COPY OF PRESENTATION TO USITT ON 30th MARCH.

OPTICAL FIBRE SENSORS FOR MEASUREMENT OF PRESSURE AND STRAIN

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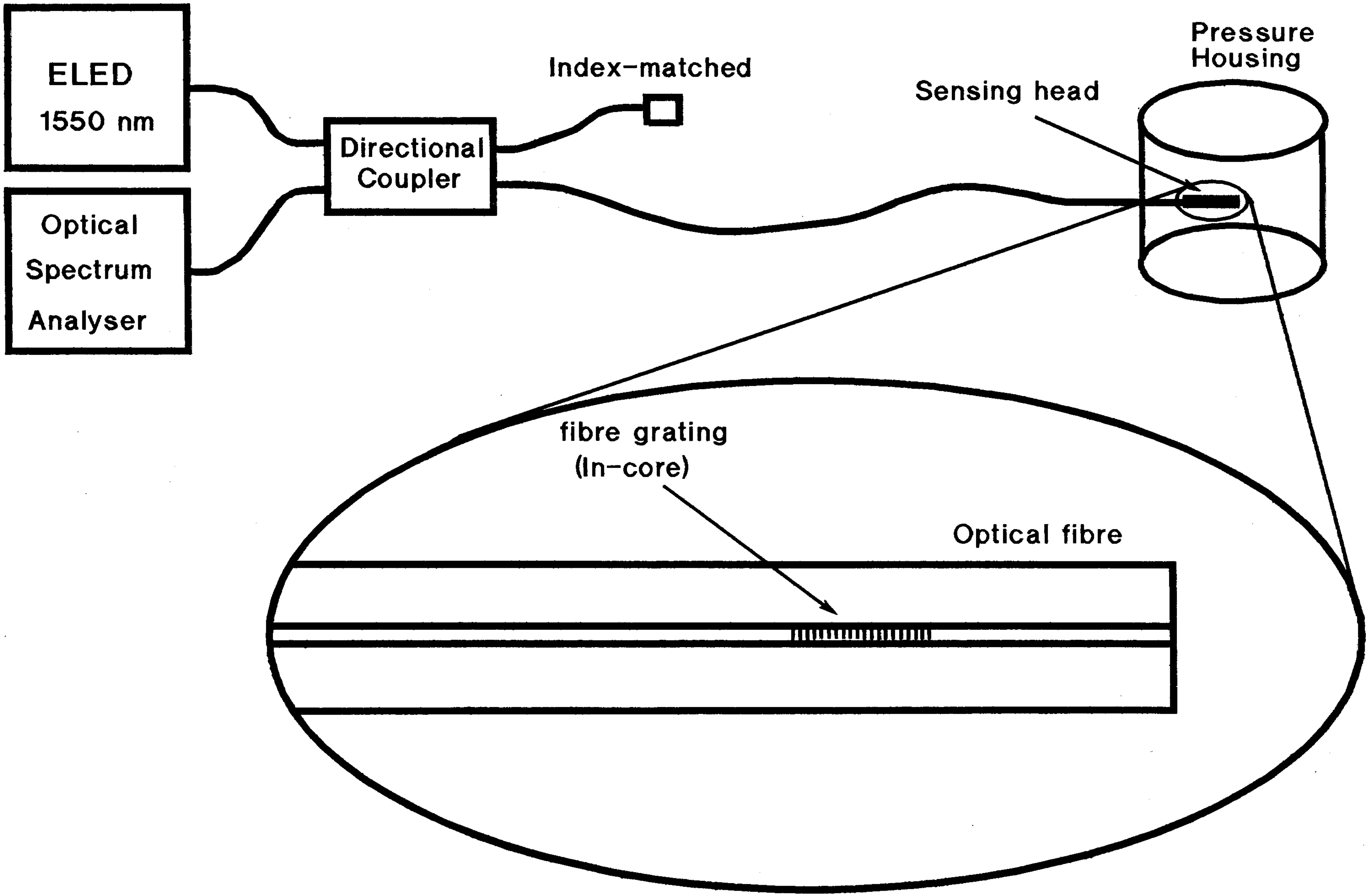
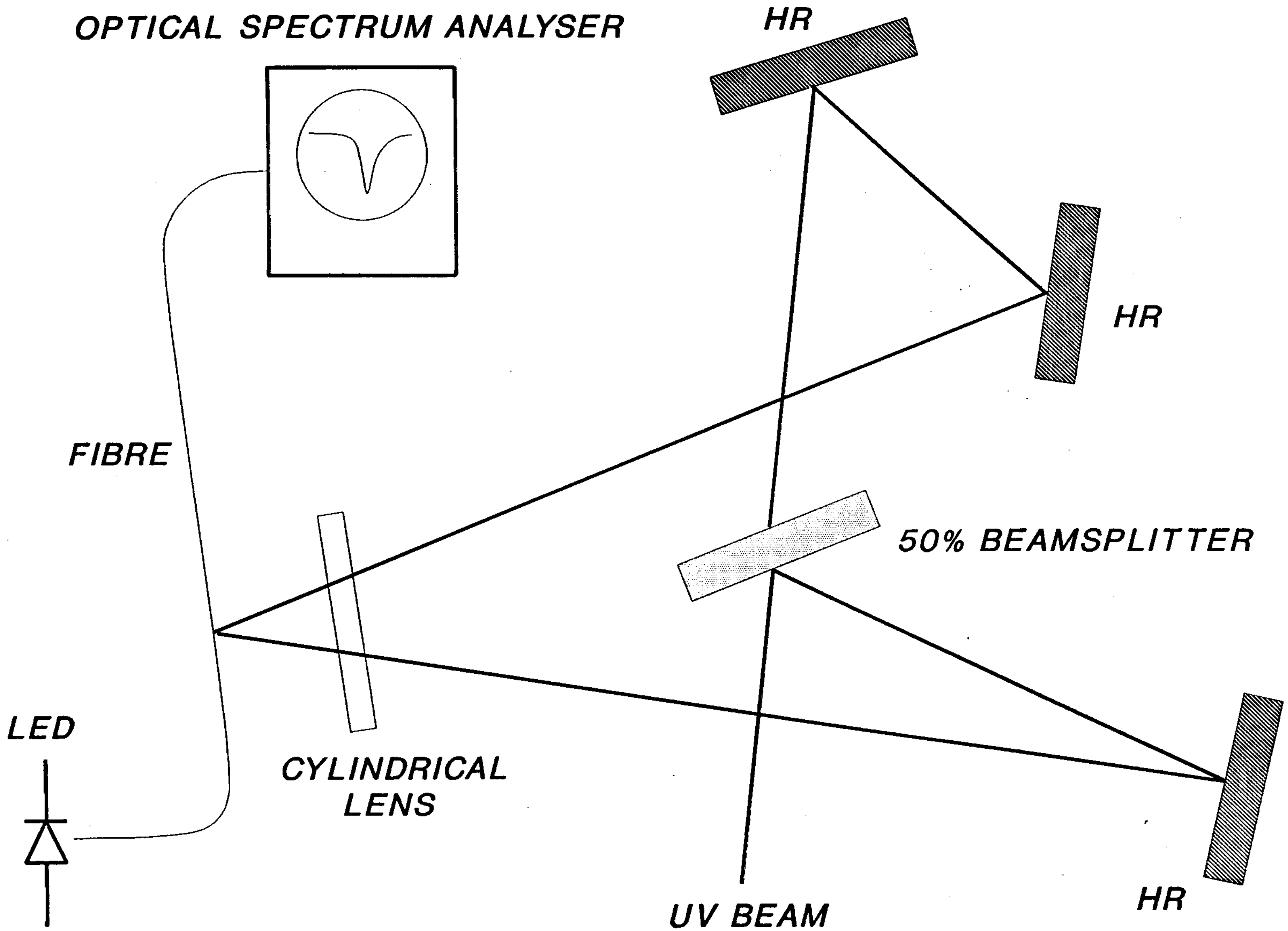


