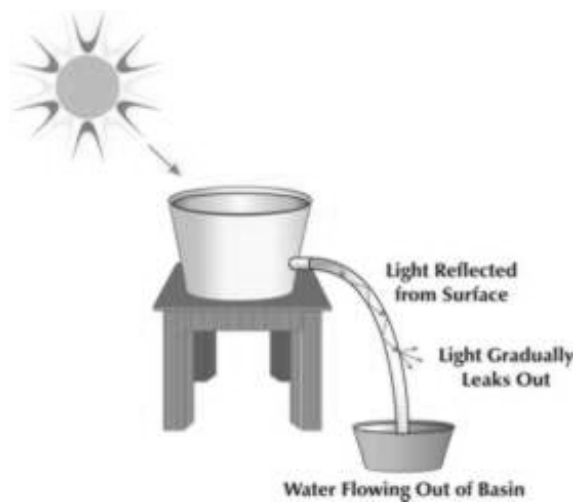


# Fiber optics sensors

單秋成

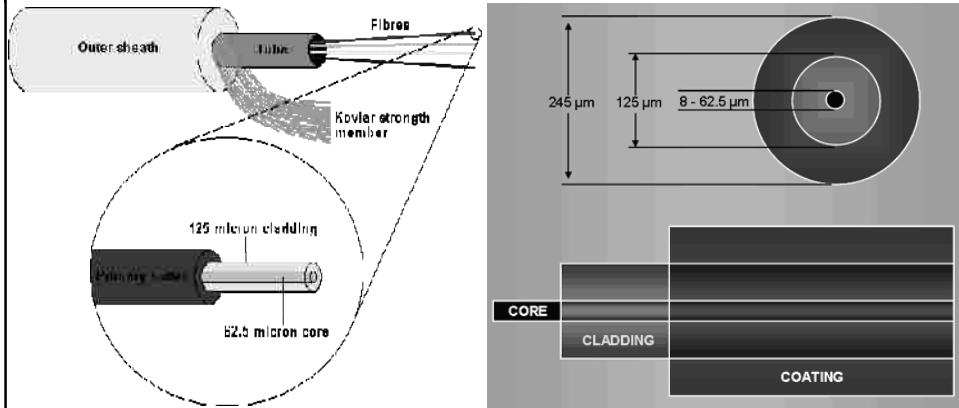
## 1870 John Tyndall's Experiment



<http://www.fiber-optics.info/fiber-history.htm>

單秋成

# 光纖的構造

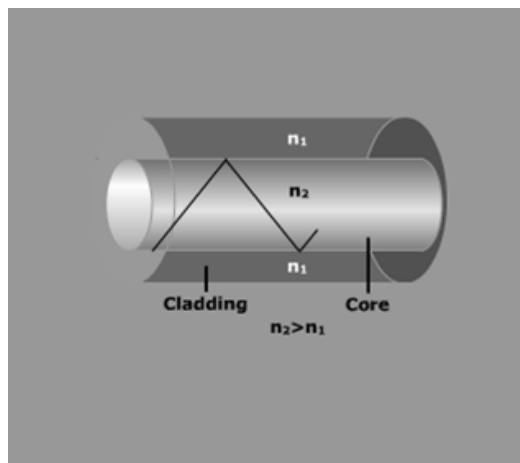


<http://www.datacottage.com/nch/fibre.htm>

[http://www.coming.com/opticalfiber/discovery\\_center/fiber101/cc.aspx](http://www.coming.com/opticalfiber/discovery_center/fiber101/cc.aspx)

單秋成

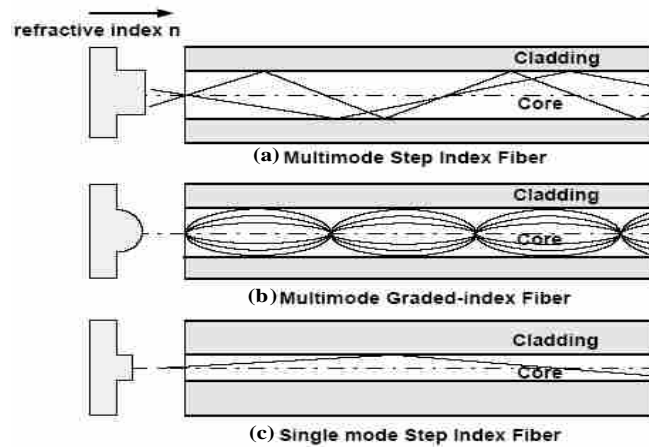
# Total Internal Reflection



[http://www.coming.com/opticalfiber/discovery\\_center/fiber101/reflection.aspx](http://www.coming.com/opticalfiber/discovery_center/fiber101/reflection.aspx)

