Four-channel high-speed strain measurement based on VT-DBR laser

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Introduction

Strain sensors have a wide range of applications in aerospace, machinery, chemical and other fields . Compared with traditional resistive strain sensors, fiber optic interference sensors have the advantages of miniaturization, high sensitivity, resistance to electromagnetic interference, high temperature, corrosion resistance, et al . The extrinsic Fabry-Perot interferometry (EFPI) sensor has an interferometric cavity with an air gap between the flat end face and the reflective endface. This structure is small in size and has a great advantage over the Mach-Zehnder interferometer (MZI) , fiber Bragg grating (FBG) and other sensors in measuring the strain of small mechanical components.

The four-channel high-speed strain measurement system proposed in this paper mainly consists of an extrinsic Fabry-Perot sensor with simple structure , vernier-turned distributed Bragg reflector (VT-DBR) laser , fiber couplers and photodetectors. A VT-DBR laser performs high-speed wavelength modulation to achieve phase shift. Four sensor cavity length variations can be demodulated simultaneously at 100 kHz by a five-step phase-shift algorithm. This multichannel demodulation method does not require cavity length differences as well as sensor cascading compared to the frequency division multiplexing demodulation method , and thus significantly reducing the manufacturing difficulty and cost of the system.

In this work, four EFPI sensors are glued to the upper and lower surfaces of a cantilever beam successively, and a VT-DBR laser four-channel system is combined to perform high-speed strain measurements. This measurement system can be used for accurate point strain measurement of small mechanical components.

Experiment setup

The proposed sensor design is shown in the inset of Fig 1. It consists of a section of hollow-core fiber (HCF) fusion spliced between two sections of standard 125 μm single-mode fiber (SMF). The HCF is spliced to the SMF endface by an arc fusion splicer (KL-300T, JILONG). The splicing parameters were modified to avoid splice point expansion or collapse and to maintain mechanical strength. The HCF is then cut into a length of about 500 μm under an optical microscope using a fiber cleaver (KL-21B, JILONG), which is the FP cavity.

Figure 1 shows the schematic diagram of the experimental setup for strain measurement. A VT-DBR laser is used for high-speed wavelength switching to introduce phase shifts in the wavelength domain. A VT-DBR laser is used for high-speed wavelength switching to introduce phase shifts in the wavelength domain.

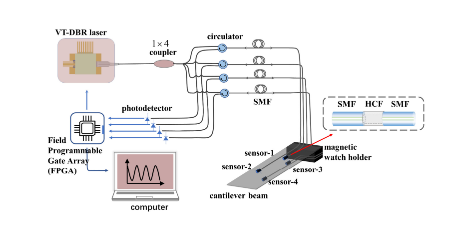

Fig. 1. Diagram of the four-channel strain test experimental setup

Experiments and Discussion

As shown in Fig 1, a four-channel sensing system is used in the experiment. Each of the four sensing probes is glued to the upper and lower surfaces of the cantilever beam in turn, and one end of the cantilever beam is placed on a magnetic watch holder, which is fixed to the operating table to apply force to the cantilever beam in such a way that the four sensing probes perform strain sensing simultaneously. A full-spectrum wavelength scanning from 1527 nm to 1567 nm is first performed to obtain the initial cavity length of each channel.

Figure 2 shows the interference spectra of the four sensors. Based on a white light interference absolute cavity length demodulation method , we obtain the initial cavity lengths of the four sensors as 529.270μm, 521.805μm, 542.163μm, and 522.848μm, respectively. The average cavity length is 529.022μm. the five working wavelengths are determined as 1560.005nm, 1559.429nm, 1558.853nm, 1558.278nm, and 1557.703nm.

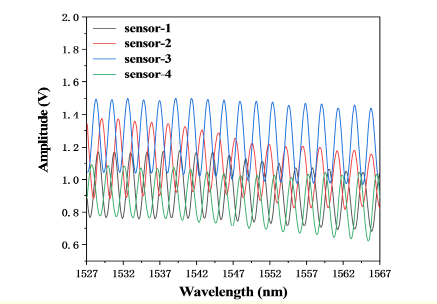

Fig. 2. Interference spectra of the four FP cavities obtained by wavelength scanning.

As shown in Fig 3, the results of the change of cavity length with strain variations at four different locations of the FP cavity after applying force to the cantilever beam, the change of cavity length decreases with time and the strain becomes smaller as the vibration amplitude of the cantilever beam decreases, so the change of strain can be monitored in real time according to the value of cavity length. Sensor 1, Sensor 2 and Sensor 3, Sensor 4 are connected to the upper and lower surfaces of the cantilever beam respectively, so there are positive and negative cavity length changes of the sensors, and the difference in the direction of the cavity length change can be obtained in the Fig 3.

The reason for the different amplitude of the fringes of 1 and 2 in the Fig 3 is that the sensors in the same plane are subjected to different strains due to the different positions of placement. According to the strain equation. The corresponding Sensor 1 will change more than Sensor 2 at the same moment with the same cavity length.

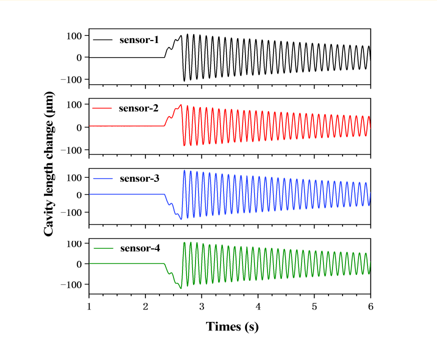

Fig. 3 Plot of cavity length-time data with strain

Conclusions

In this paper, a VT-DBR laser is used for high-speed wavelength switching, combined with a five-step phase shift algorithm to achieve simultaneous measurement of four channels of high-speed strain. The EFPI sensor in this paper is simple to fabricate, small in size, and can be used for accurate point strain measurement. The high-speed strain measurement system based on the VT-DBR laser may be suitable for more channels and more accurate strain measurements in the future.