Fig 1. Schematic of the fibre grating pressure sensor


OPTICAL SPECTRUM ANALYSER
HR
HR
FIBRE
50% BEAMSPLITTER
LED
CYLINDRICAL
LENS
UV BEAM
HR

Optical Fibre Sensor for High Pressure Measurement Using an in-Fibre Grating

M. G. Xu, L. Reekie, Y. T. Chow and J. P. Dakin

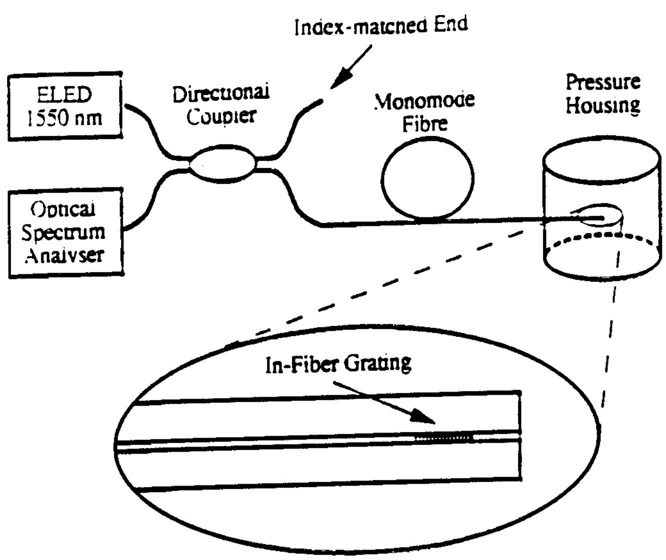


Fig.1 Schematic of In-Fibre Grating Pressure Sensor

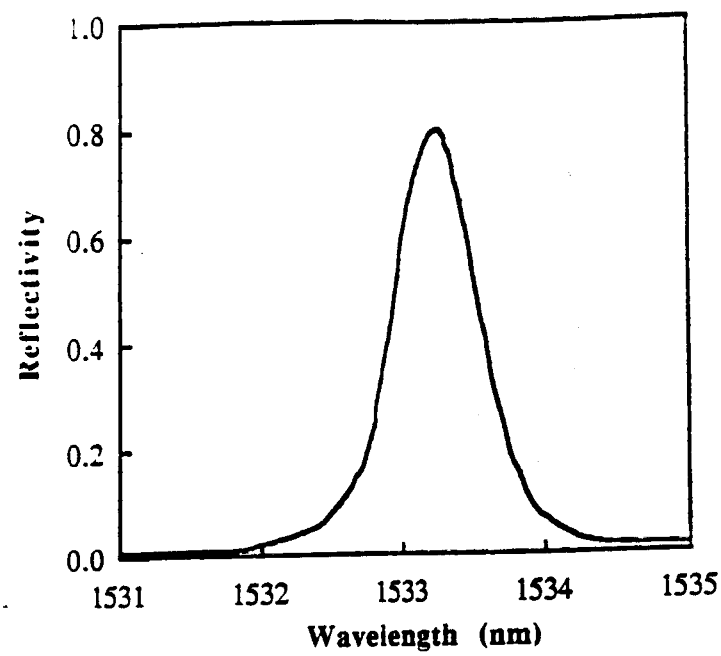


Fig.2 Reflected Spectrum From Sensing Probe

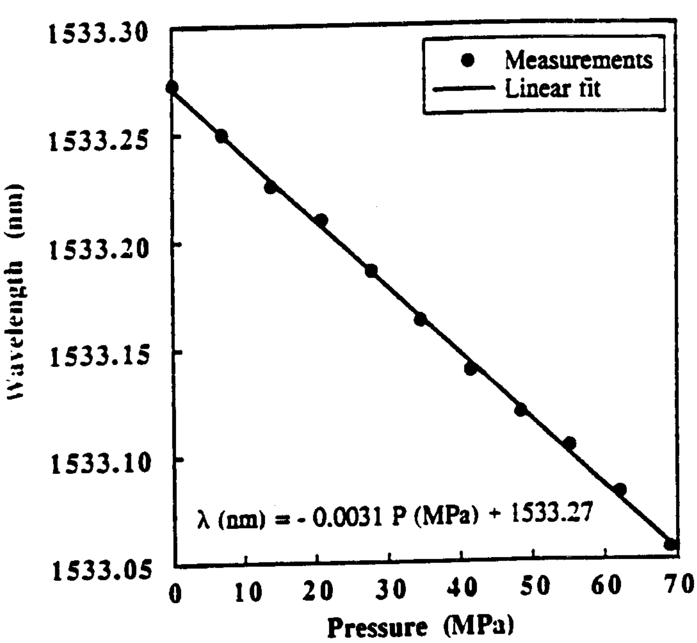


Fig.3 Pressure Response of the Sensor

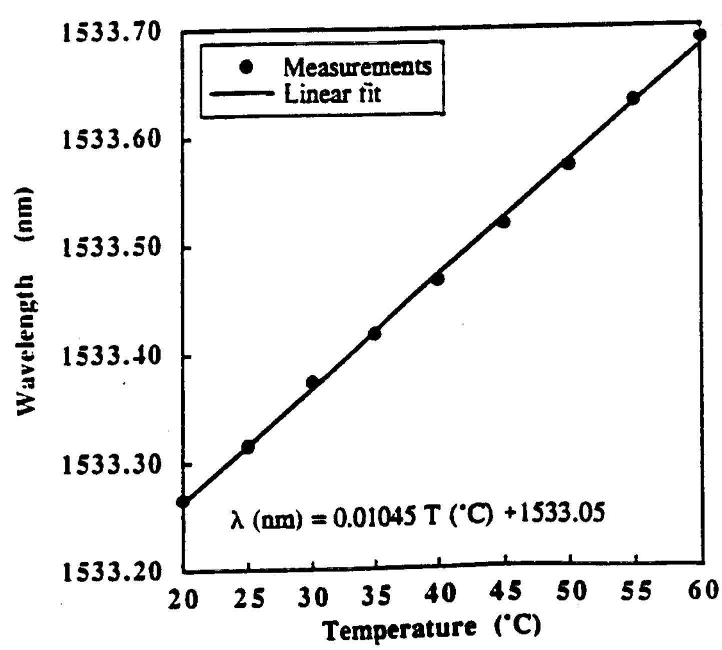
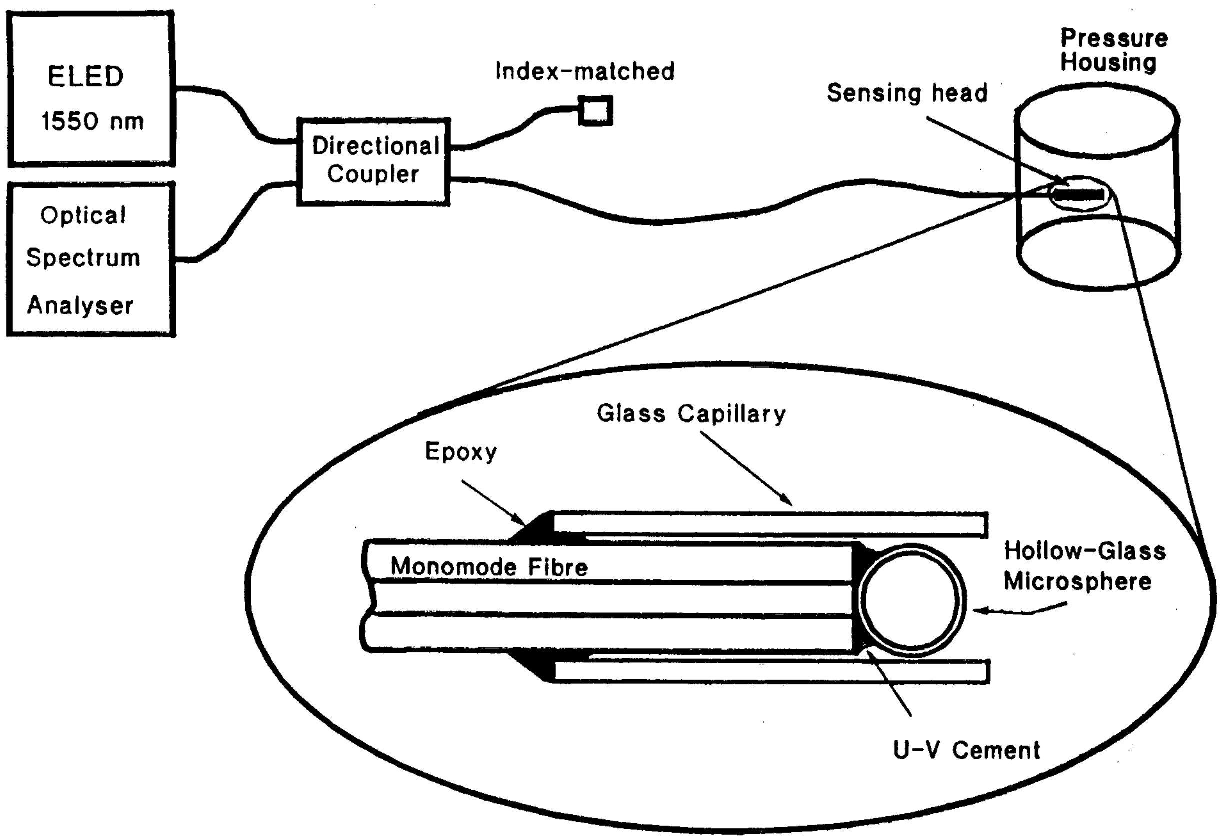


Fig.4 Temperature Response of the Sensor

A NOVEL HOLLOW-GLASS MICROSPHERE SENSOR FOR MONITORING HIGH HYDROSTATIC PRESSURE

M. G. Xu and J. P. Dakin



Intensity, I_D, received at optical spectrum analyser is:

$$I_D = k[A_1^2 + A_2^2 + 2A_1A_2\cos(\frac{2\pi}{\lambda}2d)]$$

Constants A represent field strengths, λ is wavelength, d=sphere internal diameter. Formula assumes Fabry-Perot has low reflectivity (ie. **effectively** only one reflection at each surfaces)

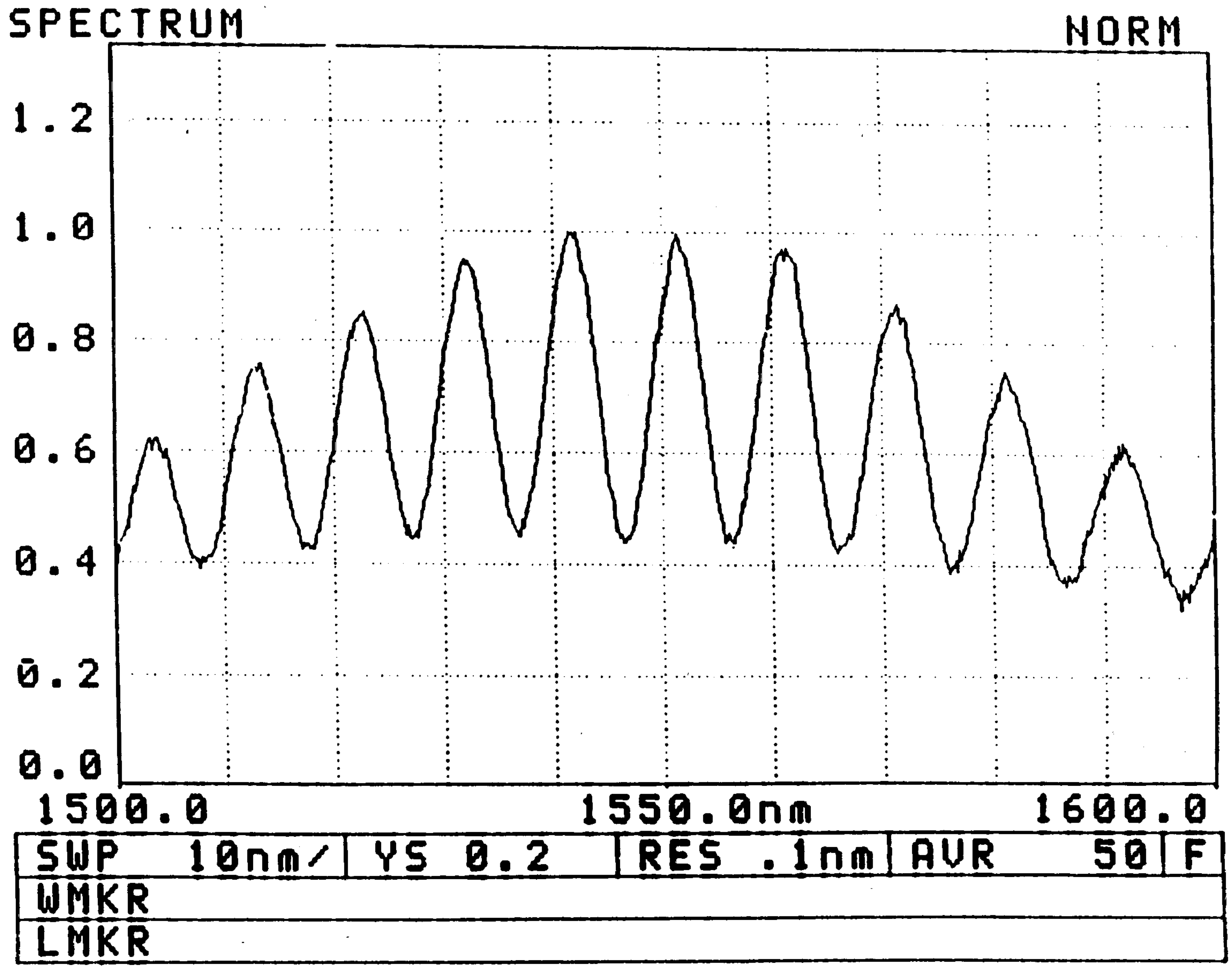
Spherical Fabry-Perot resonator:

