High Resolution Demodulation Platform for Large Capacity Hybrid WDM/FDM Microstructures Sensing System Assisted by Tunable FP Filter

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Abstract— In this paper we proposed a demodulation scheme based on tunable FP filter for the WDM/FDM sensing system of the microstructure mentioned in the previous work. Simulation is done to prove the feasibility of demodulating the microstructure with the tunable FP filter. The experiments result showed high consistence with the simulation. And with the help of the high speed FPGA module and a high resolution AD/DA card, the system has achieved a very high resolution, up to 2.5 pm, and wavelength ranges 1520 nm to 1590 nm.

1. INTRODUCTION

Optical fiber sensors have many advantages over other sensing methods. It is immune to electromagnetic interference, chemical insert, and is quite small and weightless. In the previous work [1] in my laboratory, the microstructure based on two identical FBG has been proved to have very good sensing abilities and great potential for multiplex. The microstructure inherits the good advantage of high sensitivity low insertion loss from the FBG, but has greater capability than FBG. The capacity of the microstructure depends on the product of both wavelength channel and the frequency channel. To increase the capacity, we must expand the wavelength range of the demodulation system, and achieve a higher wavelength resolution.

There have been many demodulation schemes for spectrum sensing system. In general, two ways are typical in the demodulation of spectrum. One way is to use the diffraction gratings [2, 3]. Light is diffracted into different wavelength and then is collected by the CCD arrays. This way can achieve high demodulation speed and large wavelength bandwidth. But the wavelength resolution is limited by the number of the sensors in the CCD array. The other way is to construct the narrow band pass filter or take use of the tunable laser to get the data on different wavelength [4–7]. There is also a tradeoff between the resolution and the wavelength range.

In this paper, the tunable FP filter which has the bandwidth of 15 pm is selected. A spectrum demodulation system based on the tunable FP filter is introduced. The driving signal is produced by a high speed FPGA module and a DA module, signal from the PD is collected by the AD card. In this way we successfully demodulated the spectrum of the microstructure.

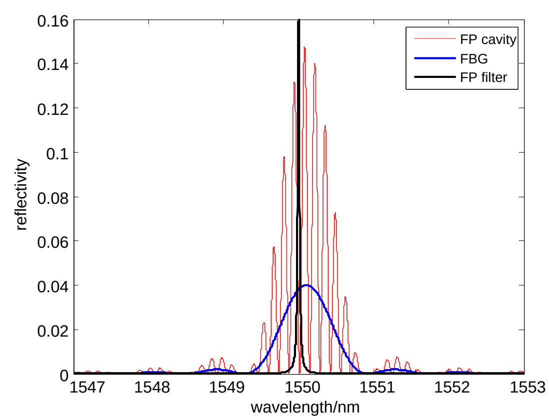

Figure 1: The typical spectrum of the FBG, microstructure and the FP tunable filter.

2. OPERATION PRINCIPLE AND SIMULATION

There have been many articles about the demodulation of FBG based on the FP filter. However the bandwidth of the FBG is about 2 nm typically, the bandwidth of the filter is about 50 pm. So when we use the FP filter to demodulate the FBG, the FP filter can be seen as a delta function. But when it comes to the FP cavity composed of the two identical FBG, the spectrum is very complex. The space of the fringe is very small. We cannot treat the FP filter as a delta function again.

Here is the reflection of the FBG.

$$r = \frac{\sinh^2(\sqrt{\kappa^2 - \bar{\sigma}^2} L)}{\cosh^2\left(\sqrt{\kappa^2 - \bar{\sigma}^2} L\right) - \frac{\bar{\sigma}^2}{\kappa^2}} \tag{1}$$

To simplify the result, we assume that the reflectivity of the FBG is quite low, then the reflection in spectrum of the microstructure can be expressed as:

$$R = 2r\left(1 + \cos\left(4\pi n_{eff} L_C/\lambda\right)\right) \tag{2}$$

L_c is the cavity length of the microstructure. The FP filter can be expressed as:

$$I_{FP} = 1/\left[1 + F\sin^2(\delta/2)\right] \tag{3}$$

$F = 4R/(1-R)^2$, $\delta = 4\pi D/\lambda$, the bandwidth of the FP filter is decided by the reflectivity of the FP filter.

