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Interferometric and fibre Bragg grating sensor interrogation using an arrayed waveguide grating.

The paper presented describes the use of an arrayed waveguide grating (AWG) to interrogate both interferometric and fibre Bragg grating (FBG) sensors. The set up utilises a broadband light source, which passed through an unbalanced Mach-Zehnder interferometer one arm contained a phase modulator to which we could apply a ramp signal the other arm an air gap to adjust the optical path difference (OPD) and which could also be blocked to effectively remove the interferometer. The light was then selectively passed to the interferometric or FBG sensors. The reflected spectral information from the sensors is then directed to a Bookham optical channel monitor (OCM), which is a 40 channel AWG with integral photodetectors providing 40 electrical outputs.

When the AWG is used to interrogate an interferometer illuminated by a broadband light source it provides information equivalent to illuminating the interferometer with 40 discrete light sources each with the bandwidth of an AWG passband. The dual wavelength technique extends the unambiguous range of an interferometric sensor by monitoring the interferometric phase difference between two wavelengths provided from two separate light sources. We removed the effect of the Mach Zehnder interferometer allowing the broadband light to be directed to a PZT mounted mirror forming an interferometer. By selecting two AWG channels we effectively synthesis the two separate light sources illuminating the system. We then applied a ramp waveform to the PZT to recover the phase difference electronically. The maximum unambiguous range in terms of mirror displacement for one channel separation was 1440μm. The requirement for active components at the sensor is undesirable so to overcome this we reintroduced the Mach Zehnder forming a second processing interferometer away from the sensor.

The simplest technique to interrogate FBG sensors makes use of the fact at the edges of the passband of a given AWG output channel; the intensity falls of monotonically with wavelength. If the nominal wavelength of an FBG lies in this region, then any variation in wavelength will produce a concomitant variation in the detected output intensity. With the effects of the Mach Zehnder removed dynamic tests recovered a strain resolution of $96n\varepsilon/\sqrt{Hz}$. The useable range however is limited to the rising part of the channel passband, less than 0.5nm equivalent to a strain resolution of 500με and the system is essentially intensity based. To overcome these problems we investigated the following two approaches.

The wide bandwidth grating approach involves the use of chirped gratings that span a few AWG channels. With the effects of the Mach Zehnder interferometer still removed a personnel computer was connected to the OCM electrical outputs to recover the grating position using centroid data fitting. We improved the range to 1890με corresponding to the grating being stretched through two channels of the AWG.

To improve dynamic strain detection we investigated a heterodyne approach, which is largely unaffected by changes in intensity. We reintroduced the Mach-Zehnder interferometer and modulated its phase. The OCM then produces an electrical carrier, phase modulated by any measurand-induced wavelength shift from the FBGs. To extend the range we electrically sum the outputs from several adjacent channels. The issue then becomes how to remove the inter-channel fading of the signal to noise ratio (SNR) when the FBG is situated between two AWG passbands. We solved this using an FBG with a wide bandwidth to recover a near constant SNR. However, the wide bandwidth of the FBG limits the sensitivity available because the free spectral range (FSR) cannot be made smaller than the width of the FBG being interrogated. To overcome this we manufactured an FBG with narrow bandwidth double peaks corresponding to one and a half channel spacings of the AWG, yielding an improved dynamic strain resolution of $17n\varepsilon/\sqrt{Hz}$.

Other key papers:

Coherence multiplexed fibre optic sensor arrays based on differential white light interferometry, V. Ivanov, et al, Institute for Physics of Microstructures, Russia. Fibre optic interferometric sensor arrays with immunity to phase noise and drifts in the interrogating interferometer was proposed and demonstrated experimentally.

A high-performance miniaturized time division multiplexed sensor system for remote structural heath monitoring, G. D. Lloyd, et al, Insensys Ltd, UK. Implementation and commercial application of a hand held optical time division multiplexed, distributed fibre Bragg grating sensor system.