Fibre Optic Sensors: An Overview

Fritz K. BRUNNER, Austria

Keywords:

SUMMARY

Engineering geodesists have the competence to measure the external deformations of structures using automated surveying techniques such as motorized digital levelling systems, autonomous total stations and GPS arrays. The analytical deformation analysis has been fully developed and appropriate software tools are available.

During the past decade, physicists have been developing new sensory capabilities to measure the internal parameters of structures as part of so-called smart civil structures. For civil structures, the primary sensing issues are: (i) measuring the reaction of the structure to external loads, and (ii) determining the internal state-of-health of the structure. For these purposes, small fibre optic sensors (FOS) are embedded and spatially distributed in the structure. FOS have been developed to detect variations in crack formation, strain, temperature and corrosion. A significant advantage of FOS is the ability to multiplex a number of continuous or discrete sensors on one fibre to form a distributed sensor system.

This paper serves the purpose to make engineering geodesists aware of these developments. It provides background information of embedded and distributed FOS using light intensity changes caused by attenuation, scattering and reflection, or phase changes caused by optical path length or refractive index variations.

1st FIG International Symposium on Engineering Surveys for Construction Works and Structural Engineering

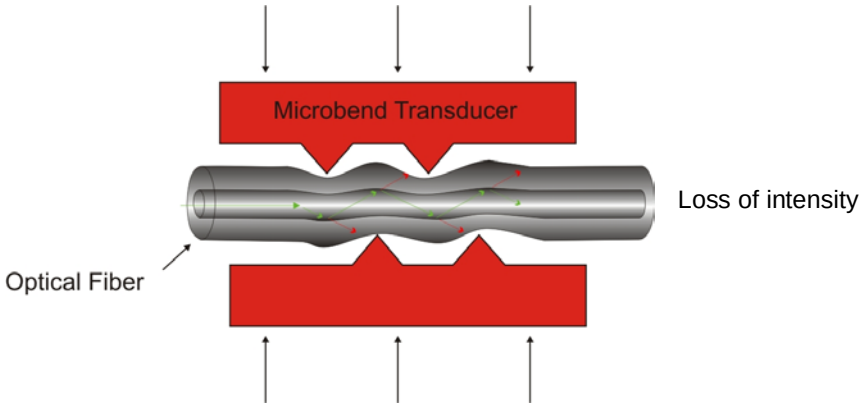
Nottingham, June 2004

Fibre Optic Sensors: An Overview

Fritz K. Brunner

Intensity: Microbending-sensor

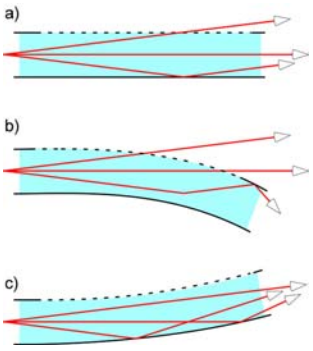
Pressure and deformation measurements

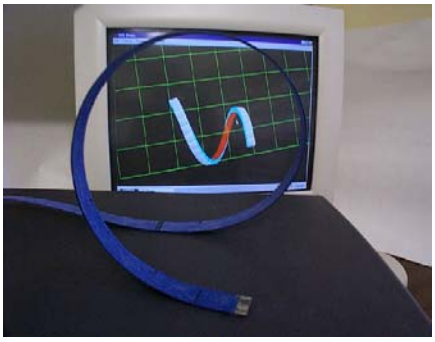


(Measures RM, 2001)

Curvature measurements

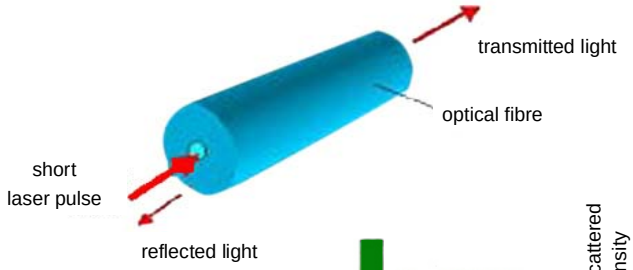
Principle of curvature measurements using FO intensity measurements