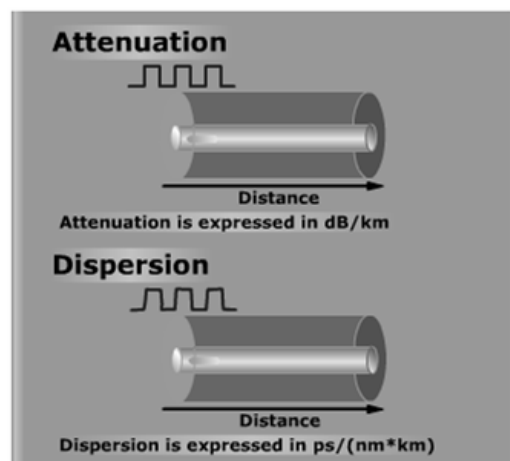
單秋成

# 光纖分類



單秋成

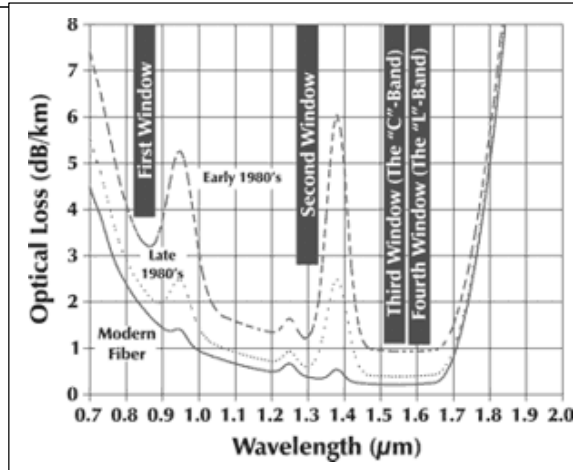
# Attenuation and dispersion



[http://www.corning.com/opticalfiber/discovery\\_center/fiber101/dispersion.aspx](http://www.corning.com/opticalfiber/discovery_center/fiber101/dispersion.aspx)

單秋成

## Attenuation in transmitted light

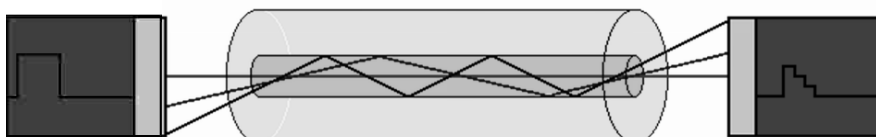
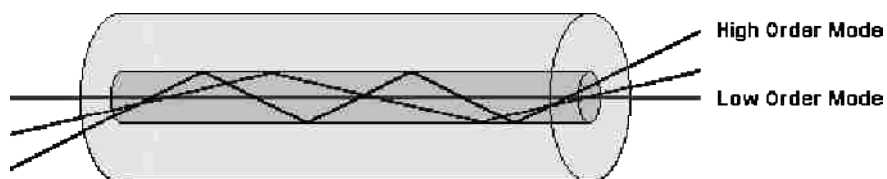


These window refers to a wavelength region that offers low optical loss. They sit between several large absorption peaks caused primarily by moisture in the fiber and Rayleigh scattering.

