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Sensitive miniature optical fibre current monitor with passive temperature stabilisation.

R.I. Laming, D.N. Payne and L. Li.

Department of Electronics and Computer ScienceThe University, Southampton, S09 5NH, Hampshire, U.K.

Tel: (0703) 559122 Telex: 47661

Abstract

A number of optical current monitors incorporating low-birefringence fibre have been described. However, when such fibres are wound into small coils birefringence due to bending is induced, which reduces the sensitivity. This effect restricts the number of turns of small diameter which can be employed and thus no highly sensitive current monitors have been developed for use as earth-leakage detectors for example.

The problem of package-induced birefringence has been overcome with the development of quasi-circularly birefringent fibre,[1] made by spinning a linearly birefringent (Bow-Tie) fibre preform during the draw. Optical rotation lengths as short as 7.2 mm have been obtained, which is sufficient to overcome all but the worst packaging effects. Thus multi-turn current sensing coils of small diameter can be easily made, whilst retaining full

current sensitivity. Potentially such coils 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.

It is well known that the birefringence in a highly stress birefringent fibre is temperature sensitive, and this leads to a similar sensitivity in the quasi circular (i.e. elliptical) induced birefringence in a spun Bow-Tie fibre. Temperature compensation is required for accurate current measurements and can be achieved either actively by incorporating a polarisation controller or passivley. Passive temperature compensation schemes are preferred, the most practical of which is shown in figure 1. 0.1mW of optical power from a pigtailed laser diode with peak emission at 821 nm and a broad spectral bandwidth of 11 nm was polarised, passed through a beamsplitter and launched into a 100 turn, 25 mm diameter fibre coil. Light at the far end was reflected back down the fibre by a mirror and separated into two linearly-polarised components with a polarising beamsplitter. The intensities of the two orthogonal polarisation states I_1 and I_2 were measured and processed to obtain the current i, where

$$i \propto \frac{I_1 - I_2}{I_1 + I_2} \qquad (1)$$

As well as the reflect-back technique, the broad-spectrum source was necessary to average the temperature-dependent residual ellipticity in the quasi-circularly birefringent fibre such that an accurate stable output was obtained. This was achieved to better than ±1%.

Oscilloscope traces of the sensor noise output and response to a signal current of 1A rms at 25 Hz are shown in figure 2 for a measurement bandwidth of 1kHz. The maximum sensitivity was detector shot-noise limited to 1 mA rms $Hz^{-1/2}$. A more powerful light source and refinement of the optics should result in a maximum sensitivity of 100 μA rms $Hz^{-1/2}$.

The quasi-circularly birefringent fibre described here permits large numbers of small diameter turns to be wound in a current-sensing coil. A current range to 500A and maximum sensitivity of 10 μA rms $Hz^{-1/2}$ is anticipated for a 1000 turn device.

Results covering the performance and temperature characteristics of the sensor will be presented as well as measurements of the immunity of the fibre to lateral side pressure and vibration.

Reference

1. Current sensors using highly birefringent bow-tie fibres, L. Li, J.R. Qian and D.N. Payne, Electronics Letters, Vol. 22, No. 21, October 1986, pp. 1142-1144.

