A FBG and Magnetostrictive Alloy based Magnetic Field Sensor with the Demodulation realized by Optoelectronic Oscillator

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ABSTRACT

A FBG and magnetostrictive alloy based magnetic field optical sensor is realized with the demodulation by a new dual-loop optoelectronic oscillator (OEO). Unlike the previously reported OEO-based sensing schemes, the stability of this proposed scheme is enhanced by using the combination of a fiber ring laser (FRL) cavity and a dual-loop OEO structure. The sensitivity of -48.40476 Hz/mT is obtained. The stability is up to 0.194 ppm, which is the highest value to the best of our knowledge among the OEO-based demodulation schemes.

EXPERIMENTAL SETUP AND THEORETICAL ANALYSIS

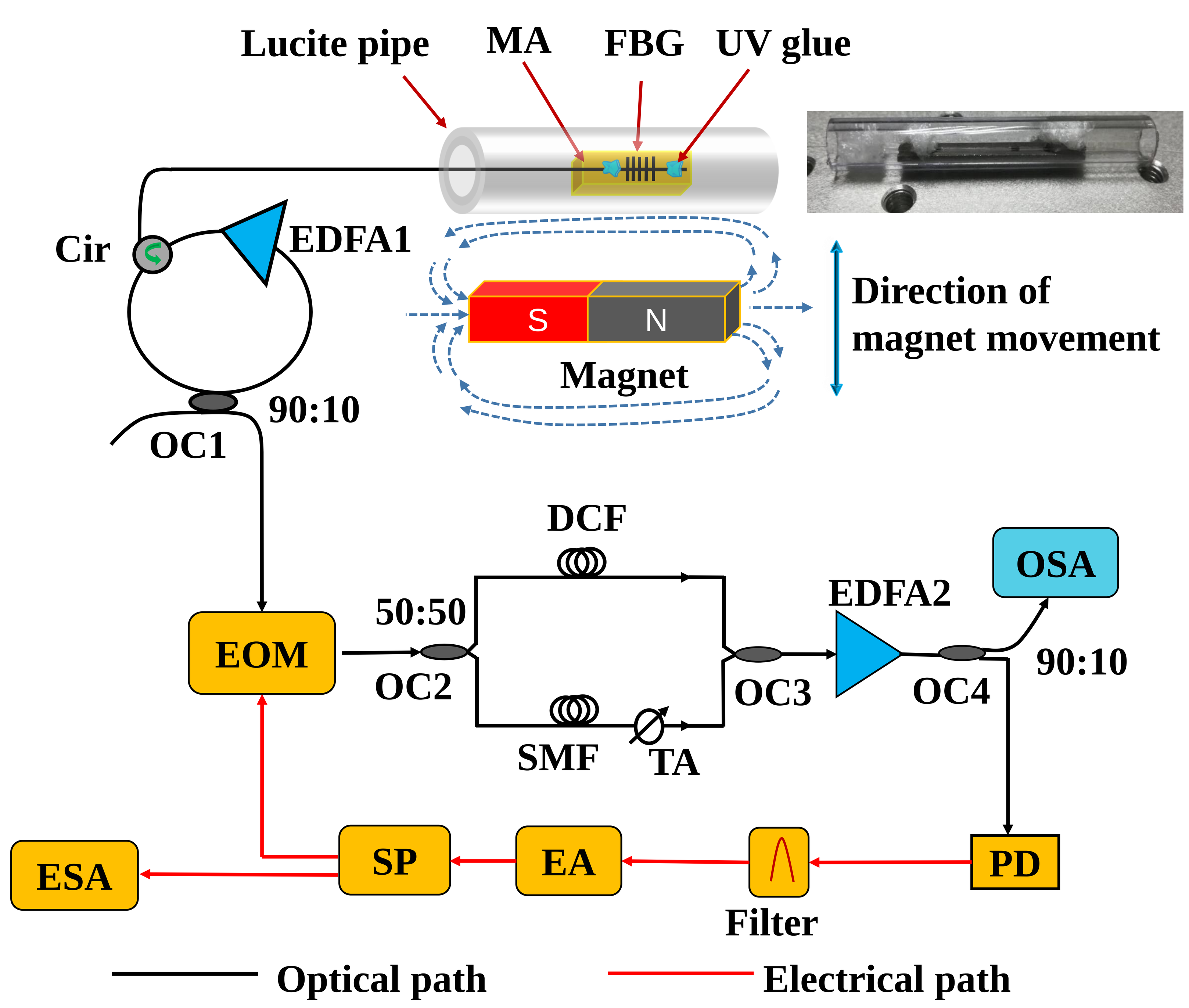

Fig.1. Experimental setup of the proposed scheme.

The wavelength shift of FBG can be obtained by:

$$\Delta\lambda = \lambda\{(1-P_e)kH + [\zeta + \alpha_f + (1-P_e)(\alpha_{MA}-\alpha_f)]\Delta T\} \qquad (1)$$

where Δλ is the wavelength variation of FBG, λ is the original central wavelength of FBG, P_e (≈0.22) is the elastic-optic coefficient of optical fiber, *k* is the coefficient of magnetostriction, *H* is the magnetic field intensity, ζ (≈7×10^(-6)/°C) and α_f (≈0.5×10^(-6)/°C) are the thermo-optic coefficient and the thermal expansion coefficient of optical fiber respectively, α_{MA} is the thermal expansion coefficient of magnetostrictive material, and ΔT is the variation of temperature.

The N^{th} harmonic of a common single-loop OEO can be written as:

$$f_N = N * FSR = N/t_m \qquad (2)$$

where t_m presents the total delay time of the m^{th} single loop in the OEO cavity, which includes optical-link delay and electric-link delay.

The frequency shift of the dual-loop OEO with the relationship of the measured magnetic field can be expressed as (the influence of temperature is ignored):

$$\Delta f_{N-dual} = -\frac{N*D}{C*FSR_1^{2}} * \lambda[(1-P_e)*kH] \qquad (3)$$