From the simulation results in Figure 1, the bandwidth of the FP filter and the fringe is in the same order of magnitude. And when we put the driving voltage on the FP filter, the cavity length D will change, so is the central wavelength of the filter. The demodulation result of the system will be calculated from:

$$I_{OUT}(\lambda) = \int_{\lambda_{\min}}^{\lambda_{\max}} R \times I_{FP} dD \tag{4}$$

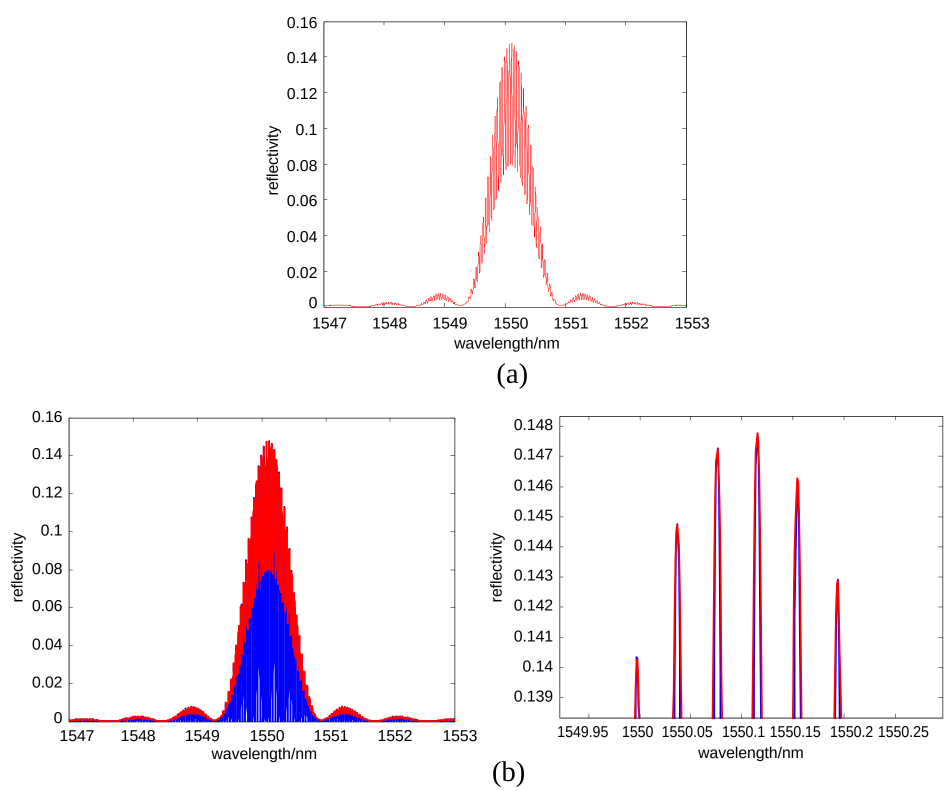

Figure 2: (a) The demodulated spectrum of the microstructure; (b) the comparison between the original spectrum and the demodulation result.

To get a better result, the bandwidth of the FP filter, we choose, is 16 pm, the cavity length of the microstructure is about 20 mm, the step change of the FP filter in wavelength is 1 pm. The simulation result of the demodulation result is shown in Figure 2.

From the results shown in Figure 2, the demodulation of the complex spectrum based on the tunable FP filter may cause some distortion but the peak of the fringe corresponds to the theoretical result correctly. The distortion is mainly decided by the density of the fringe, the bandwidth of the filter and the step of the driving voltage. Besides this the resolution of the demodulation system is just the step wavelength change of the tunable filter.

3. EXPERIMENTS SETUP

The schematic diagram is shown in Figure 3. The broadband light from the light source was transmitted to the microstructure through the circulator. The reflected light was then acquired by the photo detector. The driving signal was synchronized with the received signal by using one

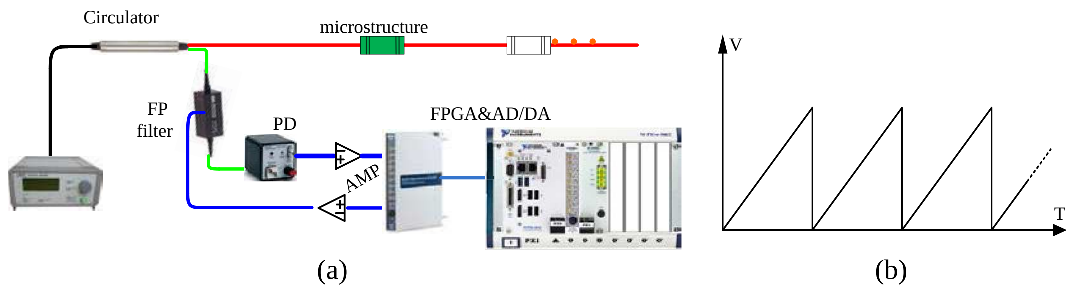

Figure 3: (a) Configuration of the system; (b) driving signal.

