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COMPACT OPTICAL FIBRE CURRENT MONITOR WITH PASSIVE TEMPERATURE STABILISATION

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ABSTRACT

Quasi-circularly birefringent fibre and broad-spectrum light-source are combined to obtain an accurate, compact and robust current monitor. Measurement repeatability of ±0.5%, a temperature drift of 0.05%/^{o}C and a sensitivity of 1mA rms/Hz$^{0.5}$ characterise the sensor.

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INTRODUCTION

A number of optical current monitors[1,2] incorporating low-birefringence fibre have been described. However, when such fibres are tightly coiled or subject to external forces, birefringence is induced, which reduces the current sensitivity. These effects render the device sensitive to external perturbations such as vibration and restrict the number of turns of small diameter which can be employed and thus no compact, robust and sensitive current monitors have been developed.

This problem of package-induced birefringence has recently been overcome with the development of quasi-circularly birefringent fibre[3] made by spinning a linearly birefringent (Bow-Tie) fibre preform during the draw. Optical rotation lengths as short as 7.2mm have been obtained, which is sufficient to overcome all but the worst packaging effects. Thus compact, robust, multi-turn current sensing coils can be easily made, whilst retaining full current sensitivity. Potentially these could measure currents in the low microamp region. Moreover, the short length of fibre employed allows high bandwidths owing to the reduced optical transit time.

THEORY AND EXPERIMENT

It is well known that the birefringence in a Bow-Tie fibre is temperature sensitive, and thus the quasi circular (i.e. elliptical) induced birefringence is temperature sensitive. Polarisation control is required for accurate current measurements and can be achieved either actively[4] or passively. Passive compensation schemes are preferred, the most practical of which is shown in Fig. 1. Optical power (0.1mW) from a pigtailed laser diode with peak emission at 821nm and a broad spectral bandwidth of 11nm was polarised, passed through a beamsplitter and launched into a 100 turn, 25mm diameter fibre coil. Light at the far end was reflected back down the fibre by a mirror and separated into two orthogonal linearly-polarised components. The intensities of which, I_1 and I_2 were measured and processed to obtain the current i, where $i \alpha (I_1 - I_2)/(I_1 + I_2)$.

Use of the reflect-back technique eliminates the need to track the orientation of the principal axis with input polarisation. Furthermore, since the sensitivity varies cyclically with both temperature and wavelength, the broad-spectrum souce averages over several temperature/sensitivity cycles and thus temperature stabilises the sensor.

SENSOR RESULTS

The sensor response was measured as a function of time, temperature and lateral side pressure applied to the fibre.

Accuracy As a result of adopting the aforementioned reflect-back and broad spectrum technique, an accurate stable output of better than ±0.5% was obtained. The current sensitivity was measured to be 0.66 of that for an ideal fibre.

Temperature Sensitivity The sensor response to current was measured as a function of temperature in the range 20-70^{o}C and was found to increase linearly by 0.05%/^{o}C. This is expected and is due to the linear birefringence component decreasing with temperature.

External Forces The effect of lateral side pressure applied to the fibre on the sensor response was investigated by loading a straight portion of fibre at the mirror-end of the coil. The fibre was 100μm diameter and coated to a diamter of 200μm.

The current sensitivity is plotted against absolute load in Fig. 2, for uniformly distributed and point load. It can be seen that a distributed load of 2N reduced the sensitivity to 99% of its full value. Applied to a low-birefringence fibre of similar dimensions, this would result in linear-birefringence of 45 degrees[5], destroying the response of a conventional fibre optic current monitor[2]. This clearly demonstrates the advantages of our fibre over standard single-mode fibre. Vibration sensitivity was also found to be low.

As expected the very high point load affects the sensor strongly, since it is localised to a length shorter than the optical rotation in the fibre and is therefore not averaged.

