Research and Implementation on Temperature and Humidity Measurement System Based on FBG

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Abstract. In the paper, we design a distributed fibber Bragg grating temperature and humidity measurement system, the clock pulse broadband light source, combined with time division and wavelength division multiplexing fiber Bragg grating sensor network technology, we will can solve complex problems with addressing to fiber Bragg grating, change of the PI film coating for the humidity, we propose a non-power temperature and humidity sensors. The use of arrayed waveguide grating sensor signal demodulation technology, through theoretical analysis confirmed the feasibility of the system. System for temperature and humidity measuring range (20 ~ 80) ℃, (10 ~ 90) % RH measurement accuracy is achieved within ± 0.2 ℃ and ± 5% RH for real-time measurement.

Keywords: Distributed, Fiber, Measurements temperature and humidity.

1 Introduction

In agriculture, food storage is a very important parameter, the traditional method of measuring relative humidity and electromagnetic interference, and high humidity has the shortcomings difficult to measure; to play a non-power electromagnetic humidity sensor interference, fire, explosion-proof and other advantages to address the petrochemical, power, textiles and other areas of flammable and explosive environment temperature and humidity measurement and control problems, prompting people to study the new non-power humidity sensor [1]. In this paper, modified polyimide (PI) thin film humidity sensor for fiber grating (FBG) coated layer to form fiber grating-based temperature and humidity sensors. A sensor principle.

FBG-based temperature and humidity sensors mainly by the temperature and humidity sensitive FBG1 and temperature-sensitive FBG2 only [2-4] formed, as shown in Figure 1. Outsourced humidity film (PI) of FBG1 while the temperature-sensitive measurement of the change in the scene ΔT and relative humidity variation ΔH, without (PI) is only sensitive to humidity coating FBG2 temperature variation ΔT, and then into the center wavelength λB1, λB2 displacement ΔλB1, ΔλB2, then ΔλB1, ΔλB2 mathematically can be At the same time come to the specific values of temperature and humidity changes.

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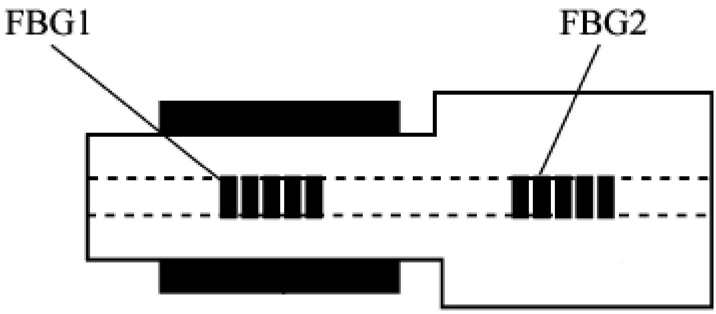

Fig. 1. Structure of the FBG temperature and relative humidity

According to the coupled mode theory, FBG reflection wavelength $\lambda_{Bi}\left(i=1,2\right)$ Satisfy the following formula:

$$\frac{\Delta\lambda_{Bi}}{\lambda_{Bi}}=\frac{\Delta n_{eff}}{n_{eff}}+\frac{\Delta\Lambda_i}{\Lambda_i} \tag{1}$$

The first right-hand side relative humidity of the ground caused by the change in ΔRH elastic-optic effect and temperature variation ΔT caused by the combined effect of thermo-optic effect of the results; ΔRH and the second is due to thermal expansion of axial strain and FBG.

As the humidity between the coating and fiber binding, ΔRH axial strain caused by FBG1 Free State for the axial strain and strain difference constraints, available from the elasticity theory:

$$\frac{\Delta\Lambda_i}{\Lambda_i}=C_1\beta\Delta\mathrm{RH} \tag{2}$$

$$C_1=\frac{E_{\mathrm{H}}(r_{\mathrm{H}}^2-r_{\mathrm{F}}^2)(1-2\mu_{\mathrm{F}})}{(1-2\mu_{\mathrm{H}})r_{\mathrm{F}}^2E_{\mathrm{F}}+(r_{\mathrm{H}}^2-r_{\mathrm{F}}^2)(1-2\mu_{\mathrm{F}})E_{\mathrm{H}}} \tag{3}$$

Where, respectively, the wet film humidity expansion coefficient, Poisson's ratio and Young's modulus; respectively, humidity and film cross-section of the fiber cladding radius. Consider the elastic-optic effect, thermo-optic effect and thermal expansion effects, FBG1 reflection wavelength can be expressed as relative change:

$$\frac{\Delta\lambda_{B1}}{\lambda_{B1}}=\mathrm{C}_1(1-\mathrm{p_e})\beta\Delta\mathrm{RH}+\left[\mathrm{C}_1(\alpha_H-\alpha_{\mathrm{F}})+\xi\right]\Delta T=K_{T1}\Delta T+K_{\mathrm{H1}}\Delta\mathrm{RH} \tag{4}$$

Where $\mathrm{p_e}$, ξ Optical fiber were effective elastic coefficient and thermal coefficient ; α_H , α_{F} Film and fiber, respectively humidity coefficient of linear expansion ; K_{T1} , K_{H1} Were FBG1 temperature and relative humidity sensitivity coefficient.