<http://www.fiber-optics.info/fiber-history.htm>

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## Multimode vs. Single-mode



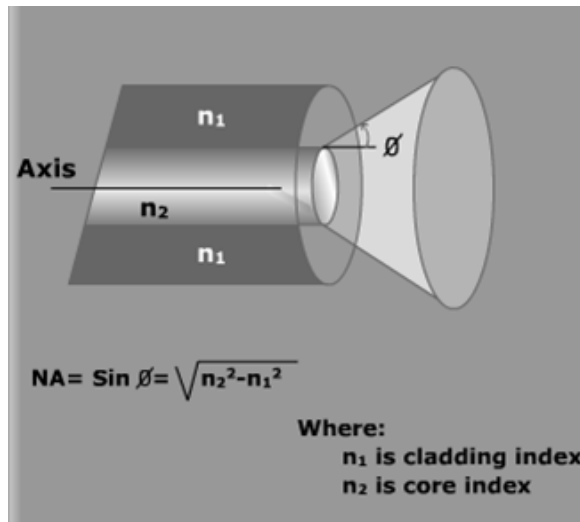
Intermodal dispersion

<http://www.datacottage.com/nch/fibre.htm>

[http://www.corning.com/opticalfiber/discovery\\_center/fiber101/multi\\_vs\\_single.htm](http://www.corning.com/opticalfiber/discovery_center/fiber101/multi_vs_single.htm)

單秋成

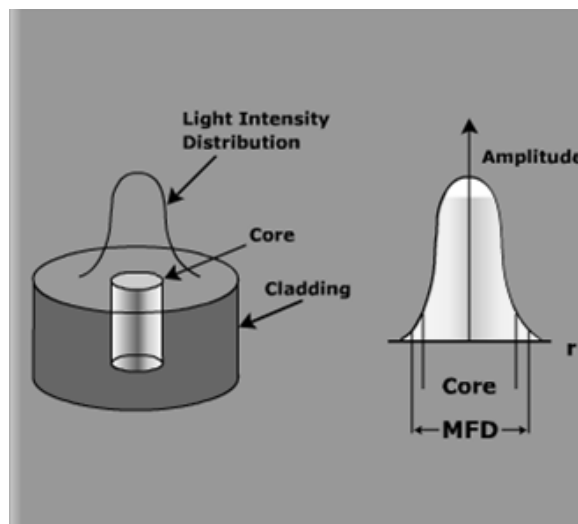
# Numerical Aperture



[http://www.corning.com/opticalfiber/discovery\\_center/fiber101/aperture.aspx](http://www.corning.com/opticalfiber/discovery_center/fiber101/aperture.aspx)

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# Mode-Field Diameter



[http://www.corning.com/opticalfiber/discovery\\_center/fiber101/diameter.aspx](http://www.corning.com/opticalfiber/discovery_center/fiber101/diameter.aspx)

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## 光纖感測系統之特點

- ✓ 徑細質輕
- ✓ 敏感度高
- ✓ 長期穩定性佳，疲勞壽命長
- ✓ 容許高溫操作，抗腐蝕
- ✓ 不受電磁雜訊干擾
- ✓ 不侷限於表面量測，可鑲埋入結構內部，與複合材料之相容性相當高
- ✓ 長距離多點量測

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## 光纖感測器的調變機制

- 吸收損失調變 (Absorption modulation)
- 色散調變 (Chromatic dispersion modulation)
- 散射調變 (Scattering based modulation)
- 螢光調變 (Luminescence-fluorescence based modulation)
- 折射率調變 (refractive index based modulation)
- 幾何形狀調變 (Geometric effect based modulation)
- 干涉/相位調變 (Interferometric and phase modulation)
- 波長調變 (Wavelength modulation)

