Simple multiplexing scheme for fibre optic grating sensor network

G.P. Brady, A.B. Lobo Ribeiro [1], D.J. Webb., L. Reekie[2],
J.L. Archambault[2] and D.A. Jackson

Applied Optics Group, Physics Laboratory, University of Kent,
Canterbury, Kent, CT2 7NR, U.K.
[1] INESC - Optoelectronics Group, R. Jose Falcao 110, 4000 Porto, Portugal.
[2] ORC, University of Southampton, Southampton, Hants SO9 5NH, U.K.

ABSTRACT

A novel approach for the interrogation of multiplexed fibre optic Bragg grating sensors is described. Signal recovery is achieved by matching a receiving grating to a corresponding sensor grating. As a demonstration, the technique is applied to strain sensing.

2. FIBRE OPTIC BRAGG GRATINGS AND SIMPLE MULTIPLEXING SCHEME

Fibre optic Bragg gratings are attracting considerable interest as sensing elements in quasi-distributed sensors [1,2]. They may be formed by illuminating germania doped fibres from the side with a periodically varying intensity pattern produced by interfering two plane waves of coherent UV light. The period is determined by the angle between the two beams. The grating then reflects at the wavelength, $\lambda=2nD$ where n is the mode refractive index and D is the grating period. Placing the grating under strain causes D and therefore λ to change. By determining the wavelength of peak reflectivity the strain to which the fibre is subjected may be found.

One application proposed for such sensors is the monitoring of strain in composite materials, which are increasingly being used in avionic structures, for example. The small size of the optical fibre lends itself readily to inclusion in composites without undue reduction in their strength. For such applications, strain information is needed at a large number of points so many gratings need to be written along the fibre. In order to interrogate and demultiplex the output signals from a serial array of grating sensors it is necessary that each sensor be uniquely identified by the wavelength of maximum reflectivity. This can be achieved in principle if each grating sensor has a specified and non-overlapping working range $\Delta\lambda_1$, $\Delta\lambda_2$, ...$\Delta\lambda_n$ If now the system is illuminated by a broad band source with a bandwidth greater than $(\lambda_1-\lambda_n)$ then the back reflected signal will consist of n components where the central wavelength of each component is directly related to the measurand it is designed to monitor.

The strain information can in principle be measured with an optical spectrum analyser but the cost, size, weight and frequent need to recalibrate the instrument makes this impractical. An interrogation scheme based upon a Mach Zehnder interferometer acting as a wavelength discriminator has been reported by Kersey et al[4]. This approach offers very high performance for a single sensor but it is not well suited to multiplexing a large number of sensors without employing time division multiplexing.

Recently a novel approach of demultiplexing the output signal from a sensor has been demonstrated where a receiver grating is matched to a corresponding sensor [3]. The sensor receiver grating pair is shown in fig. 1. Light from the broad band source (BBS) is launched into the sensing fibre where it is back reflected from the sensor grating, passing via the directional coupler to the receiver grating. Both gratings reflect at the same central wavelength when put under identical strains. The strain to which sensor is subjected is found by scanning the central reflecting wavelength of the receiver grating, using the PZT, until their strains match and a signal is seen at the detector. The sensor strain can then be deduced from the voltage applied to the PZT.

