wavelength regions in **Fig. 5**. It is observed that the dynamic range in the longer-wavelength region is wider than that in the shorter-wavelength region, and the measurement sensitivity is about ten times higher than that in the latter region.

4. Concluding Remarks

In this paper, the basic characteristics of CFBG-FPI were experimentally analyzed and applied to the vibration measurement. It has been observed from the static strain measurement that there is a difference in sensitivity between in the longer- and shorter-wavelength regions. This feature would be utilized to the simultaneous measurement of the two quantities such as temperature and strain. The application using unlike sensitivities will be examined in the future.

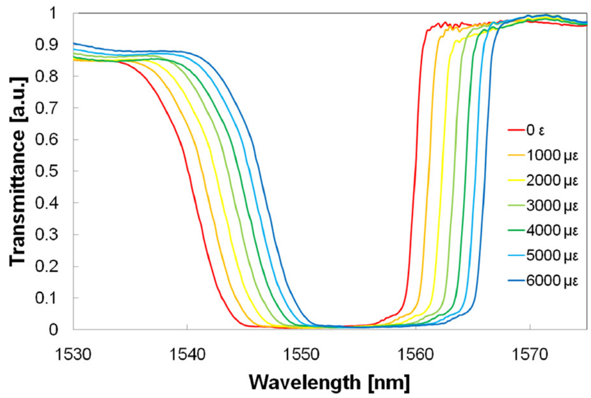


Fig. 3 Static strain characteristics of CFBG-FPI.

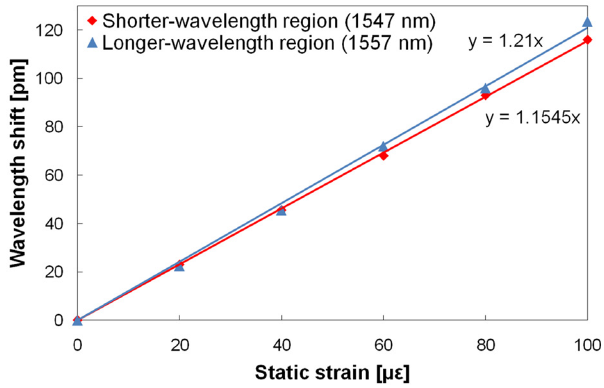


Fig. 4 Wavelength shift vs. static strain.

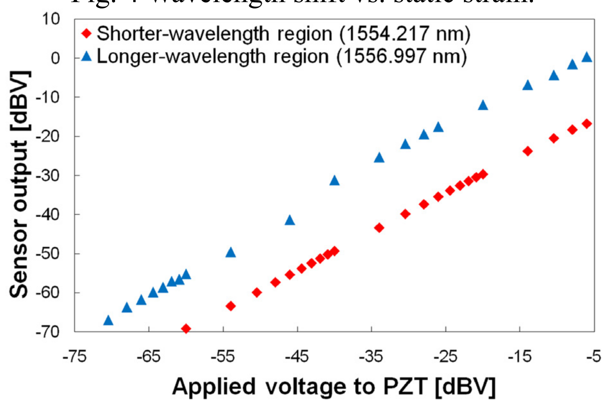


Fig. 5 Vibration measurement.

References

1. A.D. Kersey *et al*: J. Lightwave Technol., **15** (1997) 1442.
2. N. Takahashi *et al*: Jpn. J. Appl. Phys., **39** (2000) 3134.
3. S. Tanaka *et al*: Jpn. J. Appl. Phys., **43** (2004) 2969.
4. S. Tanaka *et al*: Jpn. J. Appl. Phys., **48** (2009) 07GE05.
5. A. Wada *et al*: Proc. of 47th Meeting on Lightwave Sensing Technol., June (2011) 1507.