EVALUATION OF THE FIBER FILTER FOR AN INCOHERENT DOPPLER LIDAR

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ABSTRACT

Various detection filters of the Doppler shift for an incoherent Doppler lidar have been proposed. Applying the fiber Bragg grating (FBG) filter, which uses for the optical splitter in optical communications, to the detection device of the Doppler shift was proposed. Since the FBG filter consists of diffraction gratings, only the arbitrary wavelength which fulfills the Bragg condition is reflected. Change of the ratio of the filter transmission light and the reflection light is equivalent to the Doppler shift change. Use of the transmission light and the reflection light contributes to the improvement of the signal-to-noise ratio. Moreover, 1.5 μm band using in optical communications is the eye safe wavelength. In this paper, the Doppler shift detection experiment using the FBG filter of wavelength 1.5 μm is reported.

1. INTRODUCTION

In order to measure wind profiles by the incoherent Doppler lidar, there are some methods of detecting the Doppler shift. The double edge technique which uses two narrow band filters located symmetrically for laser frequency was proposed[1]. The double edge molecular technique which sets two etalon filters at the skirt of the Rayleigh spectrum was proposed[2, 3]. In these methods, Doppler shift components are obtained from change of the transmission signal ratio of each filter. The method of using two slopes of one iodine absorption line around 532 nm was also proposed[4]. Laser frequency is located in each slope of one absorption line alternately. The Doppler shift is obtained from the transmission signal ratio of each slope. Since filter transmission of these Doppler lidars are from 10 % to 50 %, loss is large.

Then, we proposed applying the FBG filter to the Doppler shift detection device[5]. The FBG filter is the optical fiber which forms the diffraction grating into a fiber core[6]. Moreover, only the arbitrary wavelength which fulfills the Bragg condition is reflected. A laser wavelength is located on the slope part of the FBG filter, and a Doppler shift component is detected from the ratio of the filter transmission intensity and the filter reflective intensity. It is expected that use of the transmitting light and the reflection light contributes to the improvement of the signal-to-noise ratio. Moreover, the eye safe laser is required of three-dimensional wind observation. Originally, the FBG filter was developed as the device for the optical communication, the temperature sensor and the strain gauge used in 1.3 μm band and 1.5 μm band. Since 1.5 μm is an eye safe wavelength, the FBG filter is suitable as the device for the eye safe Doppler lidar.

We conducted the following experiments in order to examine whether the FBG filter can apply to the receiving device for the incoherent Doppler lidar. The transmission characteristic and the stability of itself were measured using the FBG filter of wavelength 1.5 μm. Moreover, the Doppler shift detection experiment was conducted using 1.5 μm laser.

2. FBG FILTER

The fiber Bragg grating is the optical fiber for which the refractive index in the core is perturbed forming a periodic or quasi-periodic index modulation profile. In the case of using a constant coupling coefficient, there are many peaks called side lobes on both sides of the main peak of the reflection spectrum. However, this side lobe is repressed using the apodized grating, which has a non-constant coupling coefficient. The characteristic of the FBG filter was measured using the system as shown in Fig. 1. The specification of the DFB laser is 1549.2 nm, 20 mW and 1.2 MHz line width. The optical circulator is 1550 nm in central wavelength and 40 nm bandwidth. The output of the DFB laser is passed through the optical fiber connected to an optical circulator. This signal travels from port 1 to port 2 connected to the FBG filter. The transmission light is detected by a photo diode (PD1) and the reflection light enters the circulator again and leaves at port 3. This reflection light is detected by another photo diode (PD2). The temperature of the FBG filter is controlled by the heater by less than 0.01 °C.

The reflective characteristic of the FBG filter is shown in Fig. 2. A central wavelength is 1549.85 nm, and full width at half maximum is 0.24 nm. Side lobes are on the both sides of the main peaks of the reflection spectrum. The measurement sensitivity is 0.0043 /(m/s) from 30 % to 70 % to the reflection. This value is 60 % of the measurement sensitivity 0.007 /(m/s) of the two wavelength iodine method. The reflective characteristic of the FBG filter at various temperature is shown in Fig. 3. The wavelength shift per unit temperature is 4.6 pm/°C (610 MHz/°C). Therefore, the temperature error 0.01 °C of the FBG filter is equivalent to wind error 4.6 m/s.

