Fiber-optic displacement sensor

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1. INTRODUCTION

Fiber-optic technology offers the possibility of development of physical sensors for wide range of physical parameters. Their main advantages lie in their all-dielectric construction giving electrical isolation, immunity from E.M. field, information security and others.

This paper describes a microbend displacement sensor with high sensitivity and wide dynamic range designed on the bases of multimode sensor-oriented fiber. A number of high sensitive sensors has been design on the basis of microbending induced mode coupling of core to clad modes.[1,2] Usually these sensors need very accurate alignment of input end face with light source for selective mode excitation.

We propose a modified sensor configuration based on microbending induced mode coupling. With a modified sensor configuration the alignment requirements are reduced and the possible sensitivity to some extent is higher than with conventional configuration sensor.[2]

2. EXPERIMENTAL RESULTS

The sensor consists of silica step index multimode optical fiber and a conventional deformer (Fig.1). The deformer represents two grooved plates with five teeth. One plate of the deformer can be displaced relative to the other by manually adjusting differential micrometer or by means of a piezoelectric transducer. The silica fiber has a modified sensor oriented structure. The sensing section of the fiber represents a short segment which has the coating jacket removed. Instead of the coating jacket a thin film of chalcogenide glass material is deposited. The thickness of chalcogenide film is about 2 μm. Note that the refractive index of chalcogenide glass film is about 2.4. The deformer is applied on the section of the fiber which is coated with chalcogenide glass film. The signal, that is the light in the clad modes, was detected by a photodiode placed in an integrating sphere.[3] By monitoring the light power in the clad modes one can detect the applied deformation.

For clad modes detection the end segment of the is bent as is shown in Fig.1 to allow the clad modes out. This bent segment of the fiber is placed inside the integrating sphere just in front of the photodetector. The bent configuration of the fiber end allows the

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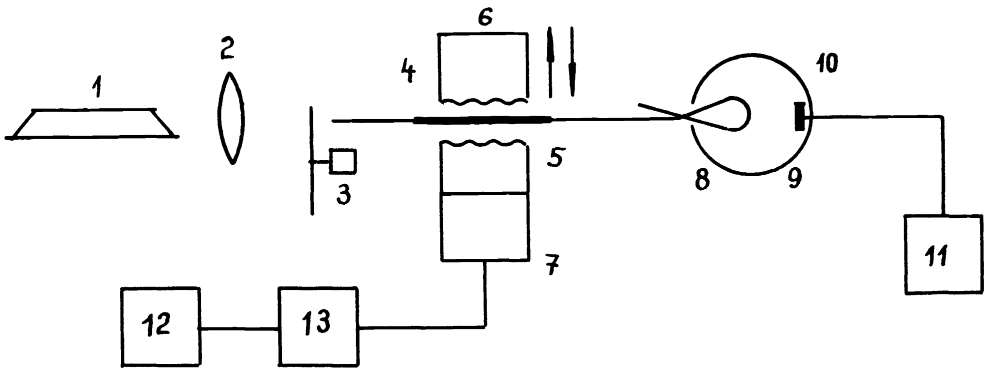

Fig.1. Experimental set-up: 1 - He-Ne laser; 2 - microobjective; 3 - chopper; 4 - optical fiber; 5 - chalcogenide glass layer; 6 - deformer; 7 - piezoelectric transducer; 8 - bend-end of the fiber; 9 - integrating sphere; 10 - photodiode; 11 - lock-in amplifier; 12 - generator; 13 - amplifier.

sensitivity of the device to be improved. In the case of monitoring the light power in the clad modes the background core light must be allowed out. Optical power in the fiber clad is attenuated in propagation to the displacement amplitude via coupling from propagation to radiation modes. The power lost from the core to radiation modes is optimum when the fiber's spatial bend frequency equals the difference in propagation constants ($\Delta\beta$) between propagating and radiation modes:

$$\Delta\beta = \pm \frac{2\pi}{\Lambda}; \tag{1}$$

where Λ is the corrugation spacing. In the case of step-index fibers $\Delta\beta$ is given by:[4]

$$\Delta\beta = \frac{2\,\Delta^{1/2}}{a} \cdot \frac{m}{M}, \tag{2}$$

where a is fiber core radius (25 µm);
m is mode number;
M is total number of modes;

$\Delta=(n_{core}-n_{clad})/n_{clad}$.

For radiation coupling of higher order modes to adjacent higher order modes and radiation modes the optimum corrugation spacing may be calculated as follows:[4]

$$\Lambda = \frac{\pi a}{\Delta^{1/2}} \cong 2 \text{ mm}. \tag{3}$$

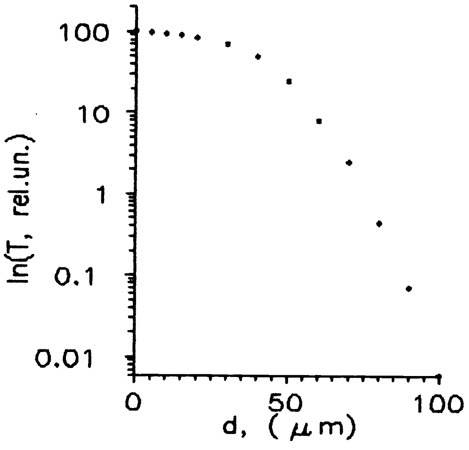

Fig.2

Optical transmission T of fiber structure was mesured with He-Ne laser as a light source. The light was injected into the fiber end face by means of conventional 90x microobjective.The output signal was monitored by a photodiode with a lock-in amplifier or with a digital millivoltmeter. The fiber transmission T was measured vs. displacement D for different fiber structure modifications. Optical transmission of the fiber strongly changed with displacement (Fig.2). Both sensitivity and dynamic range of the sensor are increased compared with similar microbend sensor.[2] For example at displacement amplitude of 100 μm the relative transmission change is more than 50000. The achieved sensitivity T/D is about 0.1 mV/Å. The sensor is simple in alignment with the light source, has a wide dynamic range and high sensitivity.

In addition to displacement such sensor can be modified to detect pressure, acceleration, etc.

3. CONCLUSION

We have shown that employment of a sensor oriented fiber with chalcogenide glass layer as absorption media to gather with a bent-end configuration let us to improve the sensibility of fiber-optic displacement sensor.

4. REFERENCES

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