TEMPERATURE INSENSITIVE FIBER OPTIC SENSOR FOR ACOUSTIC WAVE DETECTION

Ashish M. Vengsarkar, Kent A. Murphy, C.J. Chung
and Richard O. Claus

Fiber & Electro-Optics Research Center
Virginia Polytechnic Institute and State University
Blacksburg, VA 24061

INTRODUCTION

Ultrasonic detection of surface acoustic waves has been shown to have important applications in determining microstructural properties, inspection of materials for quality control and for detection of flaws in materials. Several laser generated optical techniques have been shown to be highly sensitive for the detection of ultrasound [1]. However, light transmission through air has several problems and fiber optic sensors are rapidly gaining popularity because of their high sensitivity, small size and low transmission losses.

Single mode fiber optic interferometric sensors (FOIS) have been shown to possess high sensitivities for various applications. Measurement of real time phase-shifts have been demonstrated in acoustic, temperature, magnetic and strain sensors [2-4]. In the FOIS reported so far, light from the reference arm and the sensing arm is recombined after the external perturbation has acted upon the sensing arm, and the difference in phase observed at the detector is used to give an indication of the parameter to be measured. One cause for concern in such a FOIS is the sensitivity of phase to a miniscule change in the temperature which can lead to a change in the phase in either arm of the interferometer. This happens because the reference and the sensing arms are physically at different locations and hence a change in temperature in one arm does not necessarily imply a change in the other. This leads to a misinterpretation of the observed change in phase due to temperature change being attributed to the external perturbation to be measured.

In the case of homodyne detection, the differential drift in the arms of the interferometer caused by random temperature fluctuations produces a fading in the amplitude of the detected signal. It is essential to maintain the FOIS continuously at its quadrature point. One of the techniques to maintain maximum sensitivity suggested by Jackson et al [5] uses a piezoelectrically stretched coiled fiber. Use of highly birefringent fibers have been suggested [6] in single-fiber interferometers where the interfering modes within the fiber see exactly the same temperature conditions. Recently, an integrated optic micro-displacement sensor, which used a Y junction and a polarisation maintaining fiber, was reported [7].

This paper describes a novel technique used to build a thermally stable FOIS. The sensor is easy to construct and can be used as a probe in high temperature zones for detection of surface acoustic waves.

SENSOR CONSTRUCTION

The sensor head was constructed as follows:

1. A fused biconical tapered coupler was constructed using a technique described by [8] from a 4/125 single mode fiber with numerical aperture 0.1.
2. The two output arms of the coupler were cleaved immediately after the coupled length.
3. The coupler was inserted into a cylindrical glass tube, fixed with epoxy and polished until two cores, very close to each other, could be observed.
4. Aluminium was selectively deposited at the end of one of the cores in an evacuated chamber.

The core with the reflective end was used as the reference arm and the open core as the sensing arm, as shown in Figure 1.

RESULTS

Figure 2 shows the schematic set-up of the displacement sensor.

A He-Ne laser (λ= 632.8 nm) was used as the source to inject light into the fiber and light from the second input arm of the coupler was monitored using a p-i-n detector. The sensor head was placed very close to a piezoelectric tube surface. The input to the tube was varied from dc to 100 kHz and the outputs obtained were highly stable with respect to time. Temperature variations of more than 10°C over a period of several hours did not have any effect on the observed outputs. Figure 3 shows the output at 5 kHz. Displacements in the subnanometer range were measured.

CONCLUSIONS

A stable, temperature insensitive FOIS has been demonstrated in a laboratory environment. Couplers with different split ratios can be shown to operate with equally high stabilities. The sensor is easy to construct, and has applications as a probe in high temperature environments for measurement of microdisplacements. Further improvement in sensor sensitivity is possible by using detectors with very low noise levels and by achieving higher reflectivities at the end of the reference arm core.