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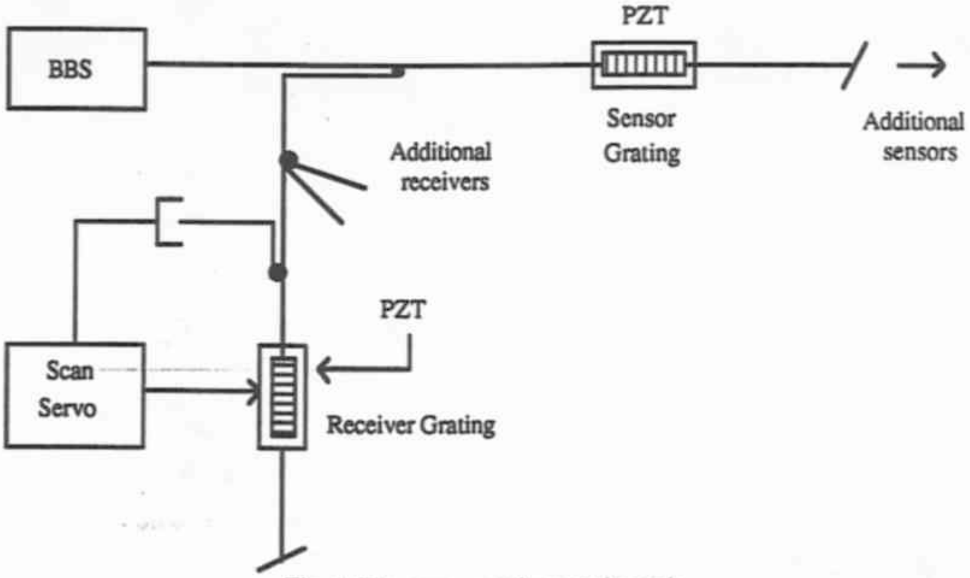

Fig. 1 The sensor-receiver grating pair.

This system can be further extended by deploying additional sensor arrays in parallel, as shown in fig. 2. The receiver gratings are now all mounted on the same PZT which is driven with a serrodyne waveform such that all grating pairs will match once per cycle, enabling the strain of each sensor to be determined. TDM is used to sequentially interrogate each serial network of sensors.

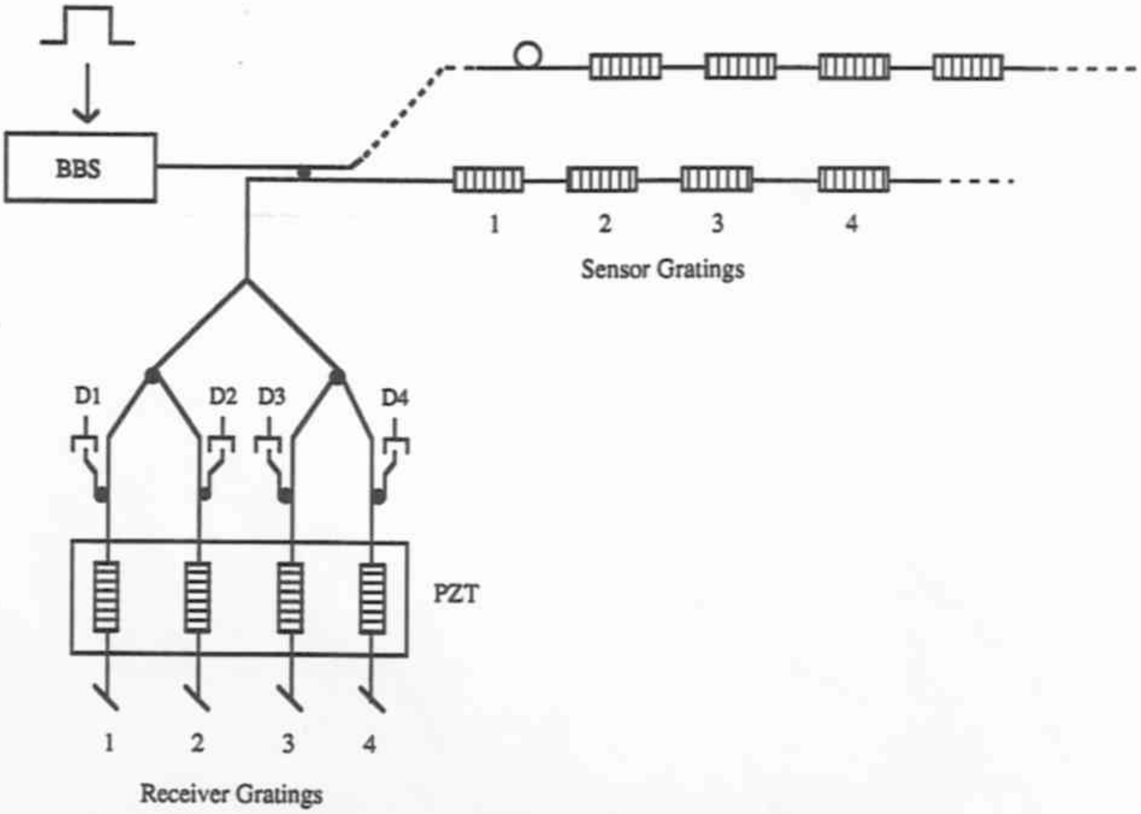

Fig.2 Multiplexing scheme for many gratings.