$$\lambda = \frac{2d}{m}$$

Maxima in reflected spectrum occur when:

$$FSR = \frac{c}{2d}$$

Reflected spectrum from microsphere with LED excitation



Wavelength shift of maxima due to application of pressure:

$$\Delta\lambda = \frac{\lambda}{d}\frac{\delta d}{\delta P}\Delta P$$

Diameter change due to pressure-induced strain in hollow sphere:

$$\Delta d = -\frac{Pd^2(1-\nu)}{4Yt}$$

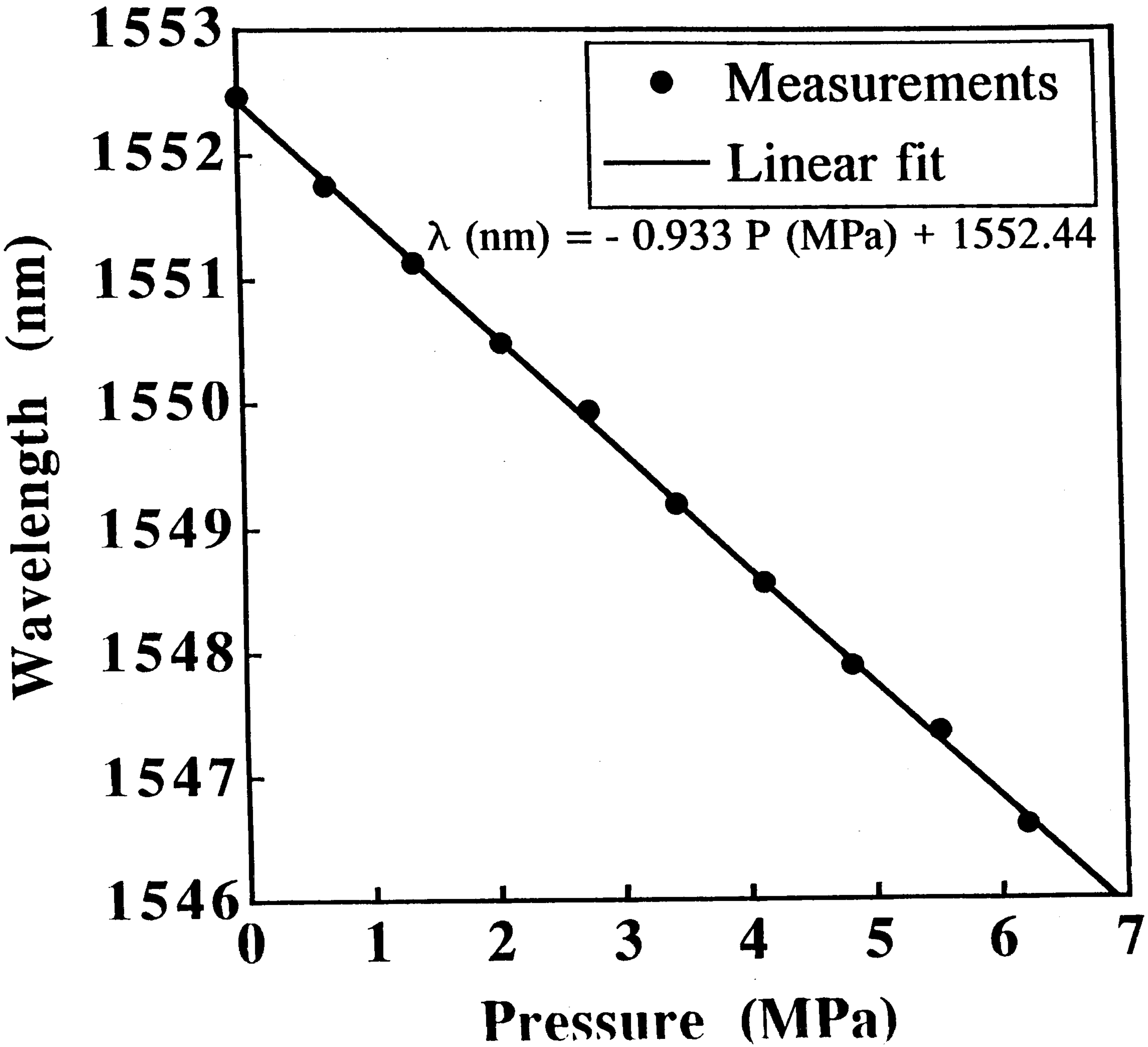
ν=Poisson ratio, Y=Young's modulus, t=sphere wall thickness.

Wavelength shift of maxima due to pressure and temperature:

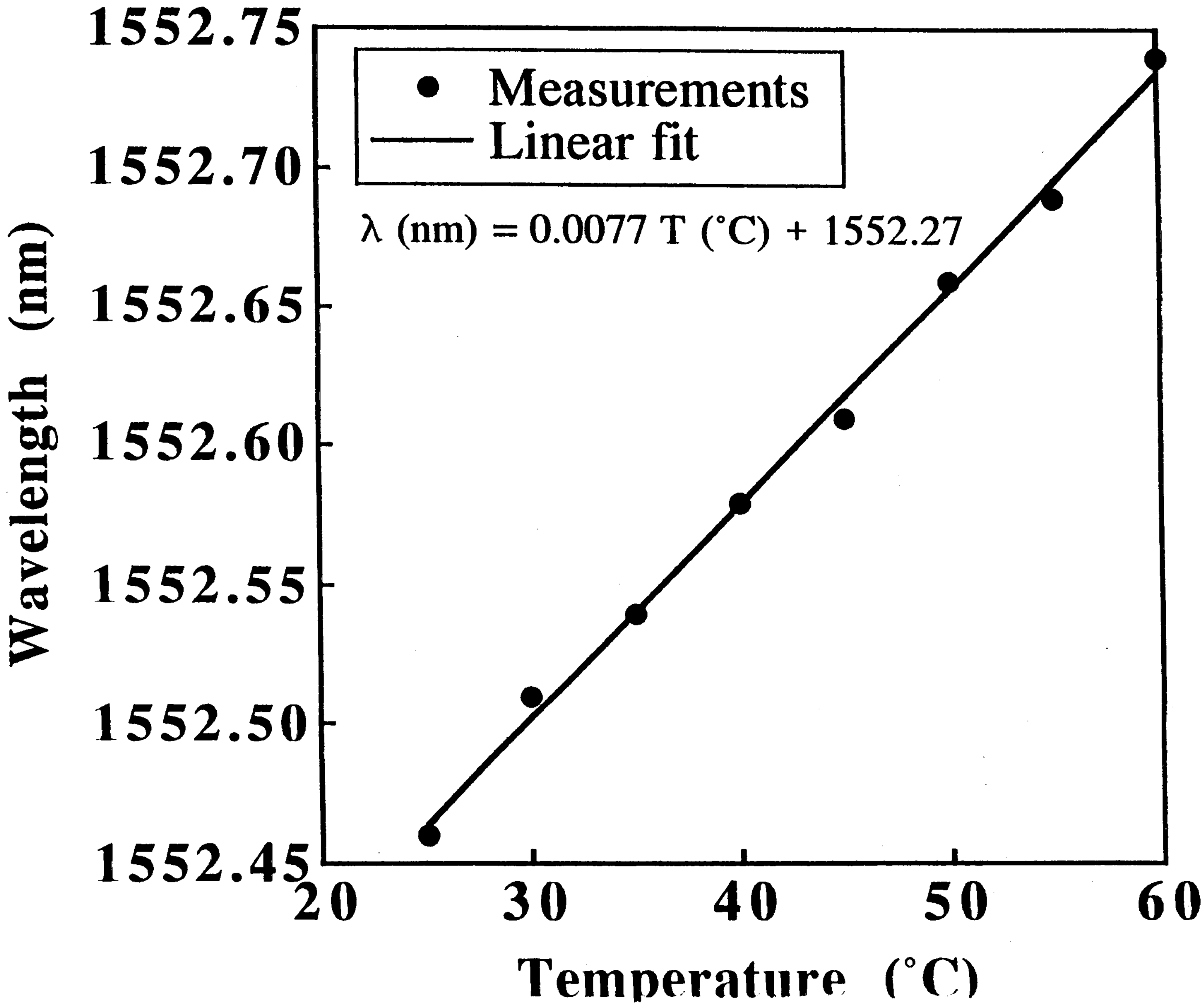
$$\Delta\lambda = -\frac{\lambda d(1-\nu)}{4Yt}\Delta P$$

$$\Delta\lambda = \frac{\lambda}{d}\frac{\delta d}{\delta T}\Delta T$$

Pressure response of the sensor



Thermal response of the sensor (ie. Temperature cross-sensitivity)



ADVANTAGES OF HOLLOW MICROSPHERE SENSOR

-Small size, compatible with fibre

-Hermetically sealed, low cost sensing element

-Wavelength-domain interrogation

-More compliant than solid-fibre sensors (about 100 times greater fractional shift in wavelength for a given pressure)