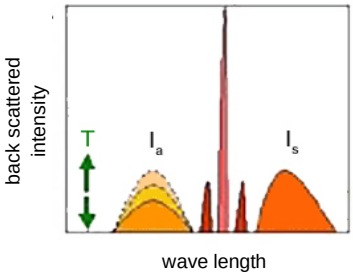




(Commercial realisation „ShapeTape“)

Raman scattering: Measurement of temperature





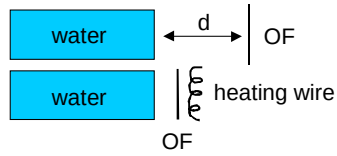
$$r_R = \frac{I_a}{I_s} = \left[\frac{\lambda_s}{\lambda_a}\right]^4 \exp\left\{-\frac{h \cdot c \cdot \Delta\nu}{k \cdot T}\right\}$$

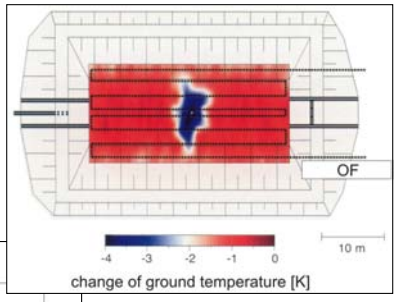
Magnitude ~ 0.8% / K

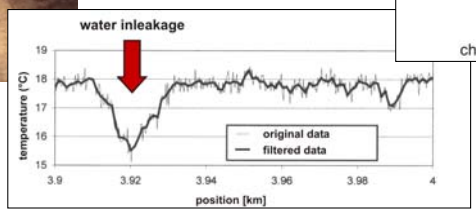
- Determination of position using propagation time (OTDR)
- Resolution: ~1°C in temperature and ~3 m in position and better using time averaging

Application: Detection of leakage

- Gradient method
- Heating method





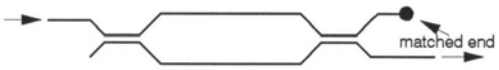


(Aufleger, 2000)

Three interferometric designs

Michelson Interferometer

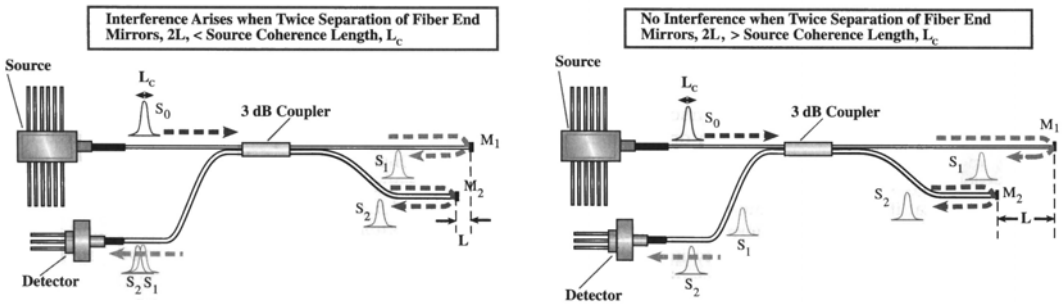
Mach Zehnder Interferometer



Fabry-Perot Interferometer

(Culshaw B, 1996)

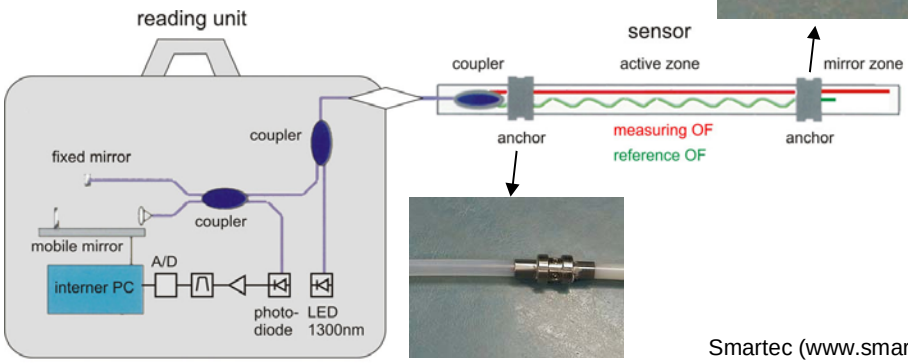
Low-coherence interferometer



(Measures RM, 2001)