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## 光纖感測器類型

### ➤ 非本質型 (Extrinsic) 感測器

- ✓ 光波被光纖導引至待測區後，暫時離開光纖，被外在環境調制，然後再耦合進光纖

### ➤ Evanescent 型感測器

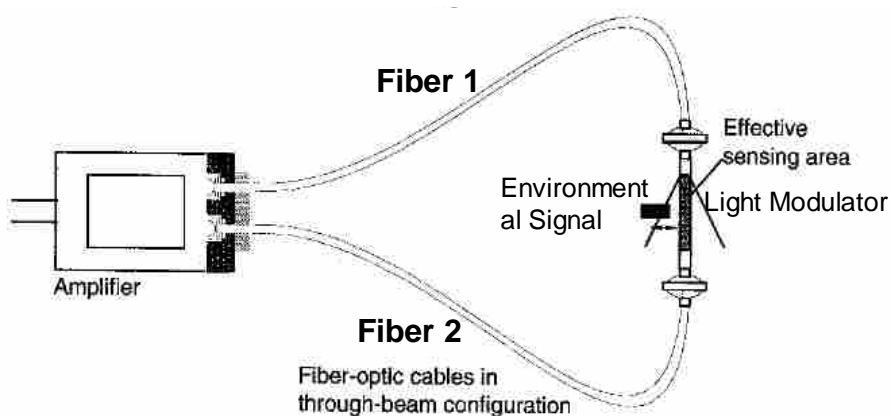
- ✓ 利用光纖受到環境的影響而導致在其內傳輸的光能量逸出或損失，從而推導該環境參數

### ➤ 本質型 (Intrinsic) 感測器

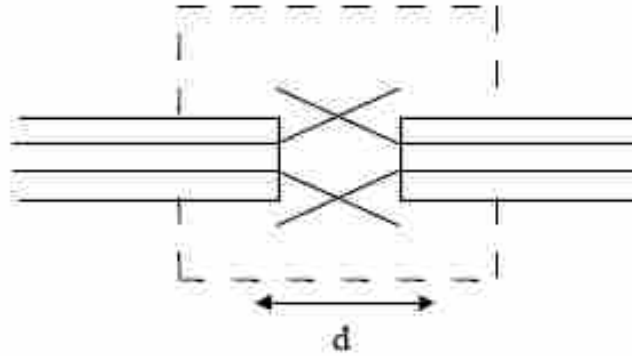
- ✓ 光波基本不離開光纖，外在環境的改變造成光纖內部特性的改變，從而影響光波的某些特性(如波長)

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## Schematic of an extrinsic fiber optic sensor



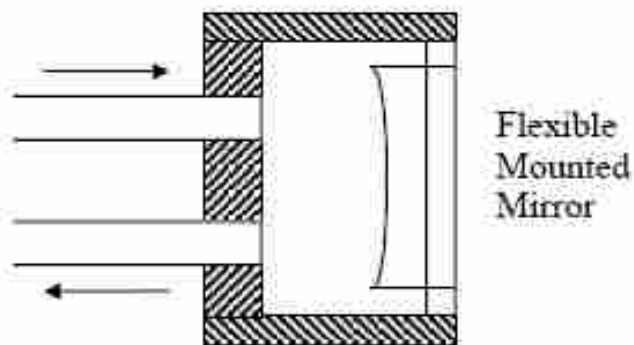
[http://oeiwcsnts1.omron.com/pdfcatal.nsf/0/FD37782283E4AEF286256B3D0061EE50/\\$File/Sensors\\_Fiber%20Optic\\_Sensors\\_Article](http://oeiwcsnts1.omron.com/pdfcatal.nsf/0/FD37782283E4AEF286256B3D0061EE50/$File/Sensors_Fiber%20Optic_Sensors_Article) 單秋成



Closure and vibration fiber optic sensors based on numerical aperture can be used to support door closure indicators and measure levels of vibration in machinery.

[http://www.bluerr.com/papers/Overview\\_of\\_FOS2.pdf](http://www.bluerr.com/papers/Overview_of_FOS2.pdf)

單秋成



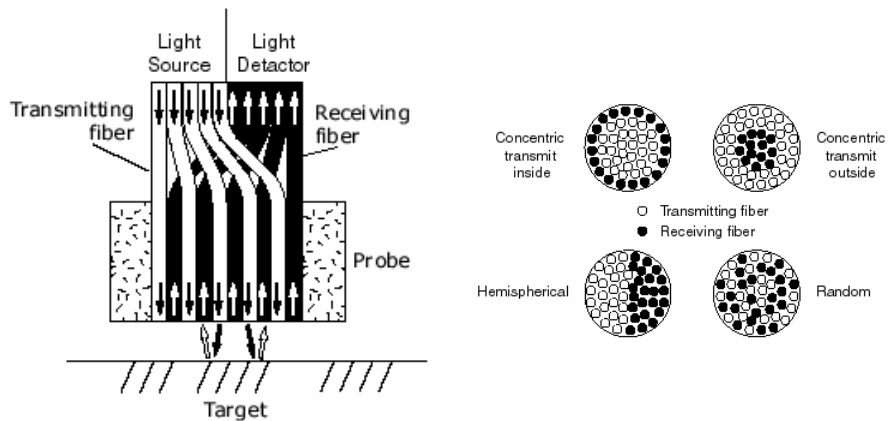
Numerical aperture fiber sensor based on a flexible mirror can be used to measure small vibrations and displacements.