3. EXPERIMENT

Work has now been done which demonstrates the demultiplexing of static strain information in a simple two sensor system. The experimental arrangement is shown below, fig. 3. The network was illuminated with a 1.55μm ELED (OKI-506G) source with a bandwidth (FWHM) of 70nm, and the launched power was 10μW. The two grating pairs reflected at centre wavelengths of 1549.9±0.1nm and 1534.8±0.1nm respectively in the unstrained case. The spectral response of the two gratings is shown in figure 4.

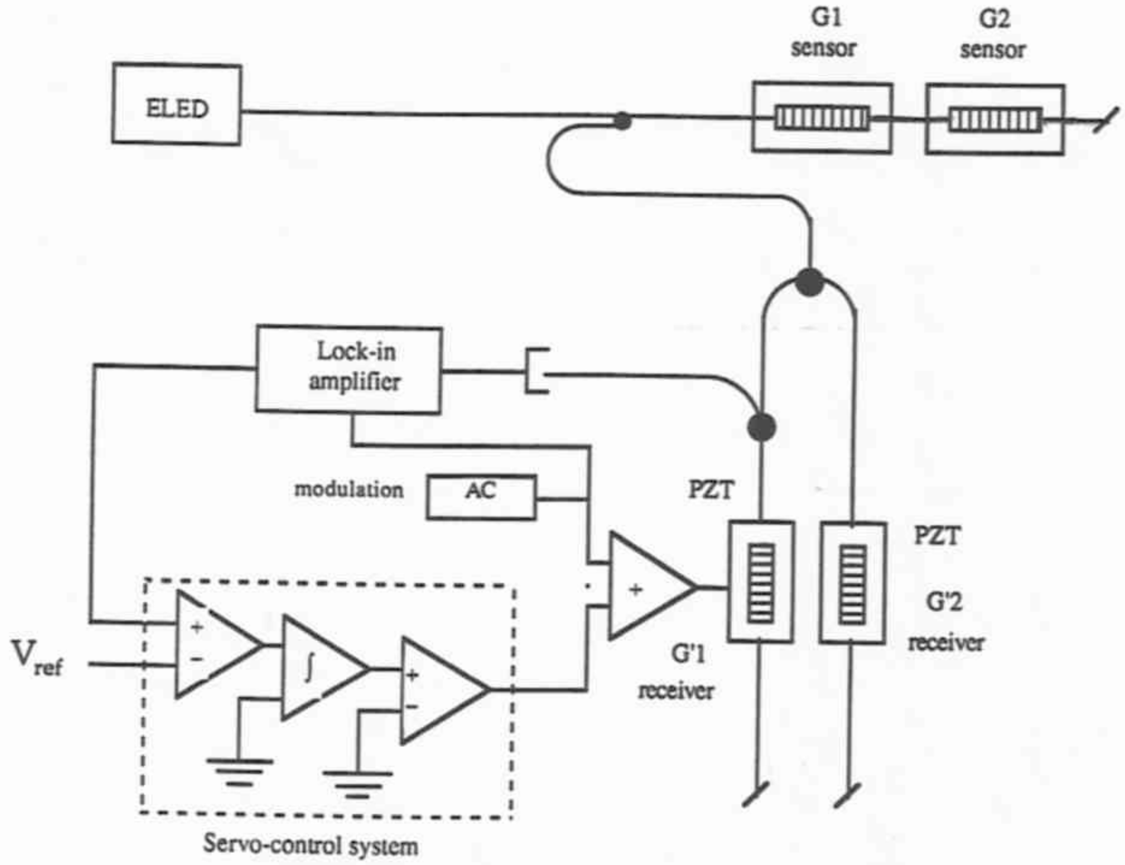

Fig. 3 Experimental arrangement for the servo-controlled simple multiplexing scheme.