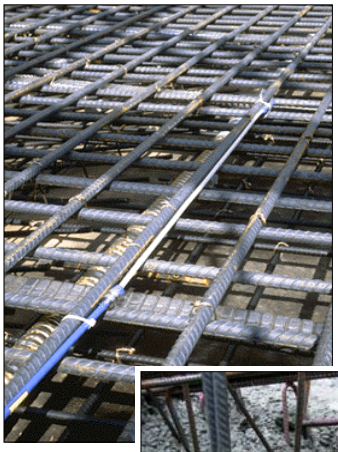
Strain sensors: SOFO

- Interferometric system
- Absolute measurements using low-coherent light
- Resolution: 2 µm
- Length of sensors: 0.2 m - 20.0 m
- Temperature compensated



Smartec (www.smartec.ch)

SOFO sensor: embedded or external anchoring



Embedding of SOFO sensors

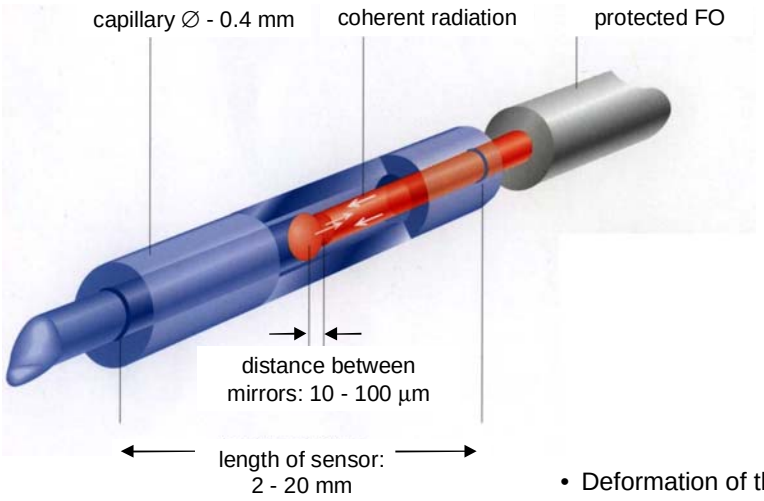
Sensor

- Iron binder
- Round bar reinforcement

FO cable

- Mounted below the reinforcement bars
- Loosely fixed with cable ties
- Use of a cabling cabinet

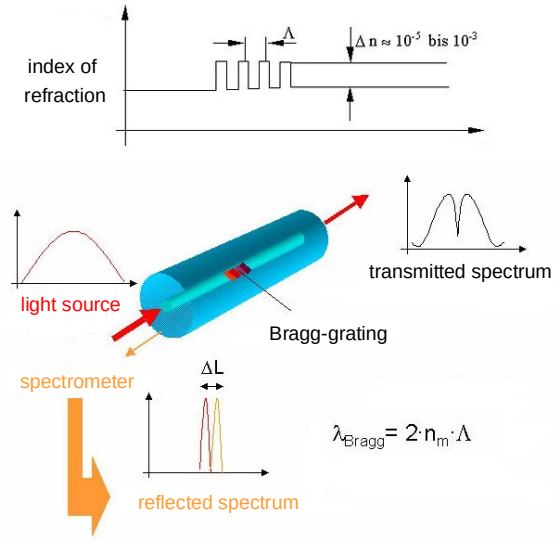
FO-Fabry-Perot sensor: Strain measurement



- Deformation of the sensor's cavity length causes a change of the distance between the mirrors

