Performance of Low Magnetic Field detection using Double Cantilever Fiber-Beam Deflection-Transmission Configuration

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1. Introduction

In recent years, a new technology, involving cantilevers of different types (a plate, beam or a thin membrane), has attracted much interest in the area of sensing and device applications [1]. Among these, the fiber optic cantilever technique has become very exciting and drawn research attention due to their flexibility, remotely addressable and multiplexed operation and capability of working in a very hazardous environment.

In this work, we report our experimental configuration that we have developed using a fiber optic double cantilever set-up for sensing low magnetic field (~5mT) using Cobalt-doped nickel ferrite ($Ni_{0.97}Co_{0.03}Fe_2O_4$) probe sample. A theoretical model is also formulated to demonstrate the effect of increasing number of cantilevers in the set up for sensing very low order field [2].

2. Probe Preparation and Characterization

Cobalt-doped nickel ferrite sample was prepared from nitrate salts of iron, nickel and cobalt by sol-gel method [3]. The crystalline structure and magnetic properties of the prepared probe material ($Ni_{0.97}Co_{0.03}Fe_2O_4$) were investigated respectively by XRD analysis and SQUID measurement. The lattice constant was estimated to be ~8.35Å and the coercive field (H_c) was observed to be 175.50 Oe.

3. Experimental Details and Result

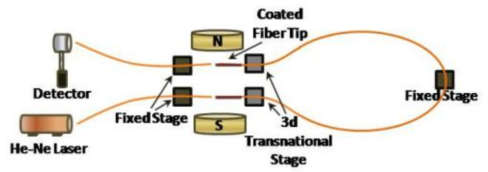

Fig. 1. Schematic of fiber-optic double-cantilever set up

Cobalt-doped nickel ferrite nanoparticles coated optical fibers were used as cantilever for the detection of magnetic field utilizing a fiber beam double cantilever set-up (Fig. 1). We recorded the intensity of light coupled into the receiving fiber as a function of gradually increasing magnetic field causing the deflections of the coated fibers. Fiber-to-fiber transmitted power variation conveyed the existence of magnetic field in the vicinity.

The experimental result of power variation with the applied calibrated magnetic field using double cantilever method for the case of a set of normal SMF fibers with 3.0 cm cantilever lengths is shown in Fig. 2. Also in this figure, we plotted the results obtained from single cantilever technique to compare the improved higher response of double cantilever method as regards the single cantilever setup.

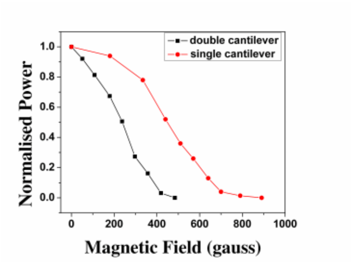

Fig. 2. Transmitted power variation with applied magnetic field using single and double cantilever techniques

4. Theoretical Model

Variation of transmitted power (T) coupled into the third receiving fiber with applied external magnetic field due to transverse misalignments (d) between two optical fibers for double-cantilever configuration is expressed as

$$T = \left(\frac{2w_1w_3}{w_1^2 + w_3^2}\right)^2 e^{-\frac{8d^2}{w_1^2+w_3^2}}$$

Here w_1 and w_3 are the spot sizes of Gaussian fundamental modes of the first input fiber and receiving fiber respectively. This transmitted power variation profile for single-mode optical fibers having mode field diameters 4.6μm±0.5μm at 632 nm wavelength is plotted in Fig. 3 which nicely interprets the experimental results

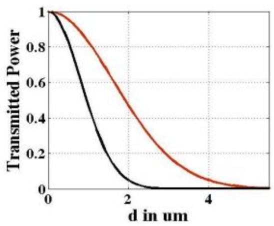

Fig. 3. Theoretical transmitted power variation profile for both single (red curve) and double-cantilever (black curve) set ups

5. Conclusions

Magnetic field of the order of 5 mT was successfully detected using double cantilever technique. This method showed a greater sensitivity than single cantilever set up. The sensitivity can be further improved by using a cascaded cantilever technique.

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