-Approx same temperature coefficient as solid fibre type of sensor

-Less temperature compensation necessary

-Expected to have a rapid response to pressure transients

FIBRE OPTIC SENSORS FOR STRUCTURAL MONITORING

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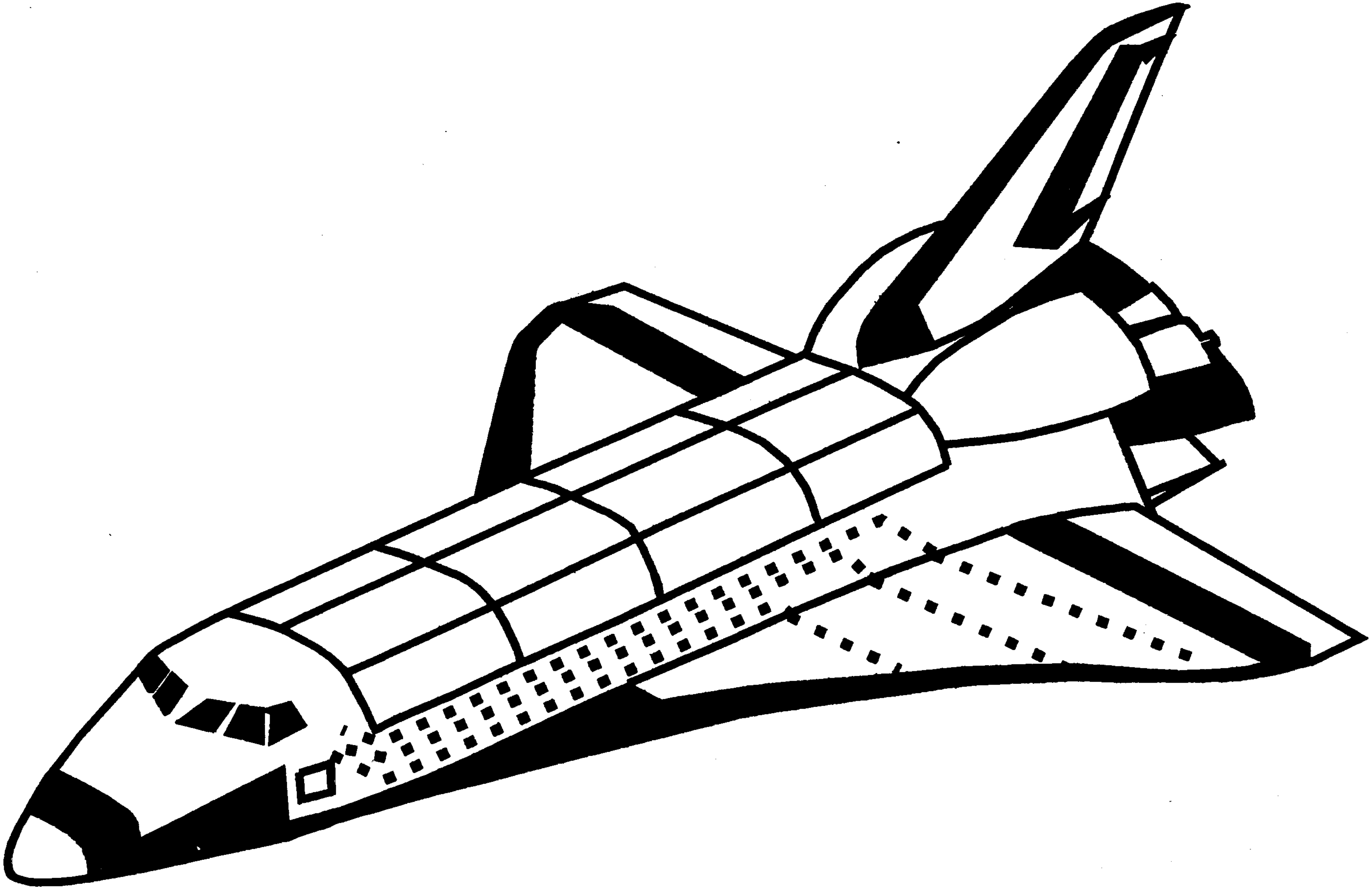
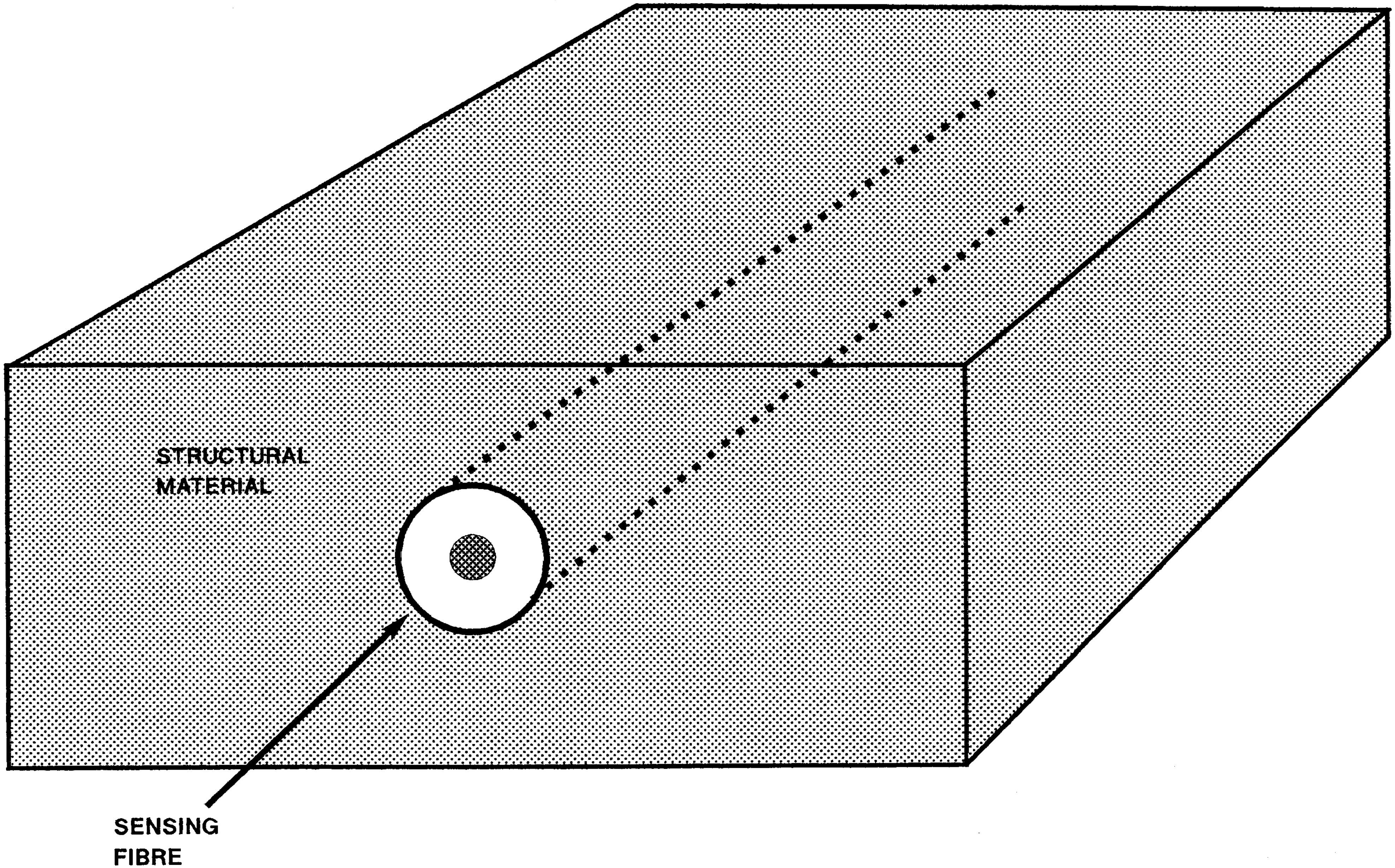
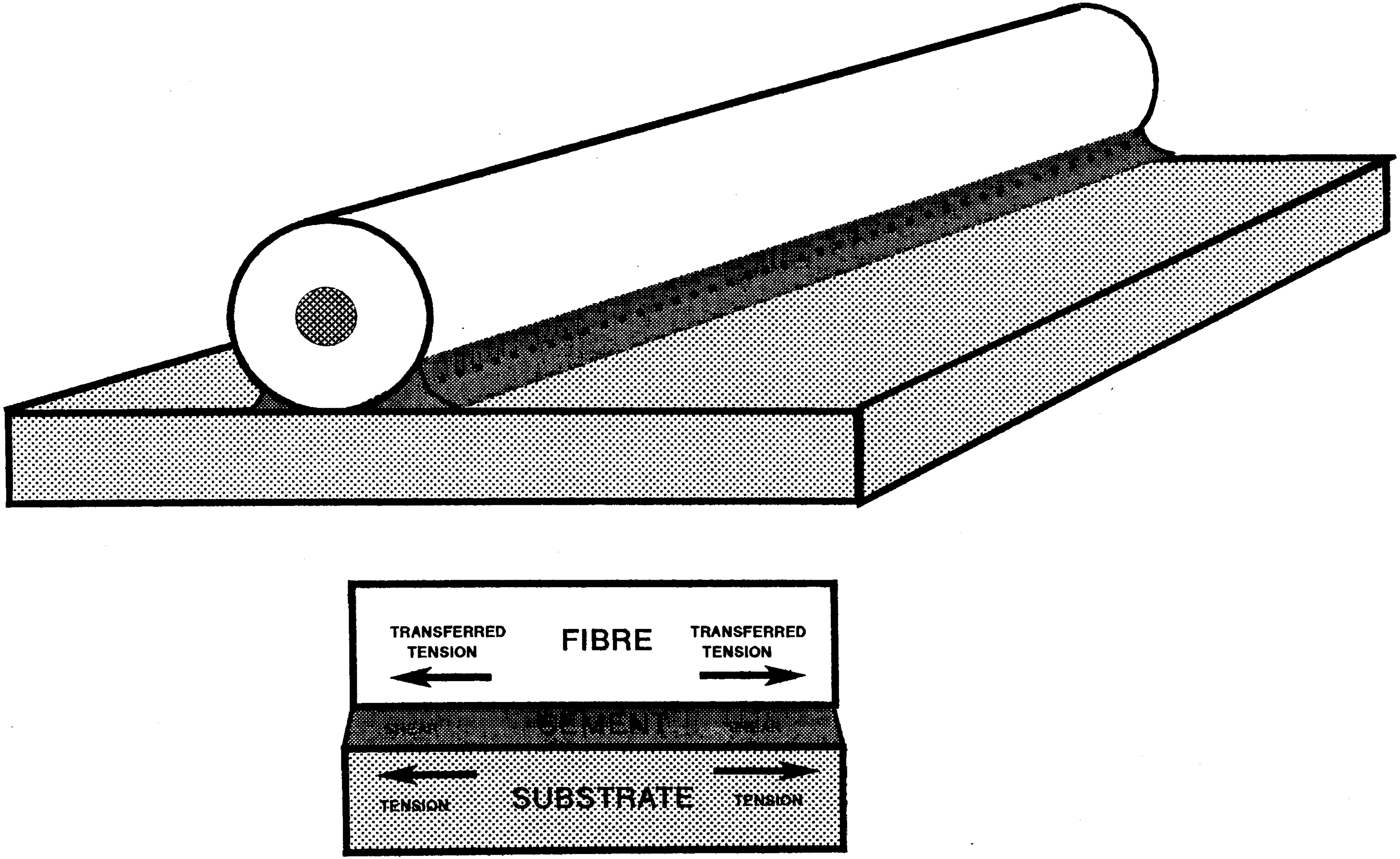


SCHEMATIC OF SMART SKINS CONCEPT FOR MONITORING OUTER SURFACE STRUCTURES OF AEROSPACE AND OTHER VEHICLES.