RESULTS AND DISCUSSIONS

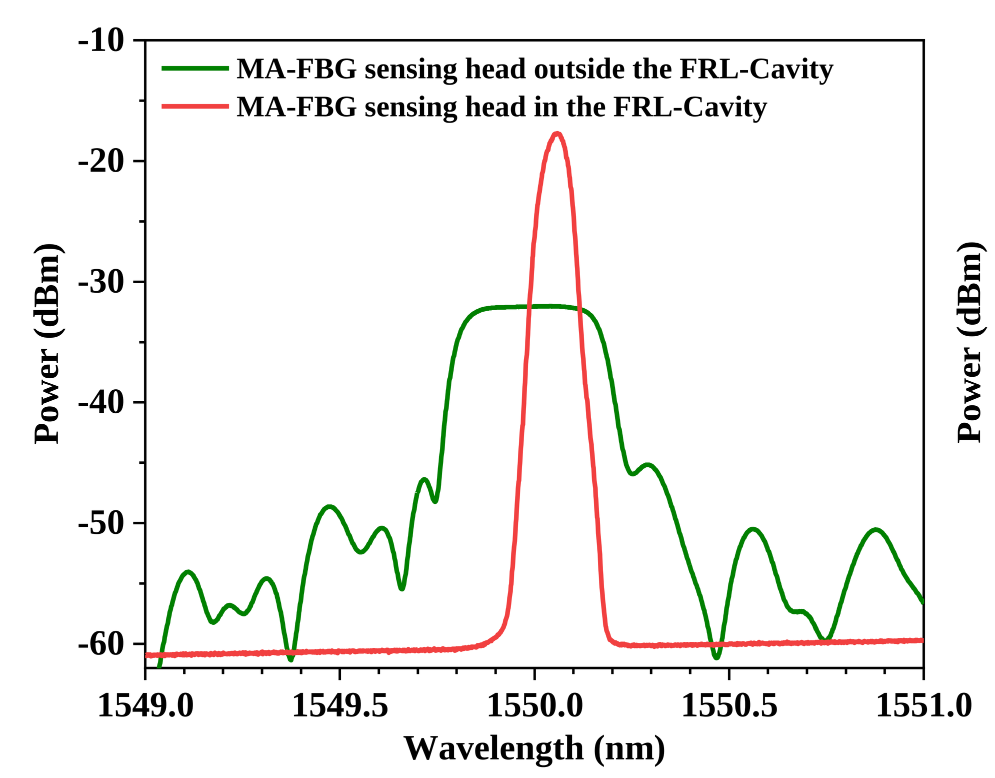

Fig.2. The measured optical spectrum of the FBG-based sensing head with two different designs.

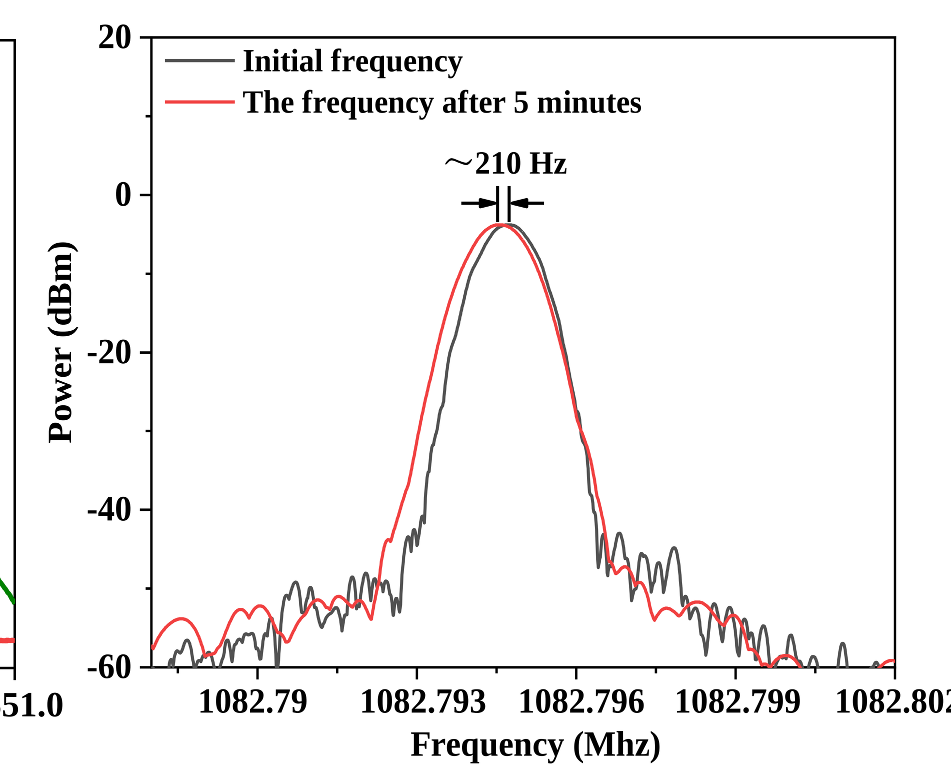

Fig.3. The measured frequency shift in 5 minutes.

