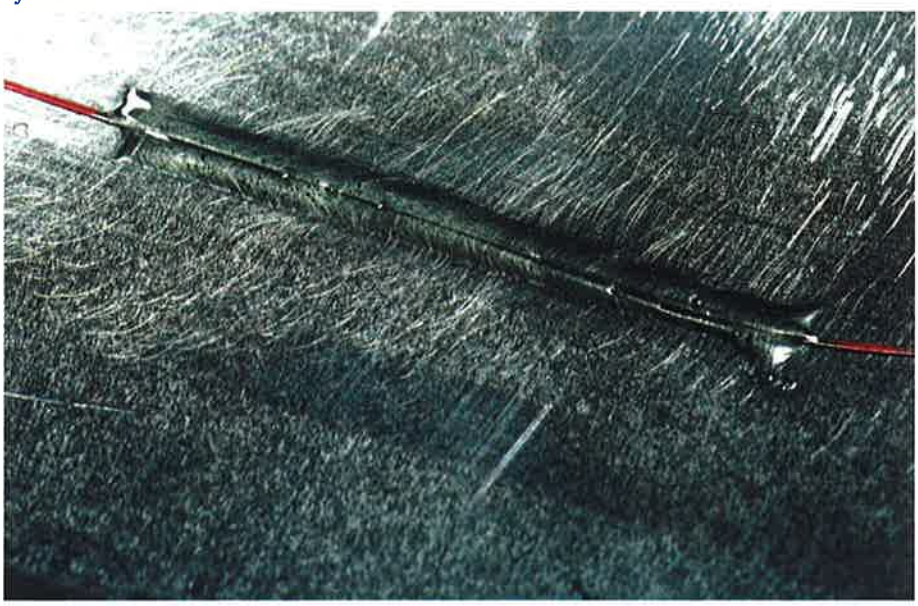
TNO Fiber Bragg Grating monitoring system

High-speed strain monitoring in ship structures

TNO has developed a new interrogation/demultiplexing system for Fiber Bragg Grating (FBG) sensor arrays. This potentially low cost system combines a high-speed readout frequency with absolute measurement for all the Fiber Bragg Grating sensor channels. This combination is of particular interest for the detection of strain changes, which is the main cause of hairline cracks that develop in metal structures (e.g., a ship's hull). A patent is pending for this system.



Fibre Bragg Grating sensor for strain monitoring in aerospace and civil structures.

TNO TPD delivers innovative and complete solutions both for large companies as well as small and medium-sized companies and for the authorities. Specialist areas include: sound and vibration, instrumentation, applied physics, information technology, mechanics, electronics, materials and process engineering. The (inter)national projects vary from systems development to consultancy.

Our solution

Sensors for measuring physical parameters are indispensable for structure monitoring. By recording and analysing the output of the sensors, the condition of the structure can be determined. Intelligent modelling can help optimise the performance of the structure and maintenance schedules can be adapted in order to reduce costs. The main damage to structures is caused by fatigue, which causes cracks to develop, impact, delamination, debonding and corrosion. All these types of damage can probably be monitored by measuring the strain at the appropriate locations of the structure. Since defects in a structure can be caught at an early stage, design tolerance excesses can be avoided.

Currently, FBG sensors are installed in various bridges, dams and buildings throughout the world to gather experimental data. Furthermore, several systems are in development for load monitoring for ships and aircraft.

Multiplexing

A self-evident benefit of FBG sensors in an array application is that each sensing FBG can have a different Bragg wavelength to reflect. Thus, Wavelength Divison Multiplexing (WDM) can be conveniently used to distinguish the different sensing FBG at the receiving side (Fig. 2).
In general, the sensing FBG sensors must have a non-overlapping operation range. Providing the wavelength separation

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between subsequent FBGs, the number of FBG sensors are limited by the spectral bandwidth of the light source. However, the total number of FBG sensors can be multiplied by using the kind of multi-line configuration that is incorporated in the TNO system. In this type of system, a number of generally identical FBG arrays are connected to the same interrogation system.

TNO interrogation/demultiplexing system

TNO has developed an interrogation/demultiplexing system for measuring with FBG sensor arrays. This system is based on a special high-speed spectrometer. The main features are:

- Absolute measurement
- High readout frequency
- Multi-line configuration
- Simultaneous readout of all channels
- Simple design with no moving parts ensures a long MTBF

Measurement of strain changes requires a strain sensor with a sufficient high detection bandwidth not adequate in most current commercial systems.
A demonstrator with the TNO system and 5 FBGs has been built and several experiments carried out. The TNO system contains standard COTS components.

The target specifications of the TNO system are:

- Readout frequency: > 10000 Hz
- Number of channels per line: > 8
- Number of lines: > 3
- Measurement range: +/- 1000 µe
- Resolution: 5 µe

Several experiments have been carried out and, depending on the optical power, the resolution has varied from less than 1 µe to several µe. Recently, a field trial with about 20 FBG sensors has been performed on the world's longest span suspension bridge carrying both trains and regular road traffic (The Tsing Ma Bridge in Hong Kong).

Opportunity

Fibre optic sensors based on Fiber Bragg Grating (FBG) technology are suitable for strain sensing. In comparison with conventional strain gauges, the FBG sensors are not susceptible to Electro Magnetic Interference (EMI) and have no Electro Magnetic (EM) emission. They are intrinsically safe and have unique optical multiplexing potential. A large number of FBG sensors can be addressed and can be read out by a limited number of lead fibres. Finally, the FBG sensors are potentially lightweight, small and can be embedded and integrated in composite structures.

If you would like further information about Fibre Bragg Grating sensors, please contact Mr Lun Cheng for additional information or visit our website.

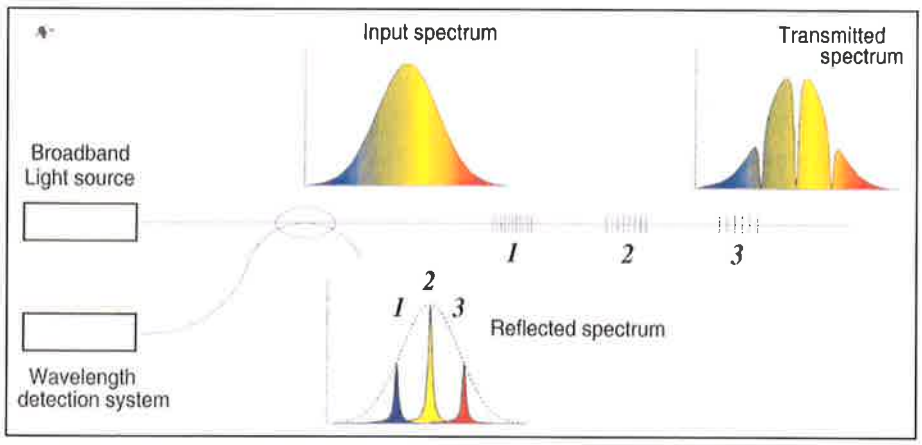

Fig. 2. Basic configuration of a WDM FBG sensor array. Each Fiber Bragg Grating (FBG) reflects a small part of the input spectrum.

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