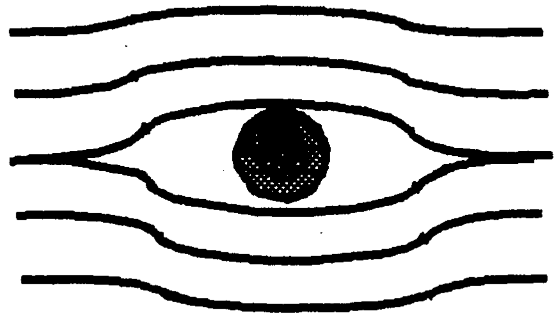


SCHEMATIC OF EMBEDDED FIBRE OPTIC STRAIN GUAGE

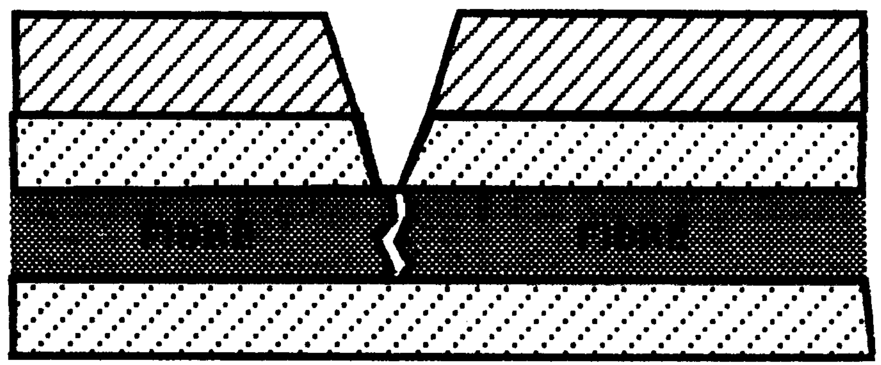


SCHEMATIC OF FIBRE STRAIN GUAGE BONDED TO A SURFACE

FIBRES IN LAMINATES FOR SMART SKINS.



SCHEMATIC OF OPTICAL FIBRE IN
A LAMINATED STRUCTURE.



FIBRE BROKEN BY A CRACK IN THE LAMINATE.
(NOTE: IT IS NOT NORMALLY NECESSARY TO HAVE SUCH A SEVERE FAULT, AND EXTERNALLY-INVISIBLE DEFECTS IN THE LAMINATE MAY GIVE RISE TO FIBRE BREAKAGE AT THE WEAKENED POINT.)

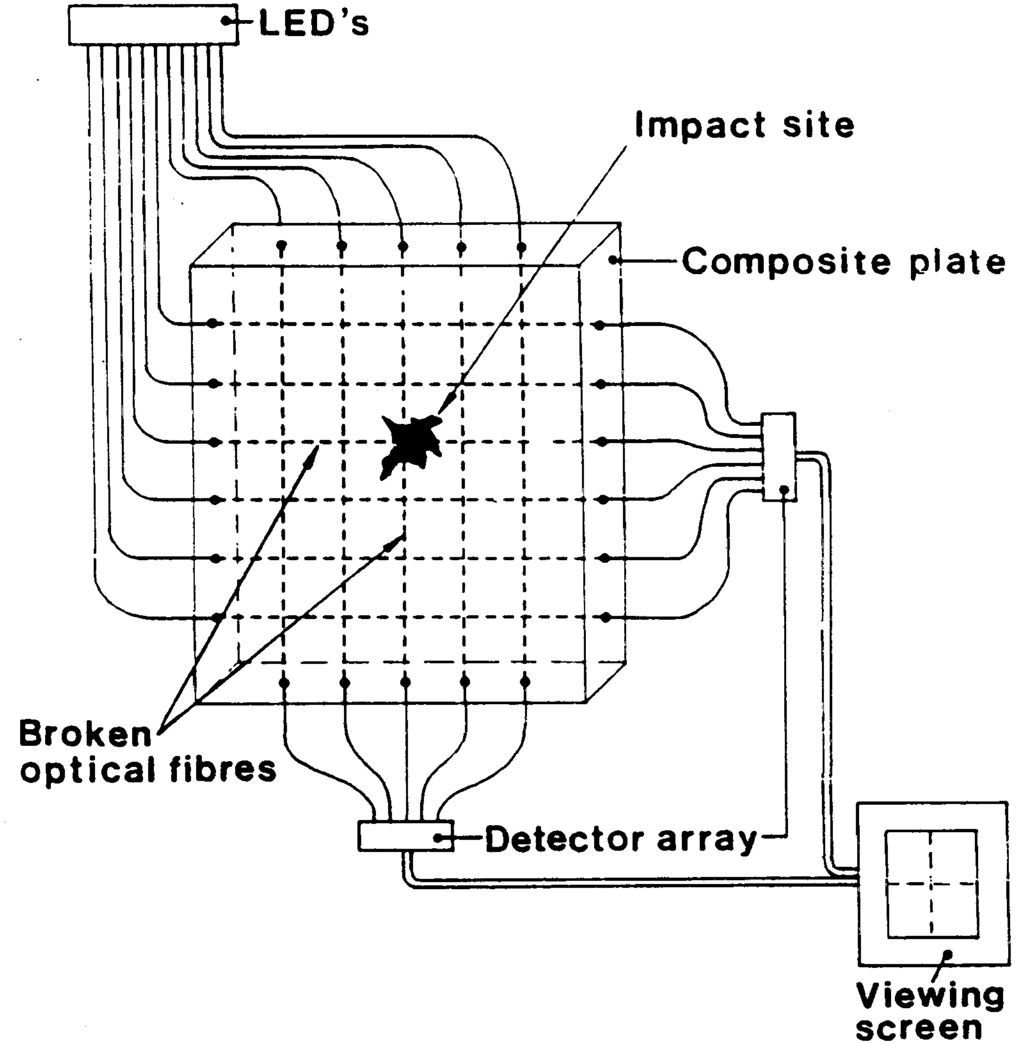
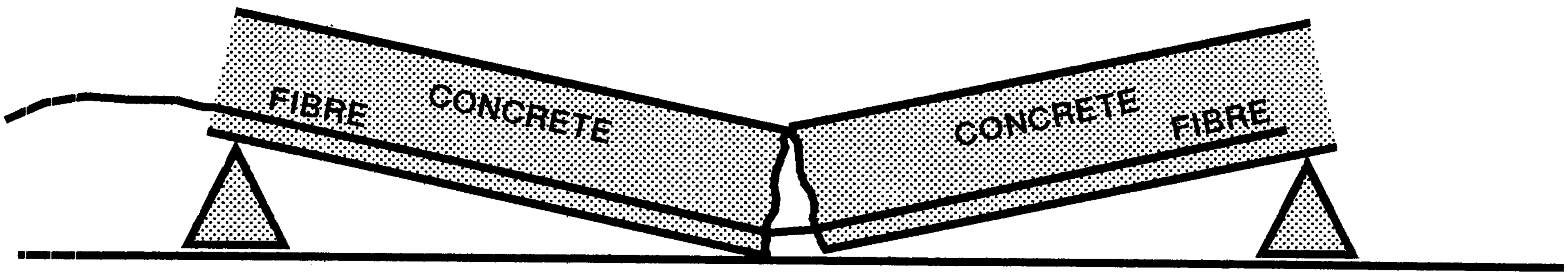
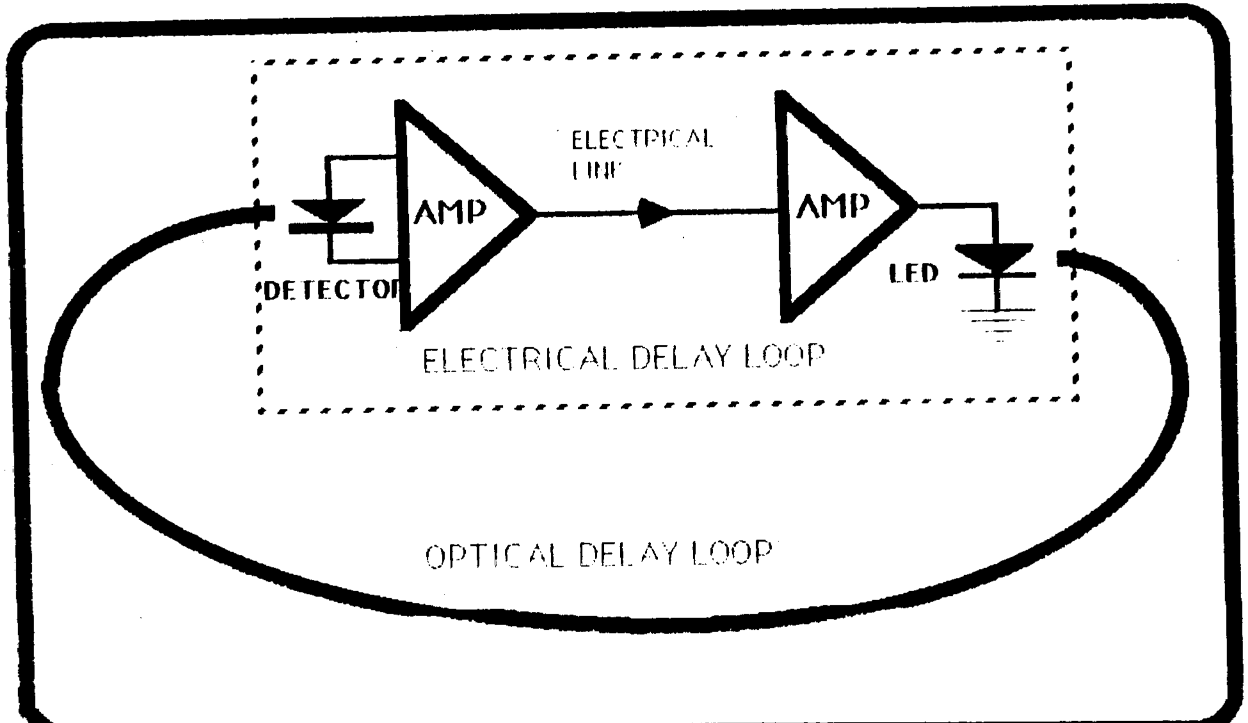


Fig. 19.11 Schematic diagram of an optical fiber system showing the location of impact damage in a composite structure.