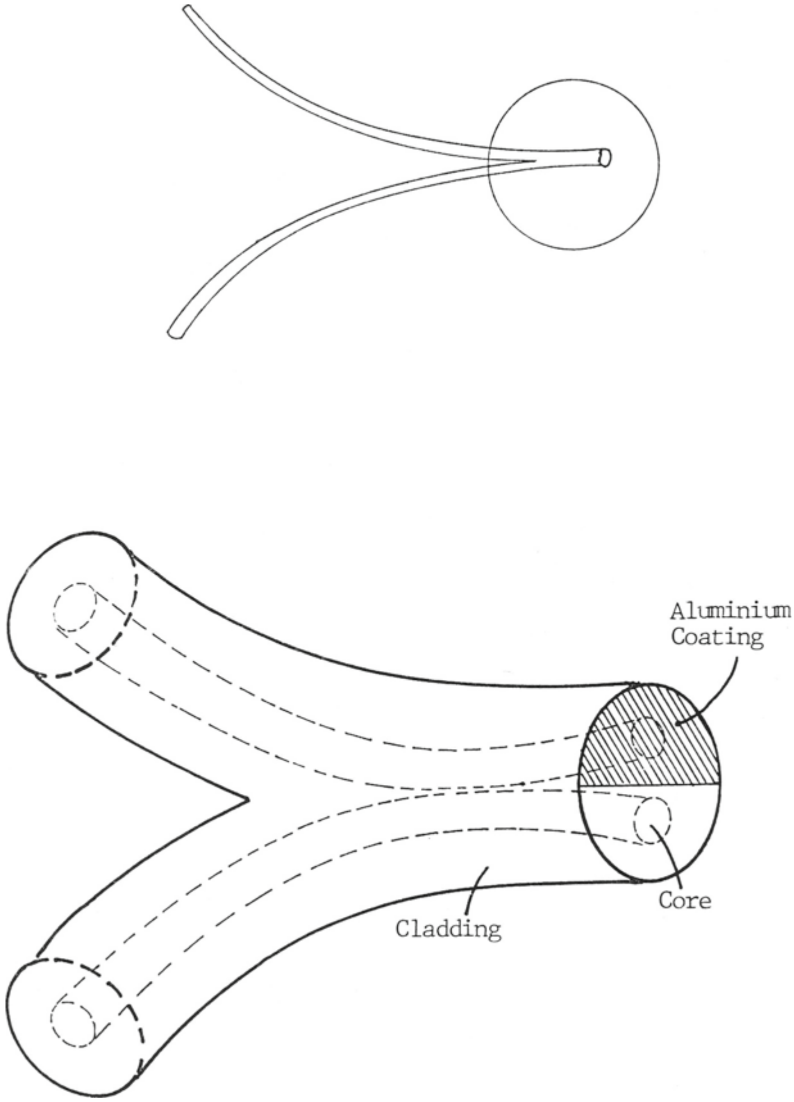

Fig. 1. Sensor details.

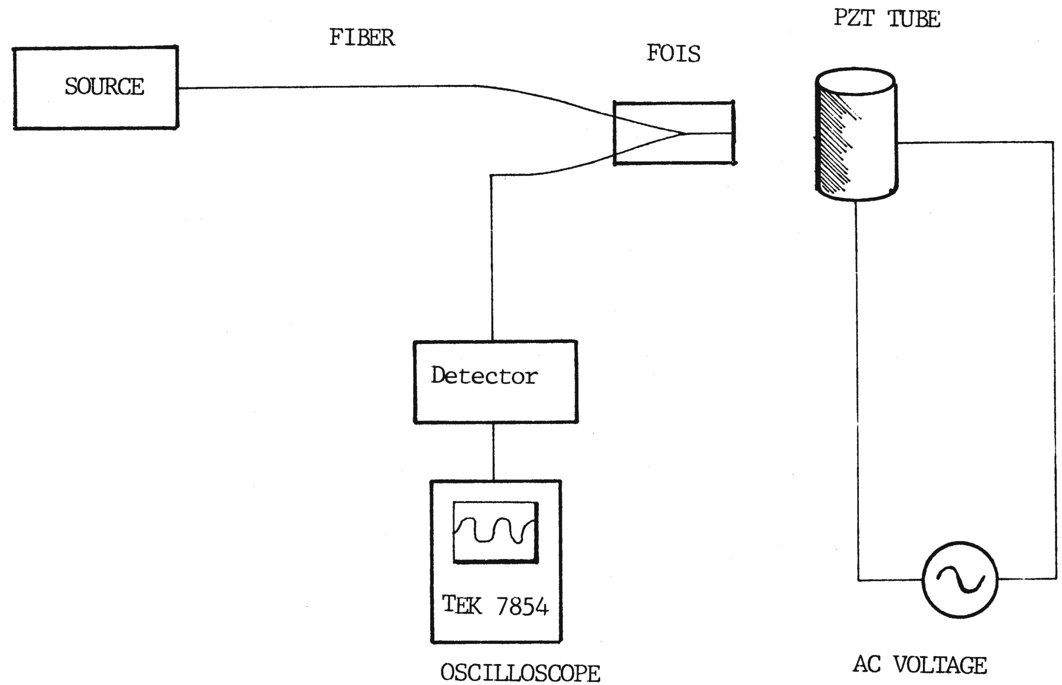

Fig. 2. Schematic of experimental set-up.

