

Shape Sensing



Short Description

High-speed, high-resolution and synchronous interrogation using multiple fibre Bragg grating sensors enables design and delivery of highly accurate shape sensing systems.

Shape sensing is useful in a wide area of two or three dimensional oriented applications. Shape sensing technology using fibres is particularly useful for its unique features of being minimal intrusive and almost weightless. This technology for measuring the shape of an object dynamically has applications in:

- The medical field providing means to track movement and position of minimal invasive instruments during surgical operations.
- The aerospace industry for monitoring deployable structures like morphing wings, hydraulic hoses, flexible booms or electric cabling during the flight.
- Civil applications for structural health monitoring in on- and offshore environments on for instance bridges, pile driving, foundation grounds, pipe lines, etc. As well as wind turbines monitoring blade shapes to improve efficiency and longevity.
- The sports and gaming industry for kinematic motion measurements.
- The automotive industry where for instance crash test dummies are used for analyzing body impacts to improve safety.



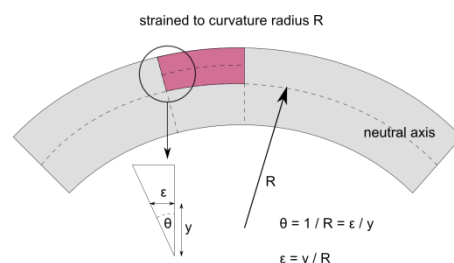
The technology of Shape Sensing using optical fibres is based on measuring strain using Fibre Bragg Grating (FBG) sensor technology. Having a fibre attached to an object causes strain in that fibre when the object deforms along the path of the fibre.

At Technobis Fibre Technologies (TFT), we have developed, industrialized, and released the Deminsys FBG Interrogator. The key characteristic of the device is the simultaneous readout of up to 32 FBG sensors (four channels with, typically, eight sensors per channel) at a maximum sampling frequency of 20kHz each.

This device allows a wide variety of solutions for monitoring aspects of the structural integrity of objects subject to dynamic deformations. Shape sensing is such a monitoring aspect that can be implemented using optical fibres for both two and three dimensional orientations.

How it works

Determining shape deformation of an object using an FBG sensor is based on strain that appears off-axis in an object during bending as demonstrated in the image below.



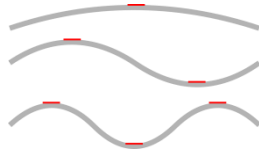
Deformation reconstruction

Consider the system as displayed in the image on the previous page, the strain in a fiber attached to the outer surface of a bending beam can be calculated with the following formula:

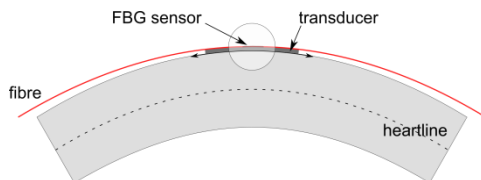
$$\epsilon = \frac{y}{R}$$

Where **y** is the distance from the heart line of the bending beam to the heart line of the attached fibre. The radius **R** is the bending radius of the beam. Likewise the radius **R** can be calculated from a given distance **y** and the measured strain **ε**.

Having multiple FBG sensors along the path to measure provides through interpolation a strain distribution. Integrating the relation between strain and radius results in a calculated curvature. The number of FBG sensors allows measurement of a similar amount of bending modes. How many bending modes are to be measured depends on the material stiffness and its deformation range.



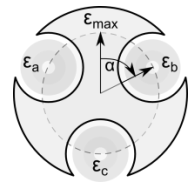
Using typical fibres implies a certain maximum strain to be measured. If a radius to be measured is smaller than allowed by the fibre, a transducing element can be used. This element - with attached fibre sensor - is then lead along the object or surface to measure both with free movement.



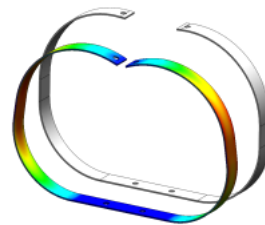
This makes the thickness of this transducing object of measurement; as the element has a much smaller dimension the centre line from the element to the fibre remains within acceptable limits, while the distance centre line of the targeted object for shape sensing to the fibre is still much bigger.

Using the same principle similarly allows deflection measurements in three dimensions. A practical solution to perform 3D shape sensing is to create an assembly of three fibres glued together. Mounting such an assembly along a deforming surface and allowing the assembly to move freely along the measurement path (with one end fixed) results in a means to monitor deflections in three dimensions.

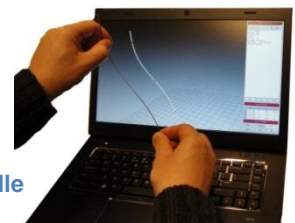
The principle of operation for three fibres is demonstrated in the image on the right. Each fibre will have a directional strain component at each interpolated integration step. This strain component can be positive (strain) or negative (compression). Integrating these directional strain components along the measurement path result in a three dimensional deformation reconstruction.



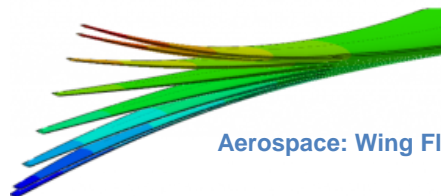
Examples



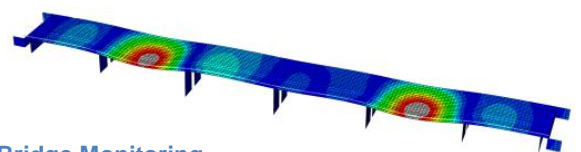
Automotive: Rib Deflection



Medical: Invasive Needle



Aerospace: Wing Flapping and Torsion



Civil: Bridge Monitoring