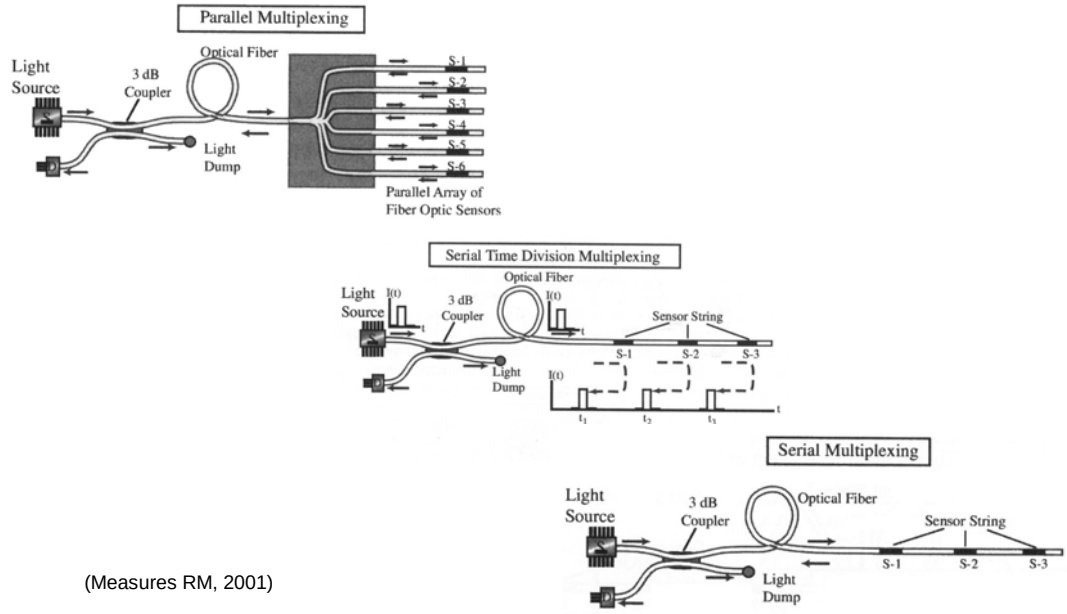
(Habel R, 2003)

FO Bragg-grating: Strain measurement



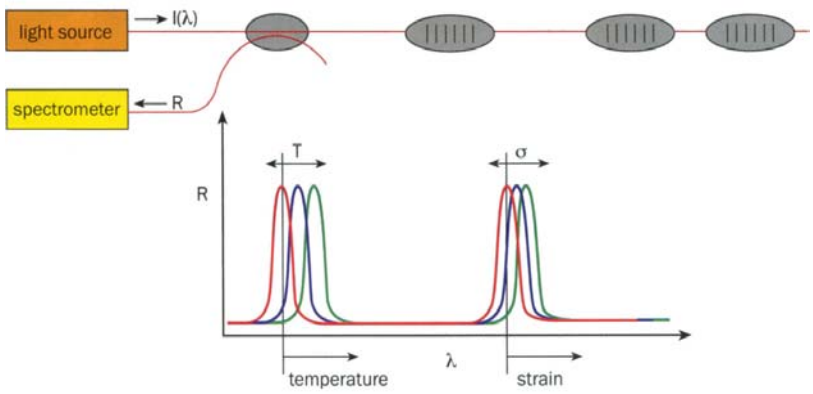
- Several Bragg gratings can be incorporated on one FO

Multiplexing of sensors



(Measures RM, 2001)

Multiplexing of FBG: Temperature and strain



REFERENCES

Ansari F. (Ed.) (1998) Fiber Optic Sensors for Construction Materials and Bridges, Lancaster, Technomic Publishing

Aufleger M. (2000) Verteilte faseroptische Temperaturmessungen im Wasserbau, Bericht Nr. 89, Lehrstuhl u. Versuchsanstalt f. Wasserbau und Wasserwirtschaft, TU München

Culshaw B. (1996) Smart Structures and Materials, Glasgow, Artech House

Habel W. (2003) Faseroptische Sensoren für Deformationsmessungen - Kriterien für eine zuverlässige Nutzung, VDI Bericht Nr. 1757: 141-158

Inaudi, D. (2002) Photonic Sensing Technology in Civil Engineering Applications, in López-Higuera J.M. (Ed.) Handbook of Optical Fibre Sensing Technology, Chichester: 517-542

Lienhart W., Brunner F.K. (2003) Monitoring of Bridge Deformations using Embedded Fiber Optical Sensors, in Stiros St. and Pytharouli St. (Eds.) Proc. 11th Int. Symp. on Deformation Measurements, Santorini, Greece: 555-561

Measures R.M. (2001) Structural Monitoring with Fiber Optic Technology, Ontario, Academic Press

CONTACTS

Prof. Dr. Fritz K. Brunner
Engineering Geodesy and Measurement Systems
Graz University of Technology
Steyrergasse 30
A-8010 Graz
AUSTRIA
Tel. + 43/316/873 6321
Fax + 43/316/873 6820
Email: fritz.brunner@tugraz.at
Web site: www.igms.TUGraz.at