Maximum Sensitivity Oscilloscope traces of the sensor noise output and response to a signal current of 1A rms at 25Hz are shown in Fig. 3 for a measurement bandwidth of 1kHz. The maximum sensitivity was detector shot-noise limited to 1mA rms/$Hz^{0.5}$. A more powerful light source and refinement of the optics should result in a maximum sensitivity of 100μA rms/$Hz^{0.5}$. A current range to several kA's is also possible.

CONCLUSION

The quasi-circularly birefringent fibre described here permits large numbers of small diameter turns to be wound in a current-sensing coil. The operation of a 100 turn, 25mm diameter coil has been demonstrated and shown to be temperature and pressure insensitive. A current range to 500A and maximum sensitivity of 10μA rms/$Hz^{0.5}$ is anticipated for a 1000 turn device.

We now envisage current-measuring instruments with single-ended fibre probes which can be coiled and uncoiled on site.

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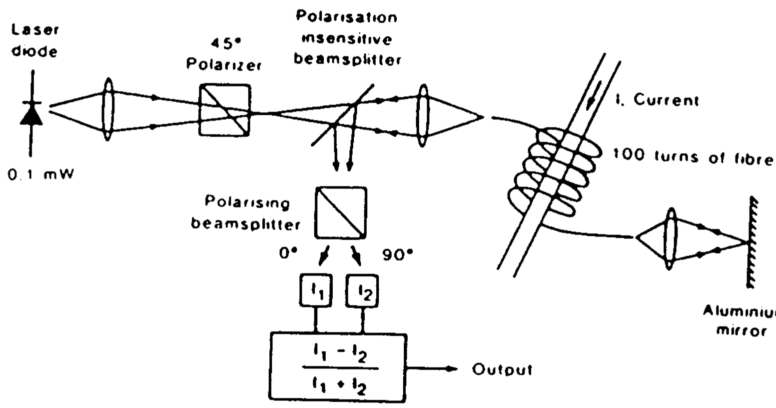

Figure 1 Schematic diagram of the fibre current monitor.

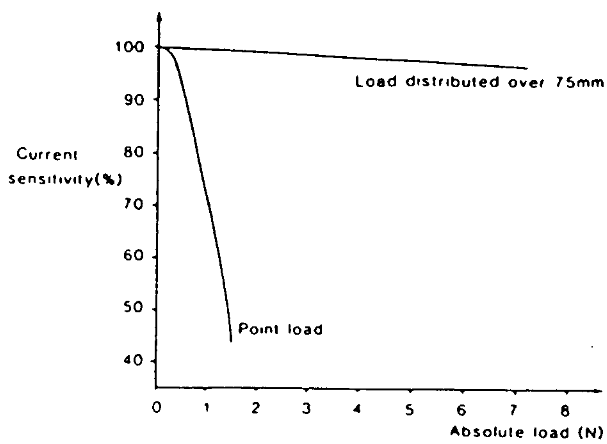

Figure 2 Current monitor response as a function of lateral force applied to the fibre.

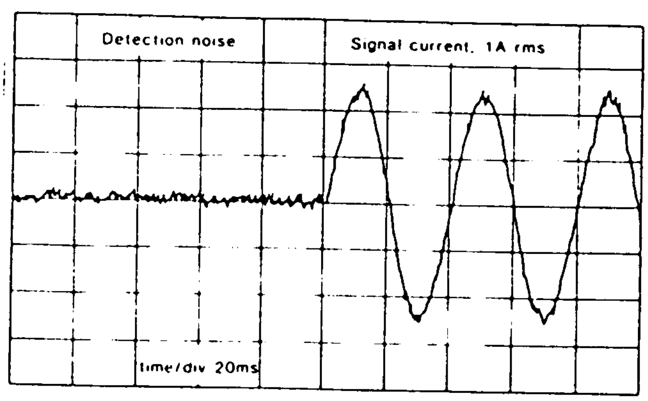

Figure 3 Oscilloscope traces of the sensor noise output and response to a 1A rms signal current at 25Hz. Detection bandwidth 1kHz, noise equivalent current 1mA rms/$Hz^{0.5}$.