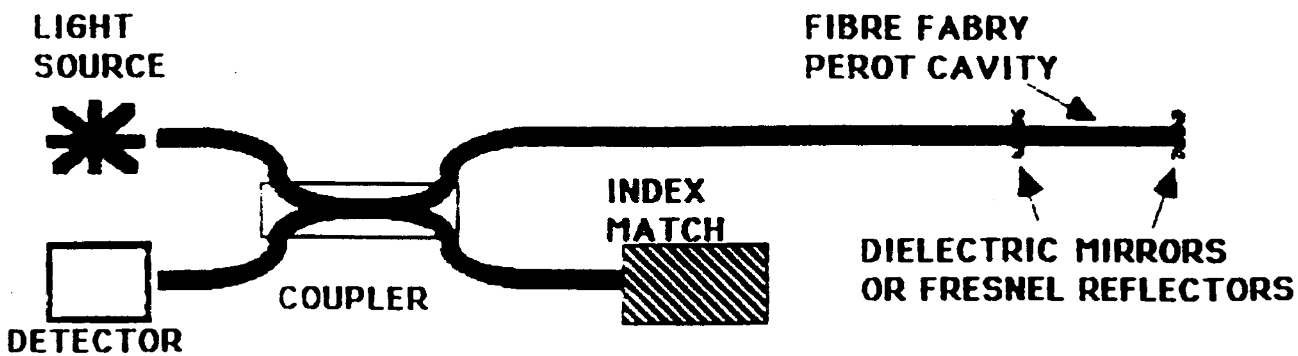


PROBLEMS WITH CRACK DETECTION IN CONCRETE BEAMS

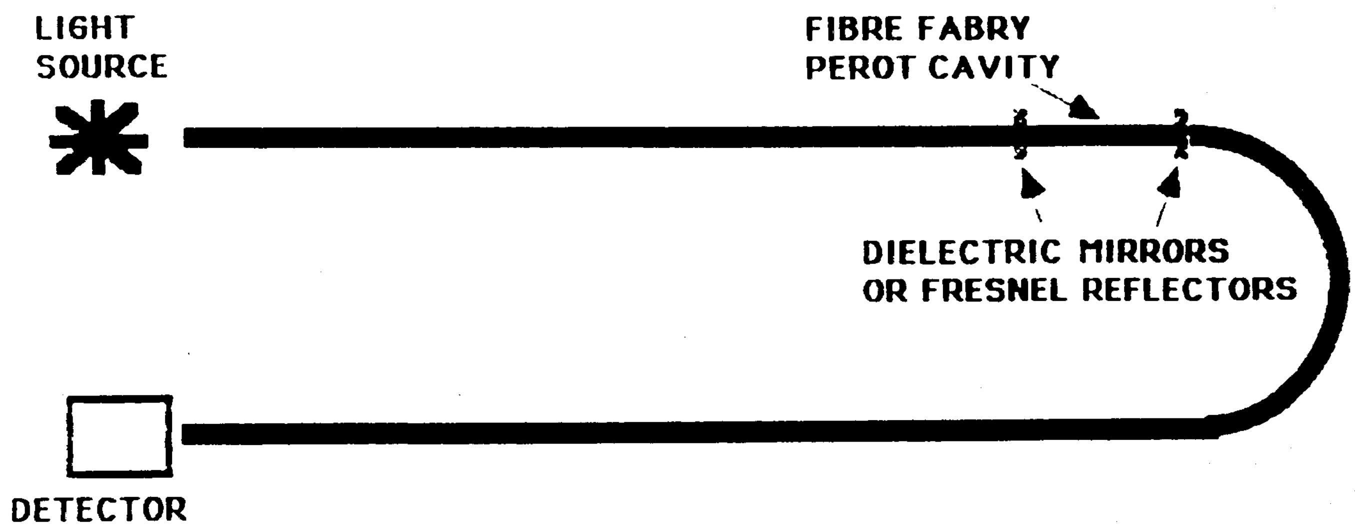
(Fibre has less adhesion to concrete and can pull out)



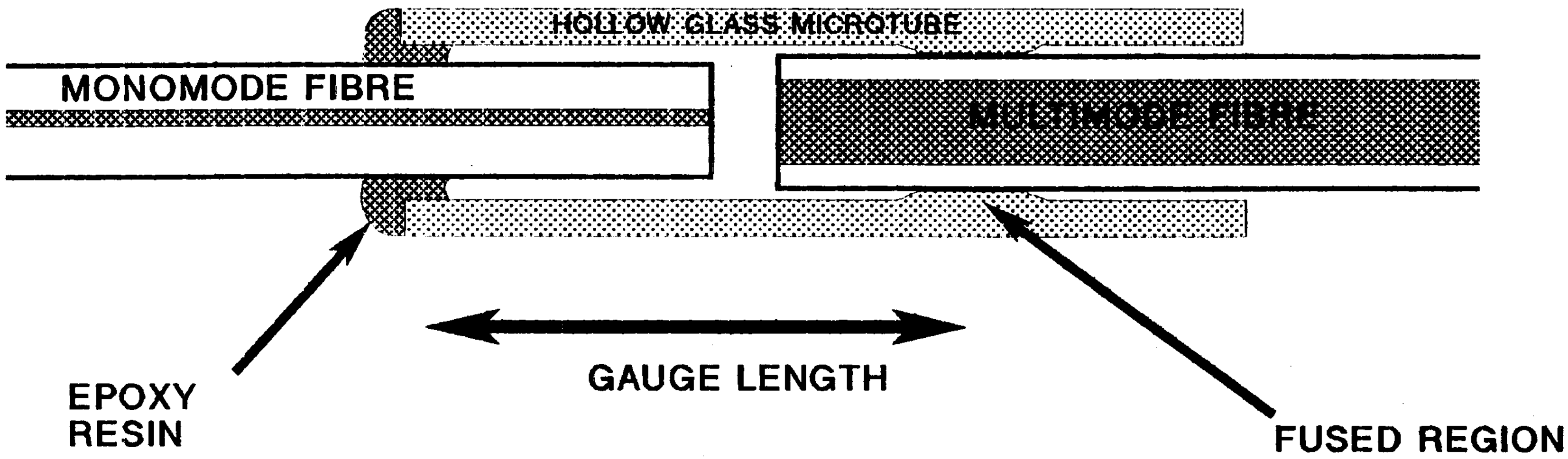
FIBRE-OPTIC LOOP OSCILLATOR
(OSCILLATION FREQUENCY DEPENDS ON
SUM OF OPTICAL AND ELECTRICAL DELAYS.)
(JOHNSON & ULRICH)



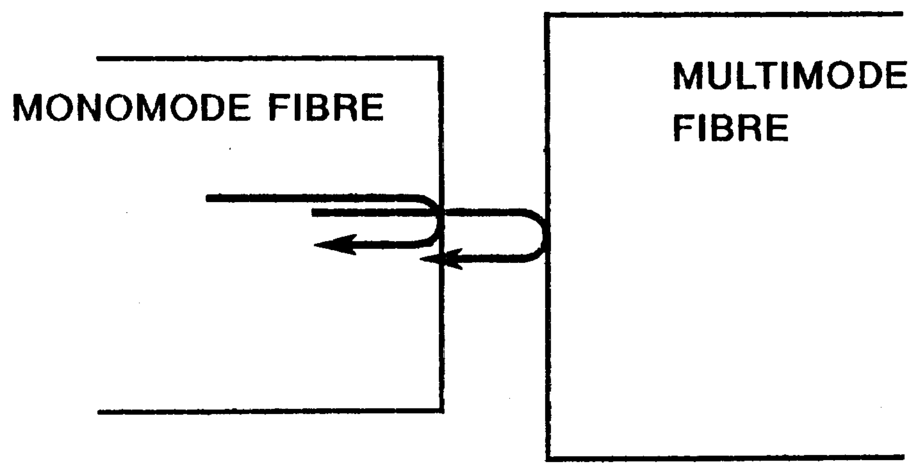
REFLECTIVE FABRY PEROT INTERFEROMETER



TRANSMISSIVE FABRY-PEROT INTERFEROMETER



FIBRE SENSOR OF CLAUS et Al, VIRGINIA TECH, USA.



SCHEMATIC OF INTERFERING LIGHT BEAMS REFLECTED FROM EACH FIBRE END SURFACE.