The response of the combined sensor/receiver pair is the convolution of their individual responses. An AC modulation was applied to the PZT holding receiver grating G'1. This has the effect of producing an AC signal proprtional to the derivative of the continued response.

Initially the servo-control system was disconnected and the output at the lock-in monitored as the voltage driving the sensor PZT was increased. The results are shown in figure 5. The servo-control system was then connected and the reference voltage Vref adjusted to cause the system to lock to the centre of the transfer function as indicated in figure 5. Once the system had been set up in this way, any variation in the sensor grating strain was mirrored by a corresponding change in the receiver grating PZT voltage.

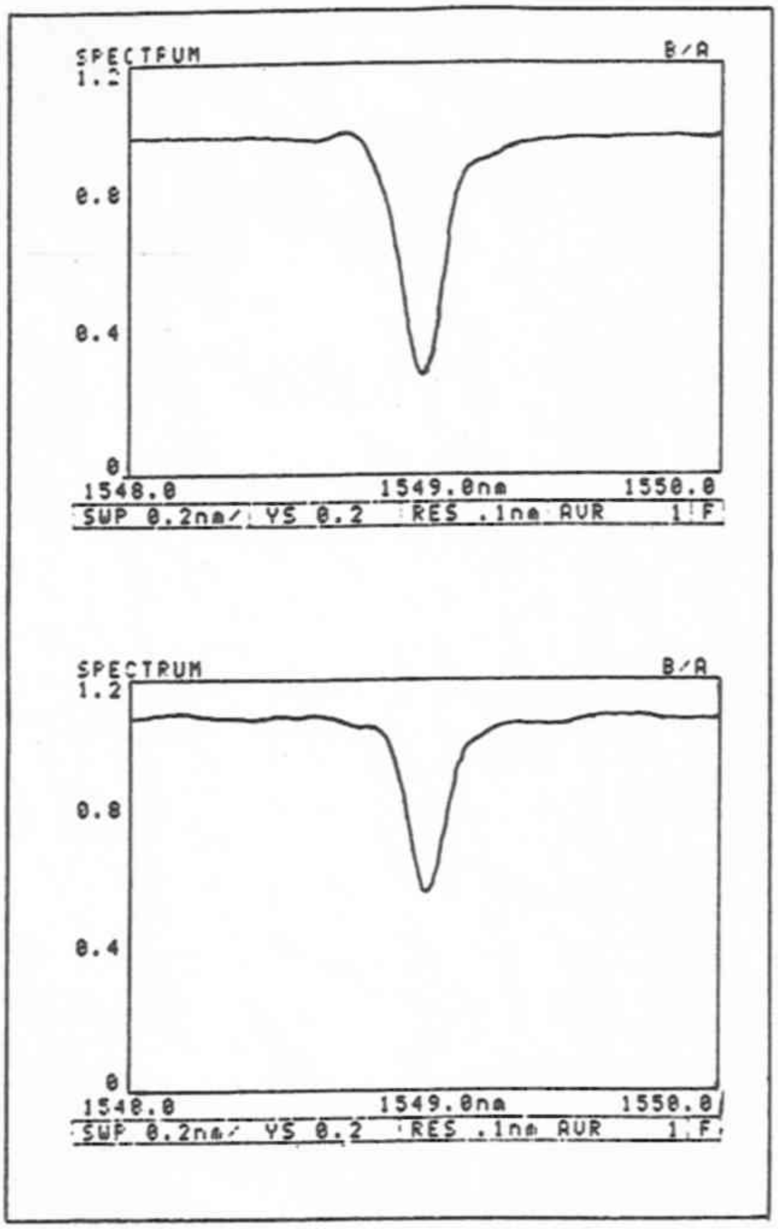

Fig. 4 Normalised transmission spectra of grating pair 1
(the top trace is the sensor grating and the bottom trace is the receiver grating)