For the temperature-sensitive FBG2, since then $\beta = 0$, $K_{H2} = 0$ Value of the resonant wavelength can be expressed as the relative displacement

$$\frac{\Delta\lambda_{B2}}{\lambda_{B2}} = [(1 - p_e)\alpha_F + \xi]\Delta T = K_{T2}\Delta T \tag{5}$$

Where KT2 temperature sensitivity coefficient for the FBG2 1 solving the equation (4) and (5) the composition of the equations, you can also come to value the relative humidity and temperature changes ΔH value ΔT.

2 Measurements System of Temperature and Humidity of Distributed Fiber Grating

Distributed FBG strain and temperature measurement system at the same time, broadband light pulses emitted by a light pulse through the 3dB coupler, the arrival time delay switch [5]. It is the pulse of light into the sensing grating portal. Delay switch to turn it in turn connected to two channels gating to ensure that all the pulse arrival time delay of light in the switch, there will be a gated channel in the state, so that pulsed light can smoothly enter the sensing grating array , so that the whole system works. System, the time delay switch with the clock signal frequency remains the same. Two adjacent pulses of light that will enter different pathways to complete the different points of measurement. After a time delay switch gating, broadband light incident to the sensing FBG array. Satisfy the Bragg lattice wave length of light from the matching conditions reflected the various grating was demodulation receiver. Demodulation system using an array waveguide grating (AWG), each array from the AWG Reuters emitted light shines through each optical tube. At this point, the light signals into electrical signals. Signal input to the computer for processing, which can achieve wavelength demodulation of fiber Bragg grating, in order to achieve the simultaneous measurement of temperature and humidity.

Analysis of existing test results, it is easy to see:

In (20 ~ 80) ℃, 10% ~ 90% RH range, the fiber grating humidity sensor output power and temperature and humidity changes is linear. FBG-type humidity sensors humidity hysteresis ≤ ± 1.5%, long-term stability is better than power humidity sensor; dynamic response time of less than 15s (depending on humidity-sensitive coating thickness PI). Mainly affected by the FBG demodulation system accuracy and PI humidity coating thickness uniformity of the limit, fiber grating sensor for relative humidity, humidity and temperature measurement accuracy was ± 5% RH and ± 0.2 ℃.

FBG-based temperature and humidity sensor linearity thanks to the humidity, chemical stability of the PI film modified humidity, with design flexibility, long-term stability and interchangeability, fast response of the outstanding advantages of an addition, FBG sensors the inherent high accuracy, intrinsically safe, multiplexing ability, etc., so that the sensor in the petrochemical, power, textiles and other areas of high temperature, corrosion and other special circumstances in the multi-point, temperature and humidity measurement and control of distributed systems has a good prospect.

Will be calculated multimode fiber grating reflectivity spectrum and reported in the literature compare the experimental spectra: near 1550nm are presented in more than one peak reflectivity is relatively small, but the experimental spectra shows a peak a few more, mainly As the experiments measured the interaction between the main mode reflection is stronger than the theoretical calculation, resulting in larger number of each reflection peak, the peak number of total number; in dispersion shifted fiber, due to the excitation mode is less so than the 850nm peak number the calculated spectrum near a lot less, and the interaction between the peaks is almost no reflection, but the main mode of self-reflectivity is relatively large. This you can see, the use of incentive model number changes [1] and other means to reduce the number of patterns that can reduce or even eliminate the inter-reflection, self-reflection of the increased peak reflectivity, the multi-mode fiber grating to practical use.

3 Conclusions

In this paper, the concept of independent raster mode, type of gradient-index multimode fiber grating numerical simulation, has been a multi-mode fiber grating reflection spectrum. You can see, the axial dielectric grating perturbation, the grating length and operating wavelength of the grating reflection spectrum will have an impact. In general, the axial length of the dielectric perturbation changes led the General Assembly and the grating peak reflectivity increases, but the main mode of interaction between the different reflections in the axial perturbation larger dielectric constant in the case has been strengthened, while the grating length it has little effect. Meanwhile, the two have little impact on bandwidth. The working wavelength in the case of larger, will reduce the main mode, corresponding to the larger peak reflectivity and bandwidth is significantly increased. Calculated and experimental spectra in comparison, to get some of the similarities and differences: theoretical and experimental spectra are presented multi-peak structure, but the experiment of self-reflection theory of self-reflection than the small, 1550nm near the experimental spectrum, each reflection is much stronger than the theoretical calculations. In the dispersion-shifted fiber Bragg grating, because it is fewer models excitation, a significant reduction in the number of peaks, each reflecting little, but the main mode of self-reflectivity is relatively large.

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