PHOTOREFRACTIVE FIBRE GRATING

Effect of temperature, T

$$\frac{\Delta\lambda_g}{\lambda_g} = (\alpha + \xi)\,\Delta T$$

λ_g=peak grating reflection wavelength

α=thermooptic coefficient

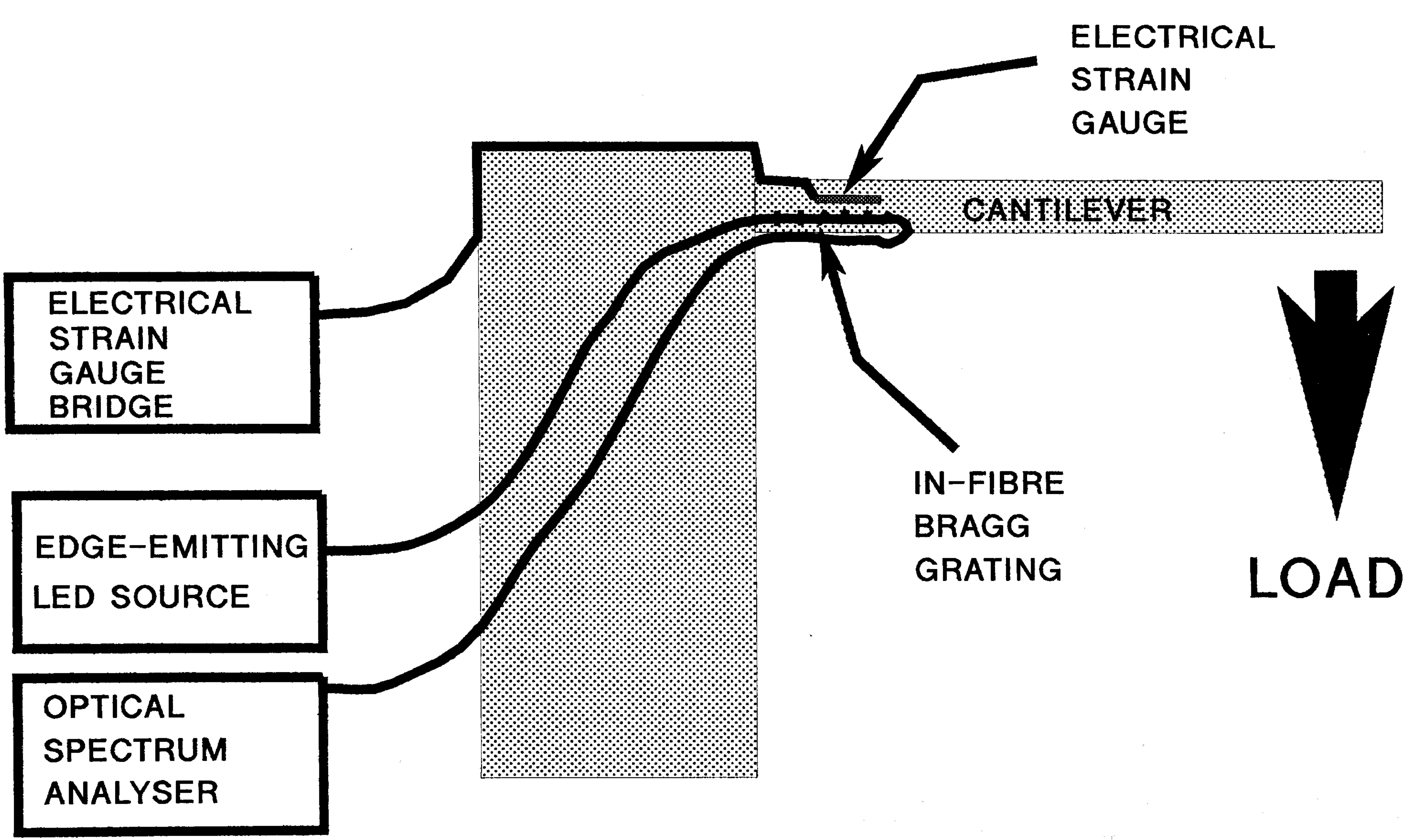
ξ=thermal expansion coefficient

Effect of axial strain, ϵ

$$\frac{\Delta\lambda_g}{\lambda_g} = (1 - P_e)\,\epsilon$$

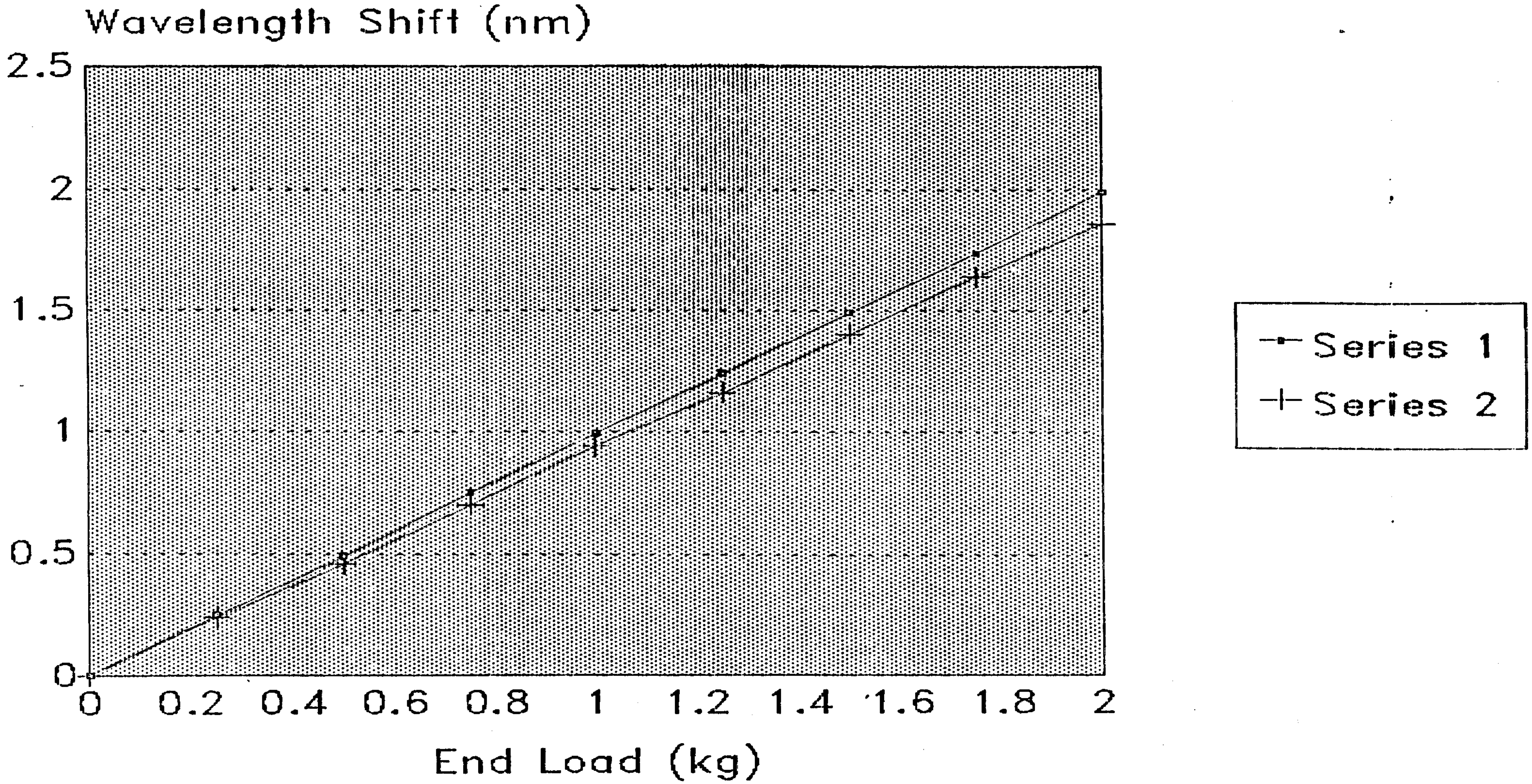
P_e=effective photoelastic coefficient

Reference: WW. Morey, G. Meltz, W.H. Glenn Proc SPIE Vol. 1169 (1989) 98

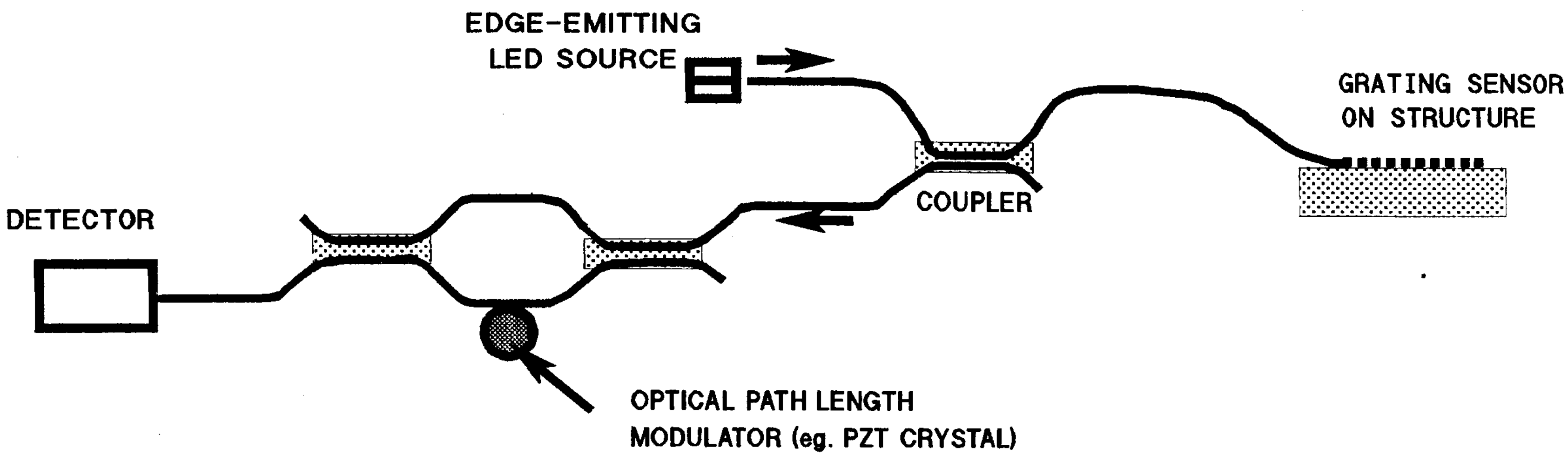


SCHEMATIC OF ARRANGEMENT FOR TESTING OF IN-FIBRE BRAGG GRATING SENSOR

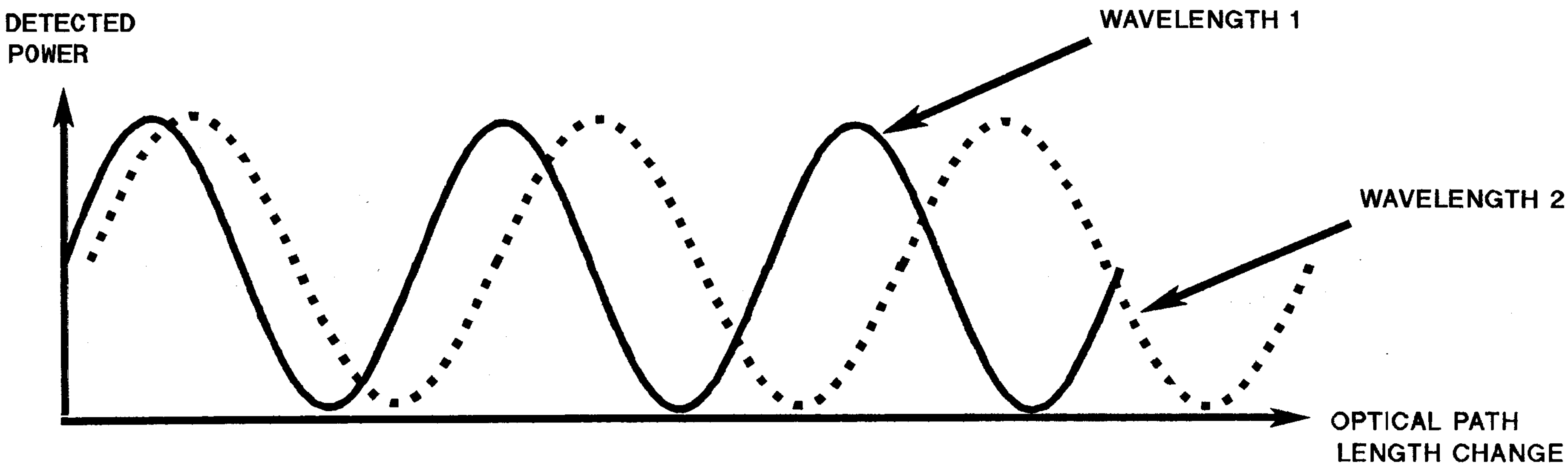
Measured and Predicted Bragg Wavelength vs. Beam End Load



