Dispersion Characteristics in Metal Coated Long Period Fiber Gratings

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***Abstract*—Based on the coupled mode theory, the influences of material dispersion on the spectral characteristics of the gold coated long-period fiber grating (LPFG) are studied theoretically. The theoretical simulation indicates that there are a series of de-dispersion grating periods, under which the electrical tuning characteristics of the tunable loss filter can be greatly improved. Besides, the spectral characteristics of metal coated LPFG sensor with sensitive film are investigated. The result shows that the resonant wavelength of the cladding mode shifts toward shorter wavelength direction when gold dispersion is taken into consideration. Also, the sensitivity of gold coated LPFG with sensitive film is studied in consideration of the dispersion. Simulation results show that the resolution of this sensor with optimal parameters to the sensitive film refractive index is 7×10^{-7}.**

Keywords- dispersion; de-dispersion grating period; metal film; long-period fiber grating

I. INTRODUCTION

In recent years, great attention has been focused on the LPFG with metal coatings, mainly due to their greater flexibility of the tuning of the LPFG resonant wavelengths and the potential applications for chemical sensing [1-2]. D. M. Costantini [1] reported a tunable loss filter based on the metal coated LPFG. The electrical tuning of the resonant wavelengths can be achieved by heating the metal layer. The metal coated LPFG with sensitive film presents a competitive advantage in sensor field for its easily tailoring the sensitivity characteristics.

Reference 3 pointed out that the maximum resonant wavelength shift was guaranteed by selecting optimal sensitive film thickness. The experimental result was in accordance with the theoretical simulation. However, there existed some deviation in the resonant wavelength. They thought that the deviation might result from a number of theory approximations and the neglect of the depth of the attenuation bands. In our opinion, the influence of material dispersion is important factor for this deviation of the resonant wavelength. Especially in optical communication wave band, the metal material dispersion is significant and can not be ignored.

In this paper, the influences of dispersion on the resonant characteristics are studied in the metal coated LPFG without or with an sensitive film. Data simulation shows that there are a series of special grating periods, under which the dispersion influence on the transmission spectra can be eliminated. On this condition, the tuning characteristics of the LPFG filter is studied and proved to be improved. Further, the influences of dispersion on the spectral characteristics of metal coated LPFG with sensitive films is discussed, and the optimum design for high sensitivity LPFG sensor is investigated, which will be guidelines for the practical design of LPFG sensors.

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II. DISPERSION OF METAL COATED LPFG

A. De-dispersion Grating Period

The refractive index and extinction coefficient are derived of the gold dispersion are derived from the discrete data[4]. Fig. 1 shows the relationship between the resonant wavelength of the 10th cladding mode (EH_{15}) and the grating period when the material dispersion of each layer of gold coated LPFG are taken into consideration separately. The line B, C, D and E in Fig. 1 present the curves without considering the dispersion, considering the core dispersion, the cladding dispersion and the gold dispersion respectively.

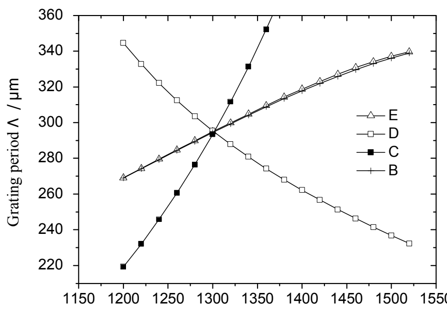

Fig.1 Relation curves between grating period and resonant wavelength with material dispersion considered

As can be seen from Fig. 1, the resonant wavelength shifts towards the short-wave direction after considering the metal dispersion for any grating period ranging from 300 μm to 340 μm. In addition, Fig. 1 shows clearly that the four curves almost intersect at one point when the grating period is 295 μm. It means that under this grating period, the material dispersion has hardly an influence on the resonant wavelength for the EH_{15} cladding mode. So this grating period is called as the de-dispersion grating period for the specific cladding mode.

B. *Tuning Property of LPFG with De-dispersion Period*

The tuning property of metal coated LPFG tunable loss filter under the de-dispersion grating period Λ_E and the deviation of the de-dispersion grating period Λ are shown in Fig 2(a) and Fig. 2(b). It is obviously indicated that the tunable loss filter designed with the de-dispersion grating period not only retains the spectral shapes and stop-band, but also has stable optical filtering percent while heating the metal coating.