[http://www.bluerr.com/papers/Overview\\_of\\_FOS2.pdf](http://www.bluerr.com/papers/Overview_of_FOS2.pdf)

單秋成

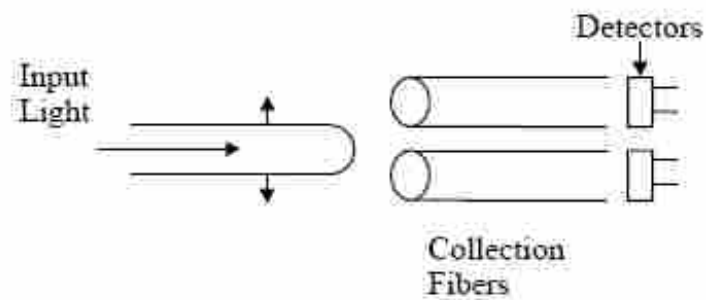


# Fotonic displacement sensor



[http://www.efunda.com/DesignStandards/sensors/fotonic/fotonic\\_intro.cfm](http://www.efunda.com/DesignStandards/sensors/fotonic/fotonic_intro.cfm)

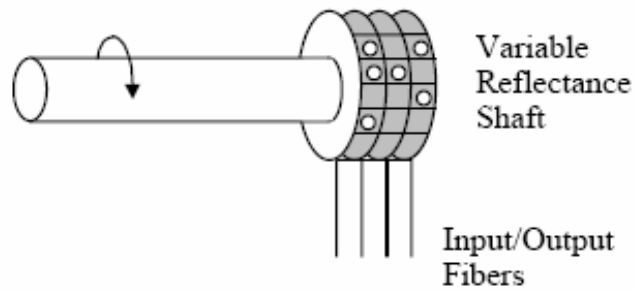
單秋成



Fiber optic translation sensor based on numerical aperture uses the ratio of the output on the detectors to determine the position of the input fiber.

[http://www.bluerr.com/papers/Overview\\_of\\_FOS2.pdf](http://www.bluerr.com/papers/Overview_of_FOS2.pdf)

單秋成

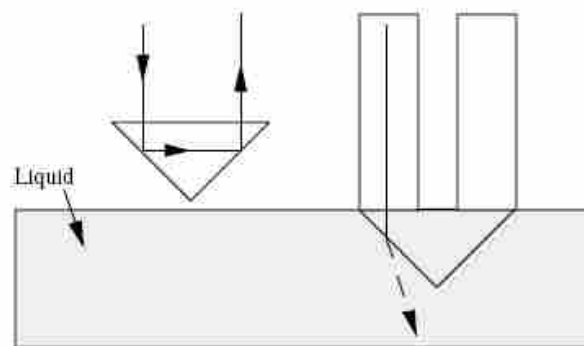


Fiber optic rotary position sensor based on reflectance used to measure rotational position of the shaft via the amount of light reflected from dark and light patches.

[http://www.bluerr.com/papers/Overview\\_of\\_FOS2.pdf](http://www.bluerr.com/papers/Overview_of_FOS2.pdf)

單秋成

## Evanescence type sensors



Liquid level sensor based on total internal reflection detects the presence or absence of liquid by the presence or absence of a return light signal.