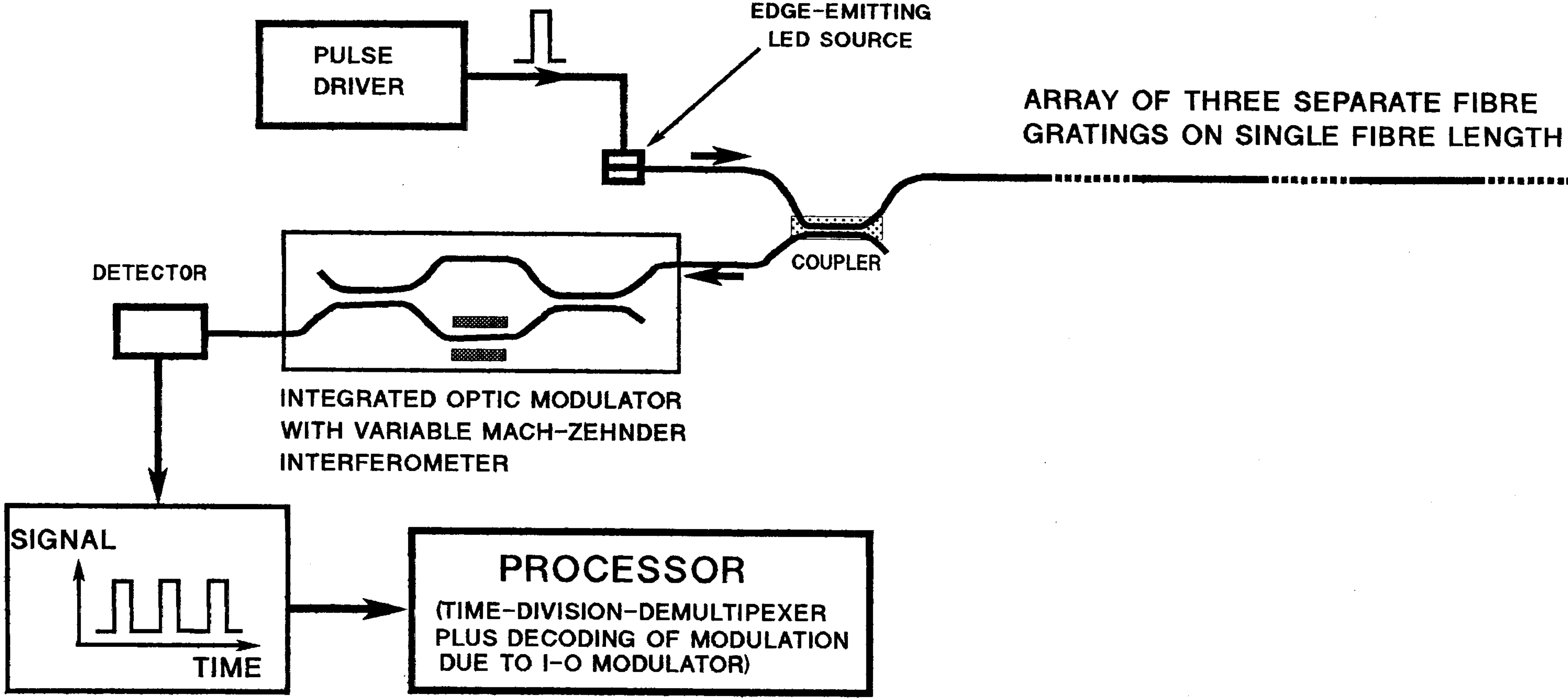
Series 1 = Detected Shift
Sreies 2 = Predicted Shift



SYSTEM FOR THE INTERROGATION OF GRATING WAVELENGTH, USING INTERFEROMETER



RESPONSE OF SYSTEM SHOWN IN ABOVE DIAGRAM, AS GRATING WAVELENGTH CHANGES

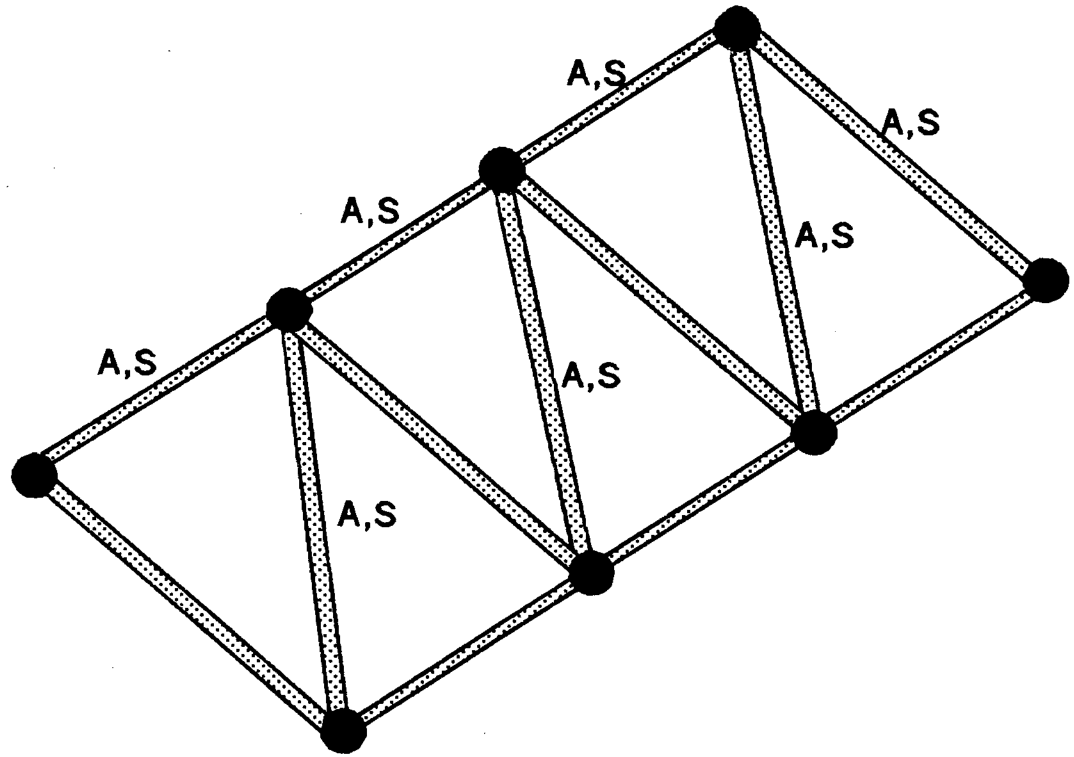


TIME-DIVISION MULTIPLEXED SYSTEM FOR THE INTERROGATION OF GRATING WAVELENGTH

(Method proposed by Kersey, Berkoff and Morey 1st Euro Conf on Smart Structures and materials, Glasgow, 1992)

Note that the detected signal shows the three reflected signal pulses from the three gratings. The amplitude of each of these three pulses varies slowly with time as the M-Z modulator is operated

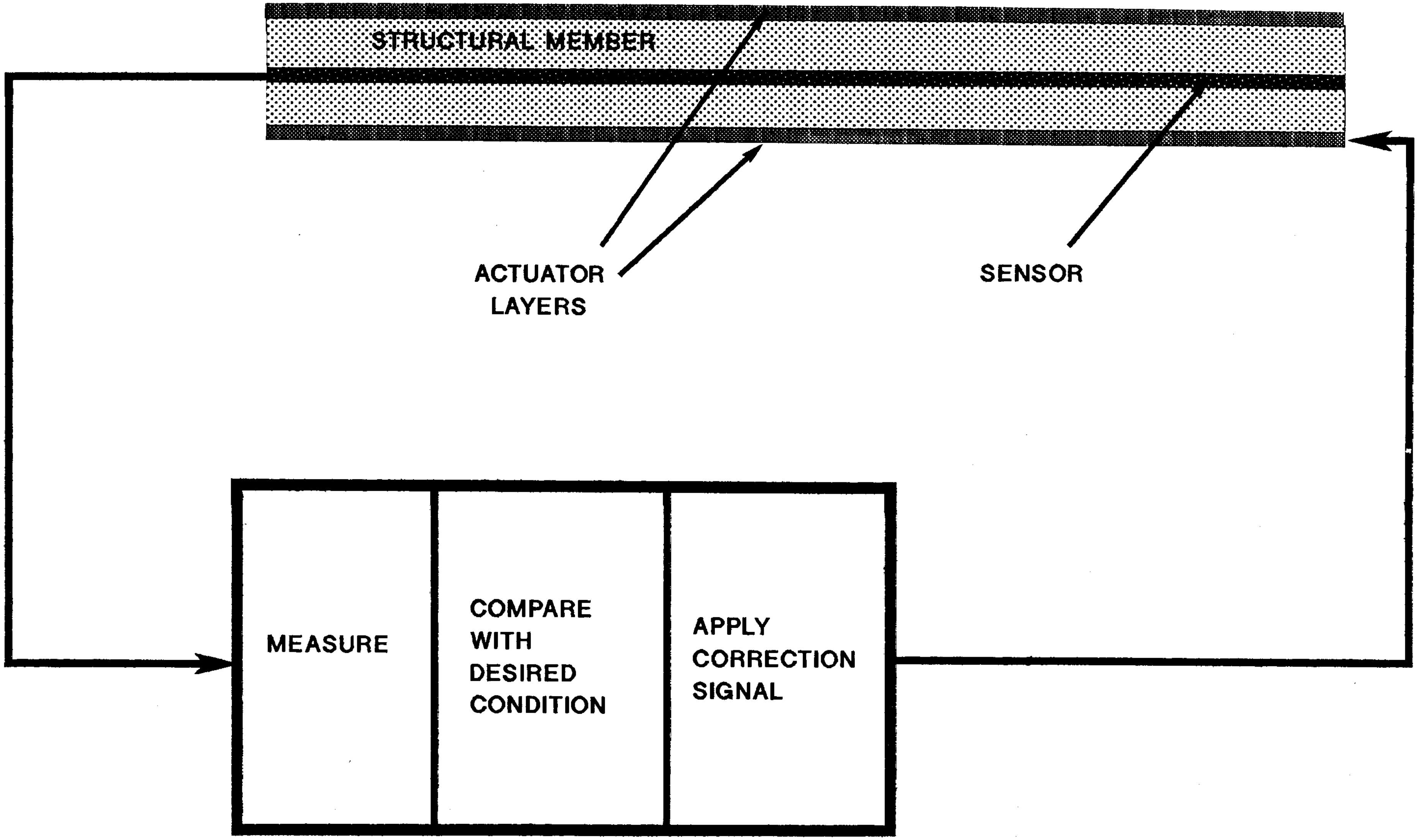
ACTIVE SMART STRUCTURE CONCEPT



SCHEMATIC OF CONNECTED-STRUT STRUCTURE WITH ACTIVE ACTUATOR (A) AND SENSOR (S) ELEMENTS IN CERTAIN STRUTS

ADVANTAGES:-

- Structure can adapt its shape in response to measured deformations
- Structure can be made effectively totally rigid
- Structure can be programmed to change to desired new shape.



SCHEMATIC OF CONTROL SYSTEM FOR "SMART" STRUCTURE

ADVANTAGES OF OPTICAL FIBRE SENSORS FOR STRUCTURAL MONITORING

- SILICA IS AN EXCELLENT ELASTIC MATERIAL, LARGELY FREE FROM CREEP AND FATIGUE PROBLEMS
- TOTAL IMMUNITY TO ELECTROMAGNETIC INTERFERENCE AND LIGHTNING STIKE, etc.
- EXCELLENT CORROSION RESISTANCE, AS SILICA IS RESISTANT TO MOST CHEMICALS
- BEING NON-METALLIC, THE SENSOR CANNOT PROMOTE ELECTROLYTIC CORROSION
- A THIN FIBRE SENSOR HAS A SMALLER INFLUENCE ON MECHANICAL STRUCTURES
- A FIBRE SENSOR CAN BE PRODUCED AS A UNIFORM CYLINDER, FOR BOTH SENSING AND TELEMETRY, AVOIDING STRESS CONCENTRATION POINTS AND FRAGILE CONNECTIONS.