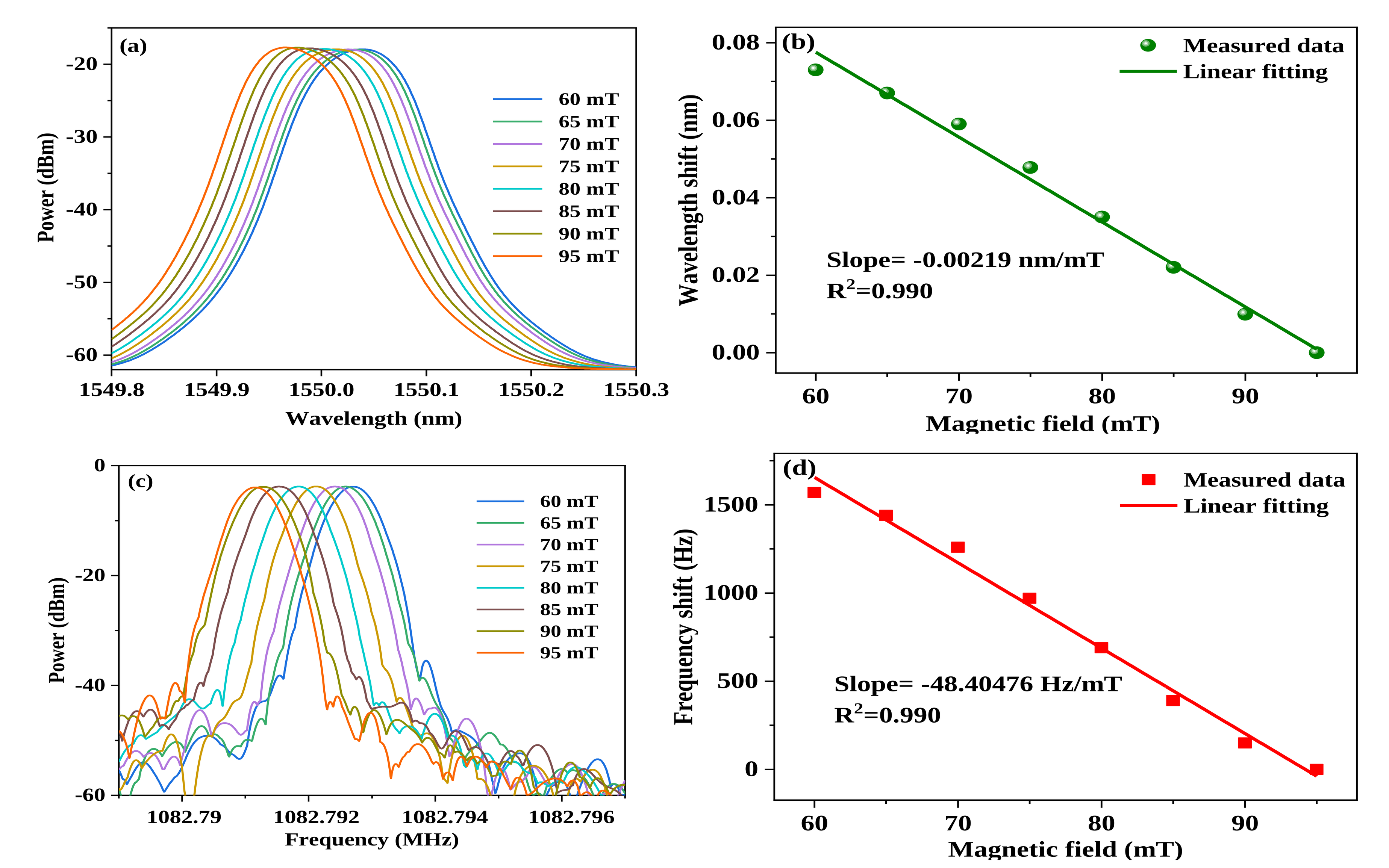

Fig.4. The measured results.(a) The measured results in optical domain, (b) the linear fitting results corresponding to (a), (c) the measured results in microwave doamin, (d) the fitting results corresponding to (c).

We define the frequency-shift value divided by the tracking frequency value as the stability, and the result is up to 0.194 ppm. This result is better than most of the reported results of the single-loop OEO based interrogation systems. In addition, the measured phase noise is -122.1 dBc/Hz@10 kHz. A pre-tension value of the FBG when it bonded on the MA strip can improve the sensitivity. Tracking a higher order resonant mode can also improve the sensitivity.

CONCLUSION

The main innovation of this system concludes two aspects: One is utilizing the FRL cavity to improve quality of the optical carrier, and the other is that by using another section of SMF to form a dual-loop structure, the stability of the system is further enhanced. The stability of the system is up to 0.194 ppm, which means it has great potential in practical applications.