[http://www.bluerr.com/papers/Overview\\_of\\_FOS2.pdf](http://www.bluerr.com/papers/Overview_of_FOS2.pdf)

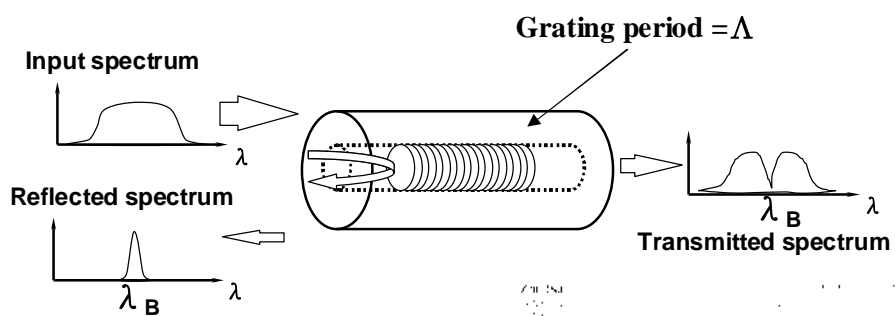
單秋成

# 光纖光柵 (Intrinsic type sensor)

單秋成

短週期光纖光柵

## Principle of Fibre Bragg Grating



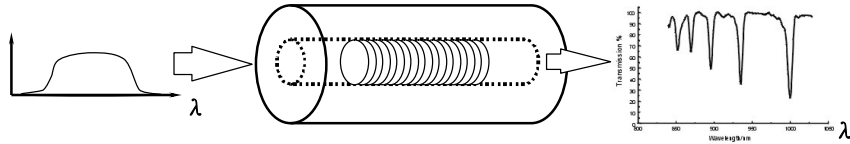
$$\lambda_B = 2n_e \Delta$$

$$\Delta \lambda_B / \lambda_B = F(T, \varepsilon)$$

$$= K_\varepsilon \varepsilon +$$

# 光纖光柵感測原理

長週期光纖光柵

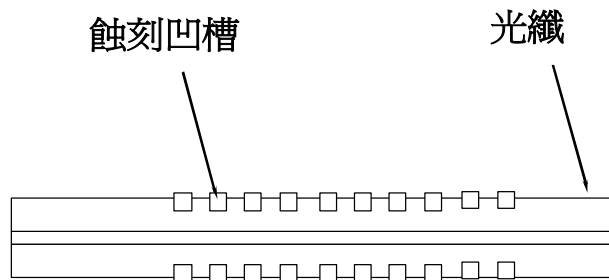


$$\lambda = F'(T, \varepsilon)$$

$$= K'_T \Delta T + K'_\varepsilon \varepsilon$$

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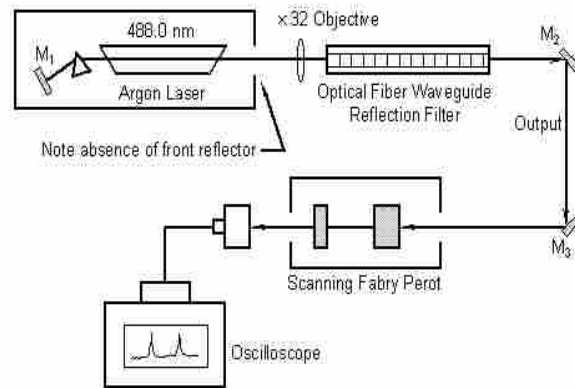
## 不同類型之光纖光柵



外力式長週期光纖光柵

單秋成

## 光纖光柵製作方法



K. O. Hill於1978年第一次製作光纖光柵的儀器架構

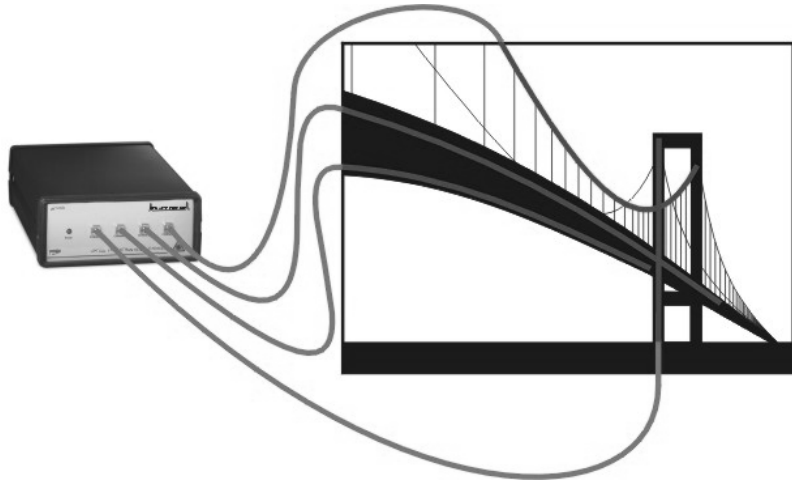
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## 光纖感測系統應用領域