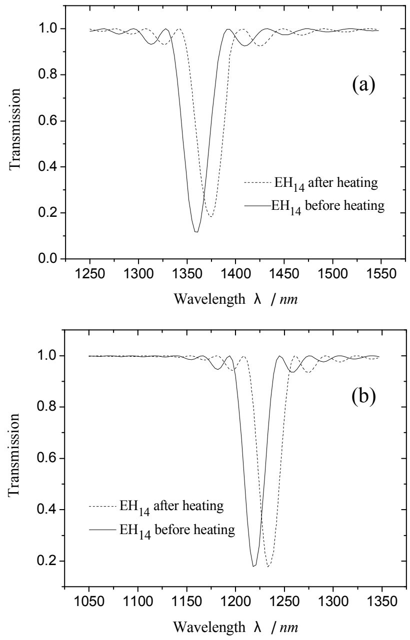

Fig.2 Transmission spectrum of the EH_{14} cladding mode as temperature rises under different periods (a) Λ=346 μm; (b) Λ_E=306 μm

III. DISPERSION OF METAL COATED LPFG WITH SENSITIVE FILM

A. *Junmping Region in Resonant Wavelength*

For a metal coated LPFG sensor, the sensitive film thickness must be chosen to guarantee that the resonant wavelength is not located at the jumping region. The dependence of the resonant wavelength on the sensitive film thickness before and after considering metal dispersion is shown in Fig. 3.

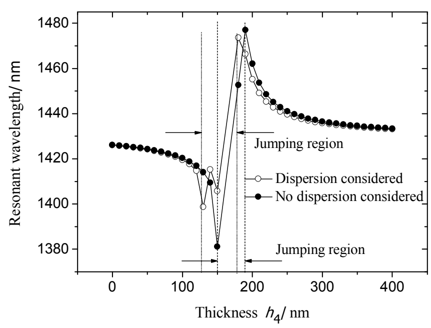

Fig.3 Relation of the resonant wavelength with the sensitive film thickness

Without regard to the gold dispersion, there exists jumping region in the sensitive film thickness of 150-190 nm. After considering the influence of gold dispersion, the jumping region is broaden and is located in the sensitive film thickness of 127-178 nm. In practice, the gold dispersion should be taken into consideration in selection of the sensitive film parameters so as to avoid from jumping region.

B. *Optimization Design of This LPFG Sensor*

In order to bring the variation of the resonant wavelength into play to the utmost, the film optical parameters must be optimized to improve the sensor sensitivity. Fig. 4 shows the dependence of sensitivity S_n on the sensitive film index n_4 and thickness h_4 when the grating parameters in consideration of the material dispersion. For a commonly used spectrometer, the wavelength resolution which is 0.01 nm. From Fig. 4, the resolution of this LPFG sensor is predicted to 7×10^{-7} when the optimal sensitive film parameters are given.

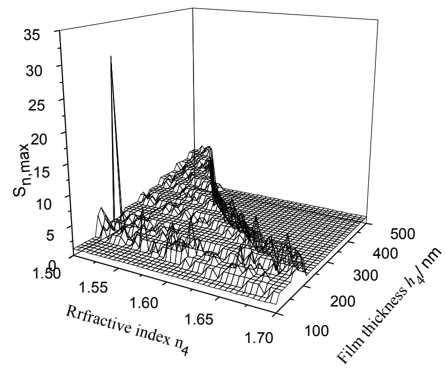

Fig.4 Dependence of S_n on h_4 for n_4 Dispersion considered

IV. CONCLUSION

Data simulation shows that There exists a series of de-dispersion grating period corresponding to the different orders of the cladding mode, by which the influence of material dispersion on the specified cladding mode and the lower orders of cladding mode can be eliminated. Under the de-dispersion grating period, the electrical tuning characteristics of the tunable loss filter can be greatly improved. the jumping region of the response of the resonant wavelength varies with sensitive film thickness is broaden gold coated LPFG with sensitive film owing to the influence of the gold dispersion. the accurate optimal sensitive film parameters dispersion is taken into consideration. supplies accurate parameter combinations in the design of this kind of sensor.

REFERENCES

[1] D. M. Costantini, C. A. P. Muller, S. A. Vasiliev et al.,"Tunable loss filter based on metal-coated long-period fiber grating", IEEE Photonics Technology Letters, Vol. 11, pp. 1458-1460, 1999.

[2] J. L. Tang, S. Chengb, W. T. Hsub, T. Y. Chiang, et al. "Fiber-optic biochemical sensing with a colloidal gold-modified long period fiber grating", Sebsirs abd Actuators B, Vol. 119, pp. 105-109, 2006.

[3] Jesus M. Corres, Ignacio del Villar, Ignacio R. Matias, et al. "Two-layer nanocoatings in long-period fiber gratings for improved sensitivity of humidity sensors", IEEE Transactions on Nanotechnology, Vol. 7, pp. 394-399, 2008.

[4] Edward D P. "Handbook of optical constants of solids", New York: Academic Press, pp. 35-38,1985.