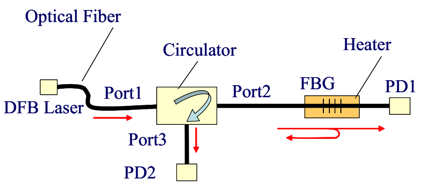

Fig. 1. The block diagram of the FBG filter characteristic measurement.

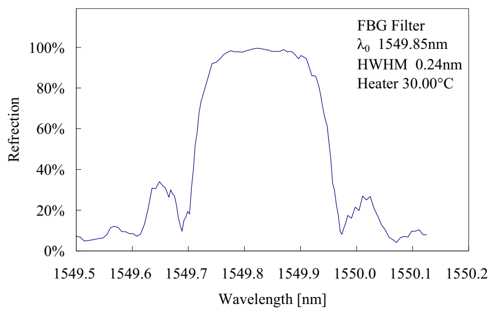

Fig. 2. The reflective characteristic of the FBG filter.

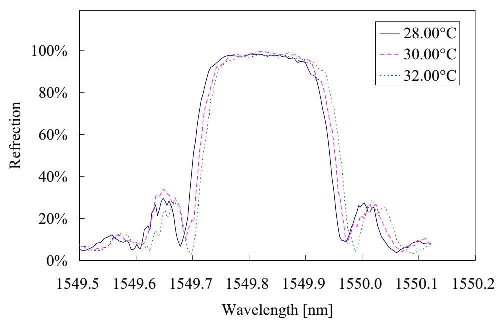

Fig. 3 The reflective characteristic of the FBG filter at various temperature.

3. THE EXPERIMENT OF DOPPLER SHIFT DETECTION

The block diagram of the experiment of the Doppler shift detection is shown in Fig. 4. The DFB laser light reflected at the mirror on the rotor is led to the FBG filter by the optical fiber through a collimator lens. The temperature of the FBG filter is controlled by less than 0.01 °C. The wavelength of the DFB laser is located on the slope of the FBG filter at 50.0 % reflection. The rotational speed of the reflecting point can be obtained from the ratio of the transmission light to the reflection light of the FBG filter.

The calculative rotational speed to the actual rotational speed at the reflecting point is shown in Fig. 5. Both showed good coincidence within the error by change of filter temperature.

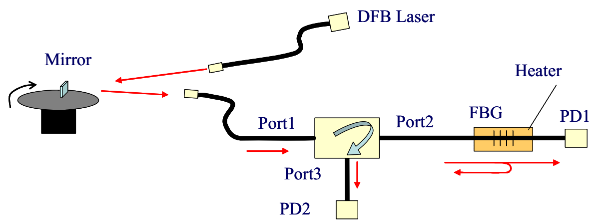

Fig. 4 The block diagram of the Doppler shift detection.

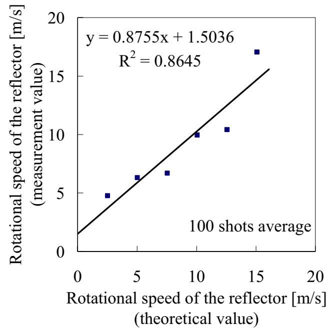

Fig. 5 Actual speed of the reflecting point and calculative speed of the reflecting point.

4. SUMMARY

Characteristic measurement of the FBG filter and the experiment of the Doppler shift detection using the rotor were conducted. The measurement sensitivity of the Doppler shift was 0.0043 /(m/s), which is 60 % of the measurement sensitivity of the two wavelength iodine method. Side lobes are on the both sides of the main peaks of the reflection spectrum. The optimal design of the grating enables improvement of the measurement sensitivity and repression of side lobes. Shift of the filter profile caused by the temperature shift of the FBG filter cannot be disregarded. It is necessary to lock the laser wavelength on the same slope position according to the feed back mechanism.

The experiment of the Doppler shift detection using the rotor was conducted and The theoretical value and the calculative value of the Doppler shift was corresponded well. This result shows that the FBG filter can be adapted for the receiving device of the eye-safe incoherent Doppler lidar.

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