- 航太結構
- 土木結構
- 船舶結構
- 鑽油台結構
- 壓力容器
- 生醫監測

單秋成

# 光纖光柵在土木結構之應用



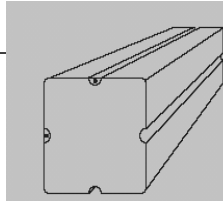
<http://www.smartfibres.com/SmartPages/Smarthome.htm#>

單秋成



[http://www.cranfield.ac.uk/sims/quality/dt\\_group/completed\\_projects/smart.htm](http://www.cranfield.ac.uk/sims/quality/dt_group/completed_projects/smart.htm)

單秋成

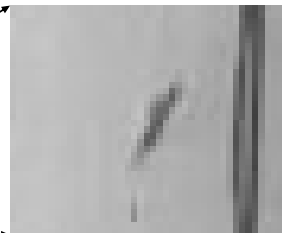
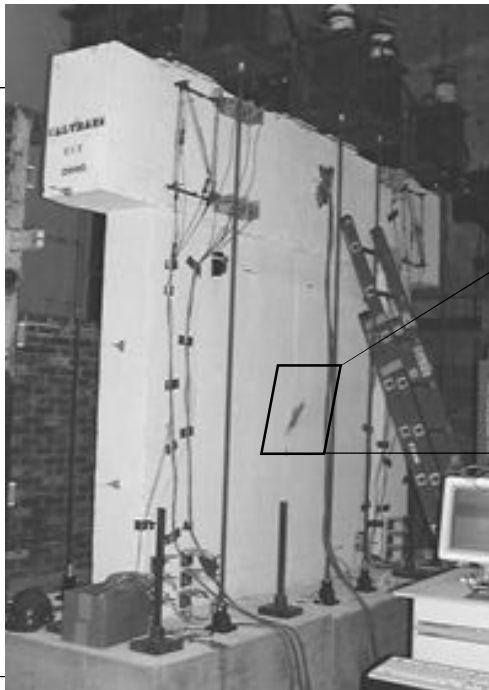


SmartRod comprises a composite pultrusion of square cross section with grooves for the mounting of FBG sensor arrays which creates a very accurate distributed bend sensor. Instrumenting two adjacent grooves allows for isolation of axial strain from bending and offers three-dimensional strain and bending to be calculated. Instrumenting additional grooves offers redundancy and measurement of and automatic compensation for temperature changes.