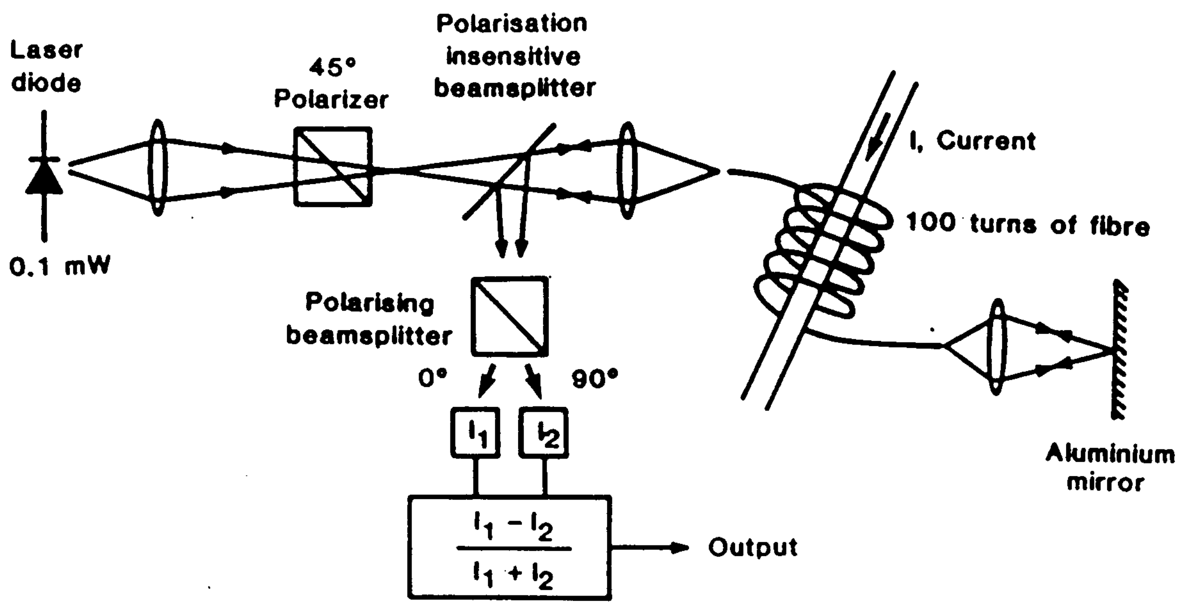

Figure 1. Schematic diagram of the fibre current monitor

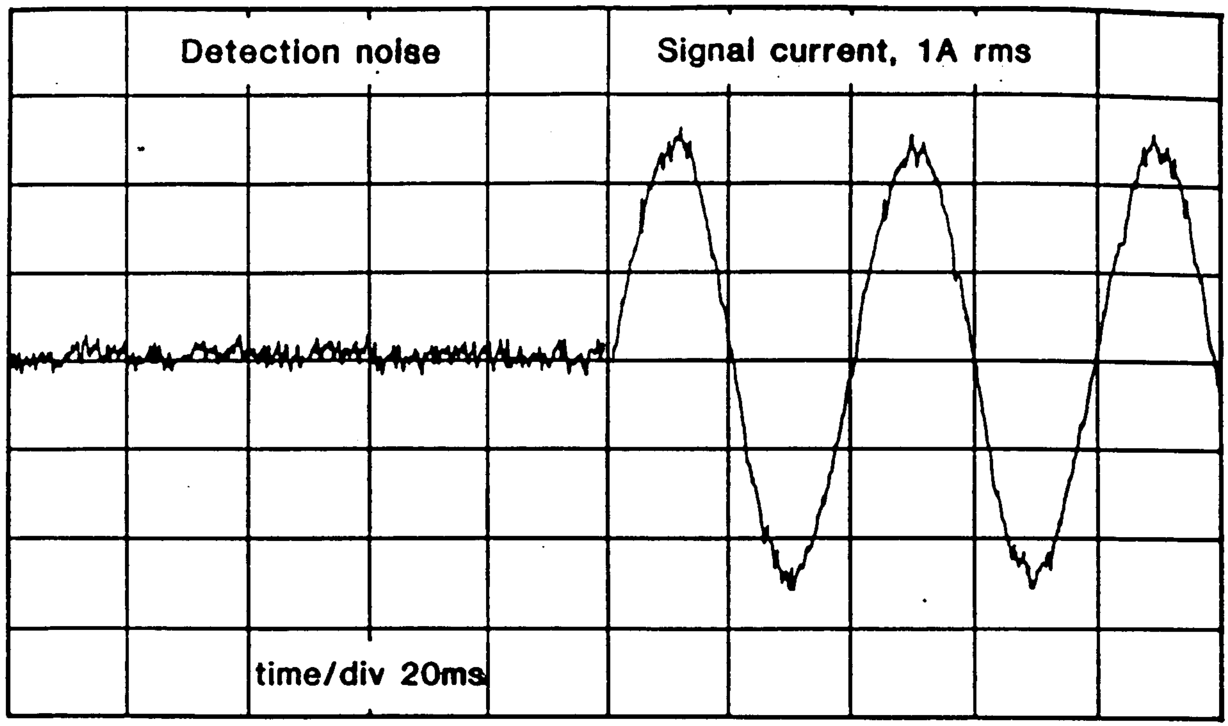

Figure 2. Oscilloscope trace of the sensor noise output and response to a 1A rms signal current at 25Hz.

Detection bandwidth 1kHz.
Noise equivalent current 1mA rms $Hz^{-\frac{1}{2}}$.