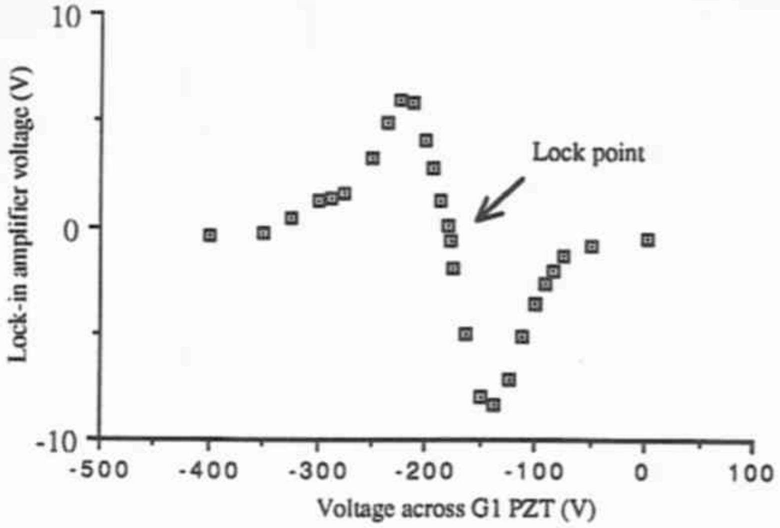

Fig. 5 Detector output when the detector grating is oscillated relative to the sensor grating.

As can be seen from fig. 6, the relationship between the sensor and receiver grating voltages, is linear except for sensor voltages above about -300V. The non-linearity is probably due to the fibre containing the gratings being slightly slack when no voltage is applied to the PZT and the fibre has to be tensioned before the voltage across the PZT is proportional to the strain produced in the sensing fibre. Below -300V the results are quite linear. The gradient here is not unity due to each PZT requiring a different voltage to provide the same strain. The r.m.s. deviation from linearity below -300V suggests that a resolution of 8.3με (micro-strain) is achievable given a sensor sensitivity of 5με/volt.

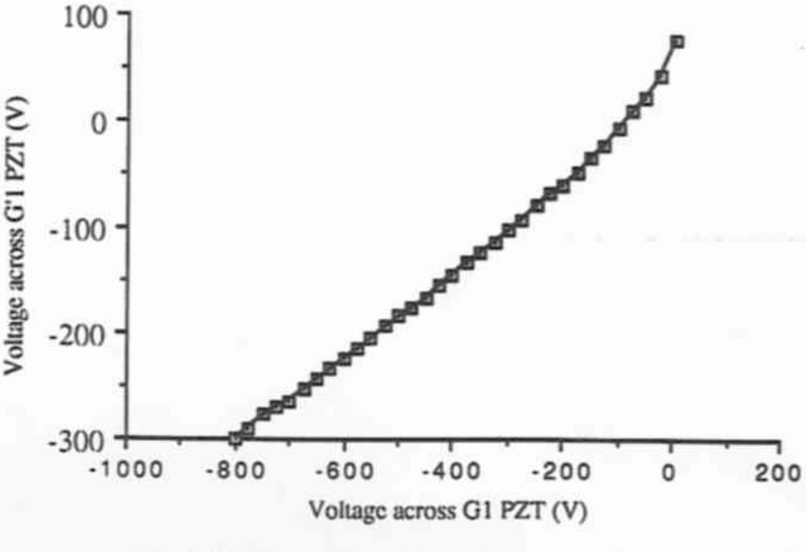

Fig. 6 Receiver grating G'1 locked to sensor grating G1.

The technique presented here allows simultaneous signal recovery from a number of sensors. The number of grating sensors which can be deployed on the fibre depends upon the maximum strain level to be measured and the dynamic range required of each sensor. For a range of 1mε, the change in the Bragg wavelength is 1.5nm. With a source bandwidth of 50nm up to 30 sensors could be deployed on the fibre. If a larger number of sensors or a greater range is required, then several fibres with similar numbers of sensors could be deployed with TDM being used to sequentially interrogate each serial array..

4. ACKNOWLEDGEMENTS

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5. REFERENCES

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