MICROBEND FIBER OPTIC SENSOR

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ABSTRACT

Microbending induced losses in multimode optical fibers have been utilized as a transduction mechanism for an intensity modulated, fiber optic sensor. The sensor was found to be simple, very sensitive, and very stable to lead environment.

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Intensity modulation induced by microbending in multimode optical fibers has been successfully utilized as a transduction mechanism for sensing. The microbend sensor reported here is simple, very stable to lead environment, and very sensitive.

The microbend sensor is shown schematically in Fig. 1. The sensing fiber is bent along its axis periodically by a deformer, a set of two corrugated pieces. Any modulation of the amplitude of the fiber deformation introduced by an external field causes mode coupling which redistributes the light power among core modes and couples core to radiated modes. Thus, by monitoring the light power in some modes, the external field can be detected. In the simplest case, which we consider here, the power in all core modes is monitored, while the radiated modes are stripped by the absorbing coating of the fiber.

In order to optimize the sensitivity, we have studied the microbending effect in multimode fibers. One of the main results of this study is that there is a critical microbending periodicity which maximizes significantly microbending loss in fibers. Also, the microbending sensitivity was found to be proportional to ℓ^q where ℓ is the length of the bent fiber and $0<q\leq 1$. For fibers with optically absorbing coatings $q=1$. In this case, high sensitivity can be obtained with long lengths of bent fibers.

In order to operate as close to the shot noise limit as possible, an LED was utilized as the optical source. These sources typically have significantly lower noise levels than lasers down to very low frequencies. An added benefit results due to the absence of modal interference which otherwise would introduce strong lead sensitivity to environmental conditions.

The microbend sensor was tested as a displacement sensor using the apparatus shown in Fig. 1. The light source was a LED (for minimizing sensor noise), the leads where high NA (for reducing lead noise) commercially available fiber, and the detector was a PIN diode. The sensing fiber was a graded index fiber with an absorbing coating deformed by a pair of corrugated pieces with 14-teeth each having a 3.75 mm periodicity, which was the critical periodicity of the sensing fiber. One plate of the deformer could be displaced electrically by a piezoelectric transducer.

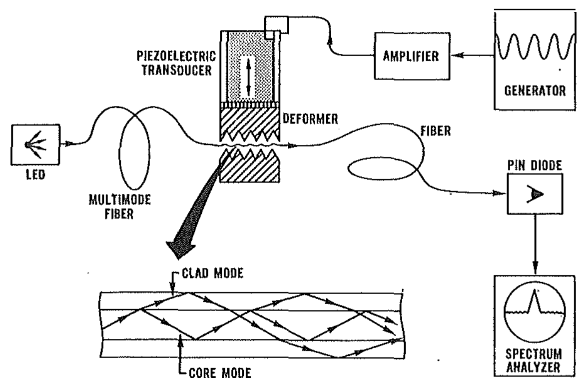

Figure 1. Experimental setup for studying the microbend displacement sensor.
Insert: Displacement induced mode coupling.

Figure 2 shows a typical spectrum obtained experimentally from such a sensor with a 10Å driving displacement at 1KHz. In this case, the signal-to-noise ratio was 58dB. The minimum detectable displacement was then calculated from the signal-to-noise ratio in the frequency range of 100 to 1000 Hz and it was found to be ~0.01Å, consistent with shot noise limited performance. The dynamic range of the sensor was found to be > 110 dB. Moreover, the sensor was found to be very stable with respect to the lead environment.

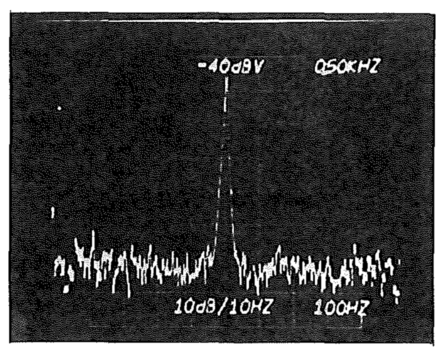

Figure 2. Spectrum obtained experimentally from the microbend displacement sensor signal at 1 kHz. Driving displacement: 10A.

Figure 3 shows several mechanical designs for the microbend sensor for detecting various external fields. For displacement detection, only one piece of the deformer moves. As a microphone (which has been already tested successfully), the deformer is air filled and a rubber boot is used as couplant. As a hydrophone, the deformer should be liquid filled for depth compensation, and as an accelerometer, one piece of the deformer is free to move. Finally, as a magnetic sensor, the deformer is magnetostrictive.

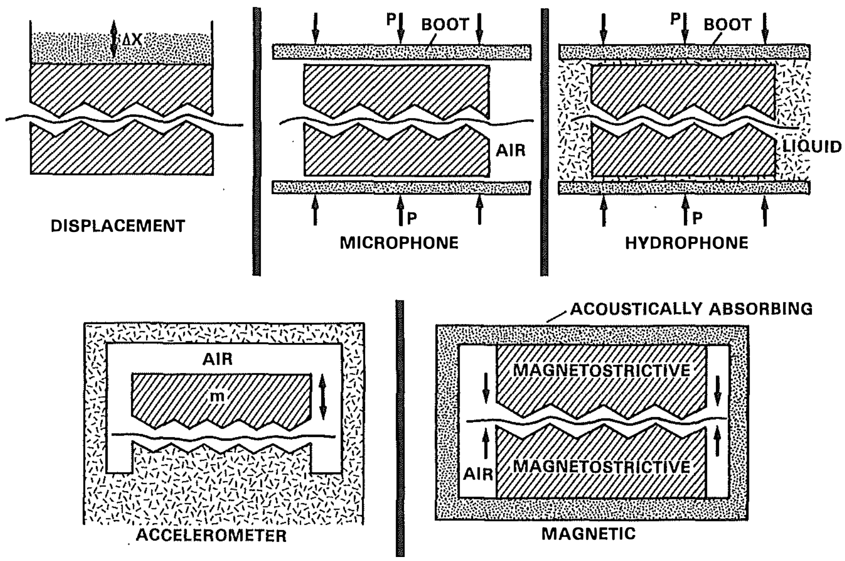

Figure 3. Microbend sensor mechanical designs for detecting various external fields.

In conclusion, we have demonstrated that the microbend sensor can be utilized to detect small displacements of the order of 0.01 . The sensor is simple, very stable to lead environment and has a wide dynamic range. Moreover, the microbend sensor can be appropriately designed for detecting various fields, such as pressure, acoustic field, acceleration, and magnetic field.