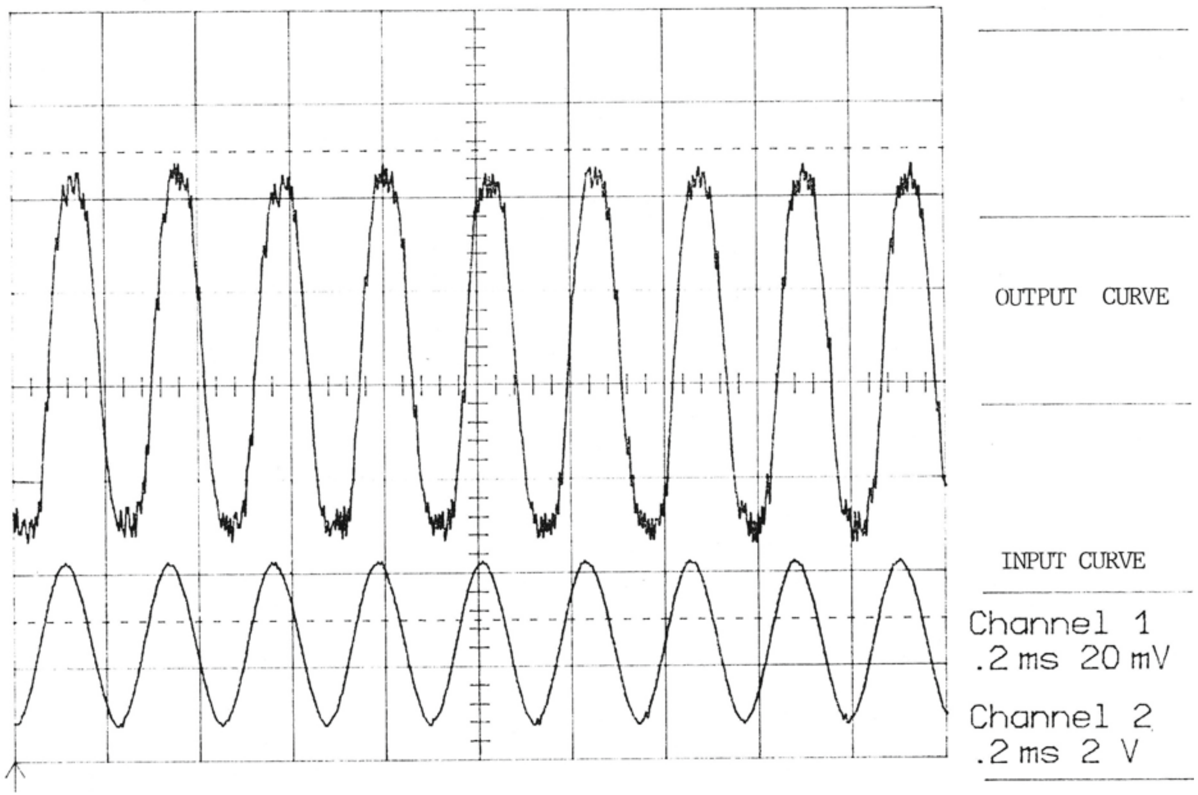

Fig. 3. Oscilloscope trace at 5 kHz.

REFERENCES

1. J-P. Monchalin "Optical Detection of Ultrasound", IEEE Trans Ultrason. Ferr. Freq. Control, v UFFC-33, p485, 1986.
2. J.A. Bucaro, H.D. Dardy and E.F. Carome, "Optical Fiber Acoustic Sensor", Applied Optics, v 16, p 1761, 1977.
3. F.R. Trowbridge and R.L. Phillips, "Metallic Glass Fiber-Optic Phase Modulators", Optics Letters, v6, p 636, 1981.
4. G.B. Hocker, "Fiber Optic Sensing of Pressure and Temperature", Applied Optics, v 18, p 1445, 1979.
5. D.A. Jackson, R. Priest, A. Dandridge and A.B. Tveten, "Elimination of Drift in a Single-Mode Optical Fiber Interferometer using a Piezoelectrically Stretched Coiled Fiber", Applied Optics, v 19, p 2926, 1980.
6. W. Eickhoff, "Temperature Sensing by mode-mode interference in Birefringent Optical Fibers", Optics Letters, v 6, p 204, 1981.
7. H. Hosokawa, J. Takagi and T. Yamashita, "Integrated Optic Micro-displacement Sensor using a Y junction and a Polarisation Maintaining Fiber", Optical Fiber Sensors, 1988 Technical Digest Series, v 2, Part 1, p 137, Conference Edition.
8. M. Slonecker, "Fused biconical tapered single mode coupler research at ITT", Fiber Optic Sensors Systems Conference, Fort Eustis, 1987.