Demonstration of etched fiber based twin-cantilever configuration in simultaneous measurement of magnetic field and magnetization

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1. Introduction

For decades, measurement of magnetic field using all-optical, remotely addressable and flexible fiber based system, has drawn the attention of many researchers. However, most of the reported measurement schemes are associated with the induced longitudinal strain measurement caused by applied magnetic field. Most of these sensing configurations require complex hardware or signal processing system for analyzing the result and that limits their area of application.

With this motivation, we emphasized on devising a fiber-optic twin-cantilever based sensor configuration, capable of detecting low order magnetic field with minimum system complexity. To increase the sensitivity further, we reconfigured the twin-cantilever assembly by incorporating etched fiber cantilevers in the scheme. In this work, we report our experimental results with improved sensitivity obtained from twin-etched fiber-cantilever assembly. Magnetic field as low as ~1mT was successfully detected using this improved scheme.

2. Experimental Details and Result

In the twin-cantilever set-up (Fig. 1), magnetic field in the vicinity was measured by modulating the amplitude of the propagating light through optical fibers utilizing induced magnetization of the probe Cobalt-doped nickel ferrite ($Ni_{0.97}Co_{0.03}Fe_2O_4$) sample [1, 2].

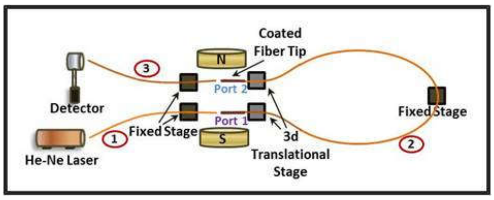

Fig. 1. Schematic of fiber-optic twin-cantilever set up

Twin sensing probes were fabricated by using etched single mode fibers (S405-XP) coated with probe magnetic materials having coated fiber lengths (1.2±0.1) *cm*. Etched fiber diameters were estimated to be (60±5) μ*m*. Variation of transmitted light at the end output fiber (fiber 3) with the application of gradually increasing/decreasing magnetic field was recorded then. As etched coated fibers are more flexible and accessible to magnetic field compared to normal ones, they showed much better sensitivity in terms of power variation as expected. The improved response of this modified scheme is shown in figure 2(left). Also in this figure, we plotted the results obtained from twin-cantilever configuration using normal fibers [3] to validate the greater response of the modified scheme.

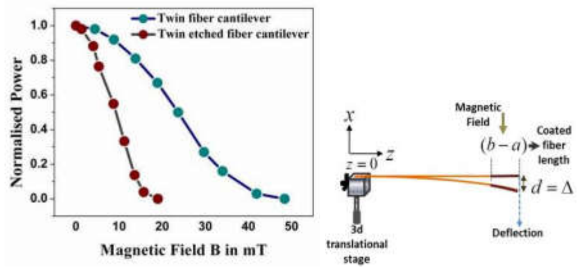

Fig. 2. Response of twin-fiber-cantilever configurations in external magnetic field (left) and schematic of bending of coated fiber (right)

3. Determination of Magnetization of magnetic sample

Apart from sensing magnetic field (B) of very weak intensity, the developed scheme is also useful in determining magnetic properties of the probe sample (sample volume V_m) like magnetization (M) by using the basic torque (τ_m) equation

$$\tau_m = V_m M \times B \qquad (1)$$

For our case of distributed torque (Fig.2 (right)) acting over the coated length (b-a), equation (1) will be modified as [2]

$$\Delta = \frac{V_m BM}{6EI}\left[2b\left(b+a\right)-a^2\right] \qquad (2)$$

Here deflection of free end of individual fiber tip is denoted by Δ. E and I are the elastic modulus and the geometrical moment of inertia of the cantilever substrate respectively. Hence, magnetization of probe sample can be obtained by computing deflections (Δ) of coated fiber tip for different values of magnetic field [2].

4. Conclusions

Magnetic field of the order of 1 *m*T was successfully detected using twin-etched fiber-cantilever technique. This method can be used in estimating magnetic properties of the probe sample also. The sensitivity can be further improved by using a cascaded cantilever technique.

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References

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