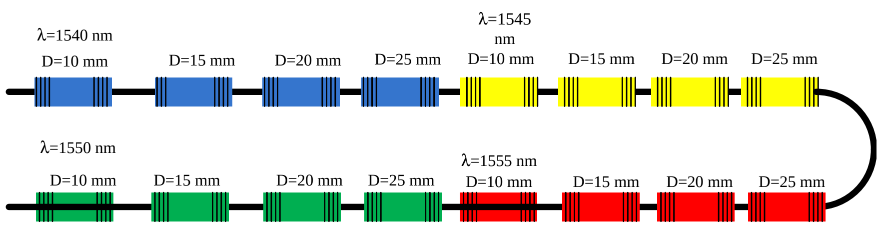

Figure 4: Schematic of the microstructure.

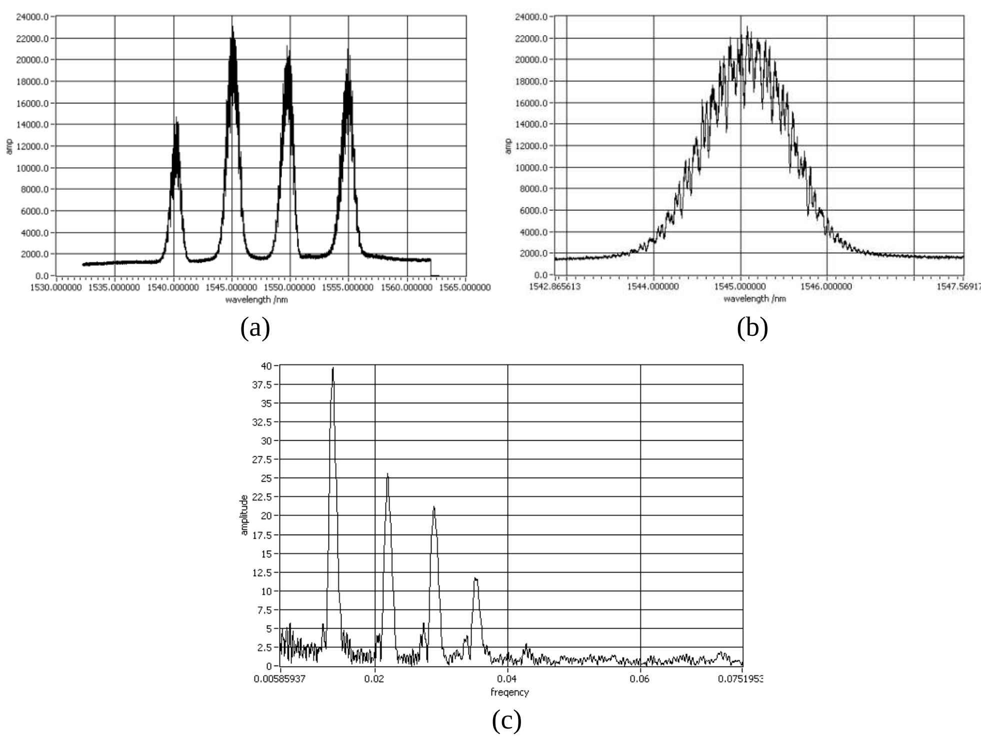

Figure 5: (a) The demodulation results; (b) one peak centered at the 1545 nm; (c) the frequency spectrum.

FPGA module. To ensure the repeatability of the detection, the driving signal is designed to be the sawtooth signal. And the data acquired from the photo detector is filtered and processed in the computer.

To test the demodulation result of the demodulation system, a sensing system of 16 microstructures containing 4 wavelengths and 4 frequencies is fabricated. The microstructure is shown in Figure 4.

4. RESULTS AND DISCUSSION

The demodulation results is shown in Figure 5. The wavelength ranges from 1532 nm to 1562 nm at the resolution of 2.5 pm. The driving frequency is 500 Hz. If we choose one peak to observe carefully, the demodulation results keep in high consistence with the simulation. After the fourier transmission, the four peak is very clear in the frequency spectrum. And due to the higher resolution, the system can double the capacity up to 2000.

5. CONCLUSION

The demodulation system based on the tunable FP filter can be used for the complex spectrum demodulation of the microstructure. The capacity and the demodulation speed of the microstructure sensing system will be greatly improved with the help of the system.

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