СЕКЦИЯ «ИНФОРМАЦИОННО-КОММУНИКАЦИОННЫЕ ТЕХНОЛОГИИ»

УДК 004.5

A NEW KIND OF SENSING TECHNOLOGY – OPTICAL FIBER SENSOR BASED ON MODAL INTERFERENCE

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Abstract. *With the development of automation and intelligentize, sensor technology has been paid more and more attention to by scientific and technical researchers all over the world. In the numerous kinds of sensors, the optical fiber sensing technology represents the development trend of the new generation of the sensor and becomes one of the most developing high-tech industries due to the properties of high temperature resistance, high sensitivity, fast response, anti-electromagnetic interference, corrosion resistance, flameproof and so on. And the optical fiber sensor based on modal interference is a hot topic in recent years because it has the unique merits of simple structure, low cost and anti-disturbance. In this paper, the research background, basic sensing principle and developing trend of the optical fiber sensor based on modal interference has been introduced.*

Introduction

From the late 1970s, as the fabrication technology of optical fiber becoming mature, fiber optic sensing technology has been widely concerned and paid great attention to all over the world. Today, there are hundred types of fiber optic sensors implemented at national defense, mining, biomedicine, chemical and energy industry and other fields. People are more familiar with the sensor based on optical fiber grating, optical fiber Fabry-Perot cavity, Mach-zehnder interferometer, Michelson interferometer and so on. Recent years, the optical fiber sensors based on modal interference become a hot topic. The modal interferometer not only has the advantages that the optical fiber sensor has, like anti-electromagnetic, corrosion-resistant, high sensitivity, enabling remote sensing, small size, light weight, but also has the unique merits such as simple structure, low cost, anti-disturbance and high sensitivity, which overcomes the shortages of harsh fabrication process and easy to be disturbed in the traditional optical fiber sensors

In recent five years, the development of sensors based on modal interference is rapid. There are a lot of researches have emerged currently in this field in a global context, such as Ireland, Portugal, Mexico, the United States, China, Korea, India and other countries. The sensors based on modal interference are able to detect many kinds of parameters such as temperature, strain, curvature; magnetic field and liquid refractive index, et al. the sensing principle would be introduced following.

Basic sensing principle

The mode in fiber is defined as one or more discrete solutions in different optical wavelength for the Maxwell equations under different fiber physical structure and boundary conditions. In fact, when there are multiple modes propagating in the fiber simultaneously, the distribution of propagating modes in fiber is extremely complex. In order to simplify the calculation, one method is to approximate these modes as linear polarization (LP) modes in the weakly guiding condition. When there are multiple modes propagating in the fiber simultaneously, the phase difference between them generates within the same distance due to the difference of modal propagation constants. And then these modes encounter and superimpose at certain locations to interference, which is known as modal interference [1]~[3]. The interference spectrum can be changed by the variation of the length and refractive index distribution of the sensing

part. Thus, once the variation of measurands causes the change of fiber length and refractive index distribution, the interference spectrum would carry the information of measurands. And then people can obtain the variation value of measurands through the technologies of spectrum analysis or light power detection. For example, a typical single mode-multimode-single mode fiber (SMS) structure is given in Fig. 1. When ambient temperature change happened, because of the thermo-optic effect and thermal expansion effect of the fiber material, the length of multimode fiber (MMF) and effective refractive index would be changed accordingly, which contributes to the change of modal phase. Therefore, the interference spectrum would shift. We can calculate the ambient temperature variation via the linear relationship between the shift and ambient temperature.

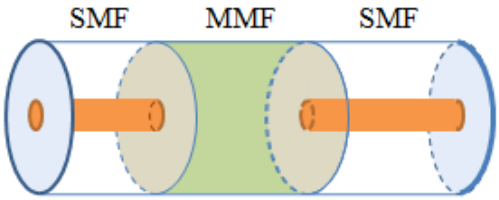

Fig. 1. Schematic diagram of the SMS fiber structure.

Developing trend

Throughout its development, it is easy to see that the study of modal interference based on modal interference in recent years has the trend to be hotter and discussed more deeply and extensively. Currently innovative idea on the mode excitation method is primarily extending into the combination of two or more structural optimization methods. The combination of taper and bending, taper and offset splicing could give consideration to more advantages of the methods. Combining with other fiber structure and special optical fiber is a large potential research field. The modal interference in PCF thinned core fiber, multicore fiber and hollow fiber is expected to be further researched and discussed. Moreover, combination with other types of special optical fiber (such as high-birefringence fiber, doped fiber) and other sensing system like fiber ring laser are of unique characteristics in modal interference and waiting for further development.

Integration and commercialization of the sensors based on modal interference need to be developed. How to package the sensor to ensure its high sensitivity, accuracy and mechanical strength, how to improve the interrogation system to abandon the complex and expensive OSA and achieve low-cost industrial production, and how to further extend the sensing range to be preferably applied in the actual environment and production, are extremely important and expected to be researched. Most of the researches now have not come down to this practice field. We could predict that once the sensors based on modal interference are produced commercially, it would bring a huge promotion in the sensing capability and low cost for the manufacturer.

References

[1] Mohammed, W.S.; Mehta, A.; Johnson, E.G. Wavelength Tunable Fiber Lens Based on Multimode Interference. J. Lightwave Technol. 2004, 22 (2), 469-477.

[2] Kumar, A.; Varshney, R.K.; Kumar, R. SMS Fiber Optic Microbend Sensor Structures: Effect of the Modal Interference. Opt. Commun. 2004, 232 (1-6), 239–244.

[3] Soldano, L.B.; Pennings, E.C.M. Optical Multi-Mode Interference Devices Based Self-Imaging: Principles and Applications. J. Lightwave Technol. 1995, 13 (4), 615-627.

[4] Donlagic, D.; Zavrsnik, M. Fiber-optic Microbend Sensor Structure. Opt. Lett. 1997, 22(11), C. 837–839.

[5] Kumar, A.; Varshney, R.K.; Antony, S.; Sharma, P. Transmission Characteristics of SMS Fiber Optic Sensor Structures. Opt. Commun., 2003, 219 (1-6), 215-219.