使用光纖光柵感測器監測連續壁變形情形

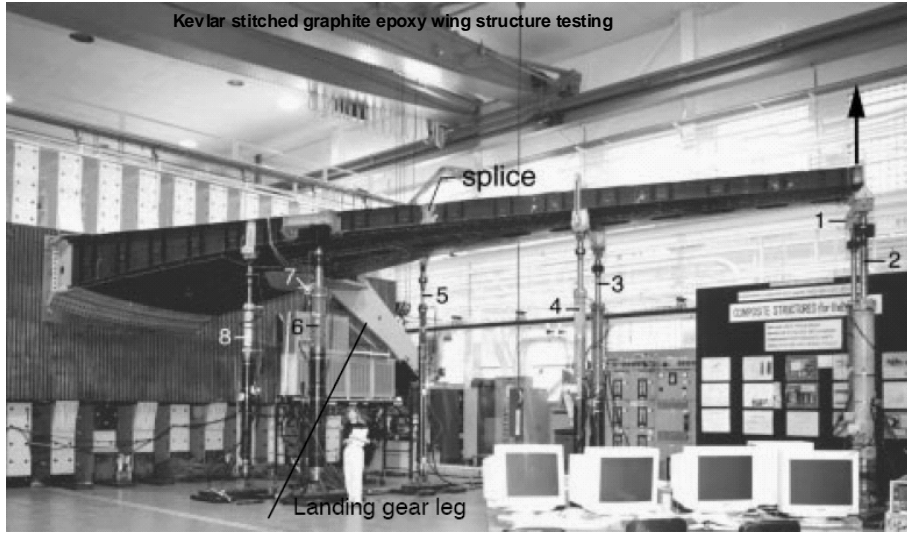
單秋成



使用光纖光柵感測器監測混凝土剪力牆受疲勞負載的破壞情形

單秋成

## 航太結構之應用



NASA Langley Research Center

單秋成

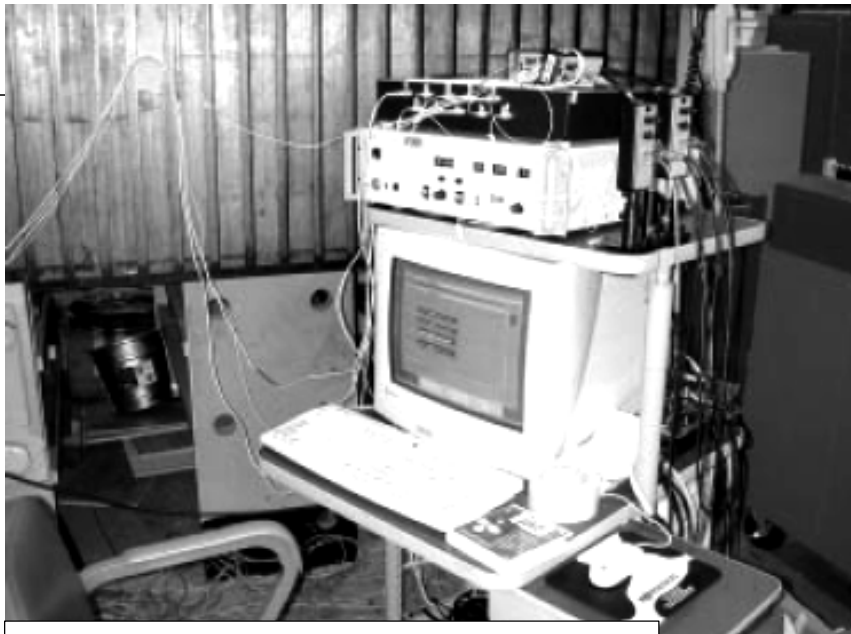
## 應變計感測系統(182個感測器)



NASA Langley Research Center

單秋成



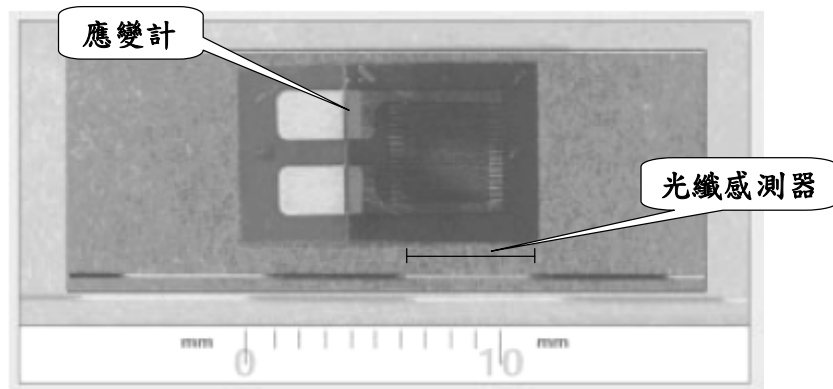


光纖感測系統(3000 個感測器)

NASA Langley Research Center

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## 傳統應變計與光纖感測器比較



NASA Langley Research Center

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## Embeddability provides superior advantages

- **Strain gauges and piezo transducers cannot be incorporated into the structure without detrimental effects and they have a limited life.**
- **When attached to outside-surface of aerospace structures, they affects the aerodynamics. Moreover they are prone to corrosion and thunder strike damages.**
- **Much longer fatigue life.**
- **As a consequence, real-time structural integrity monitoring is rarely achieved in aerospace structures, except in military research projects.**

單秋成

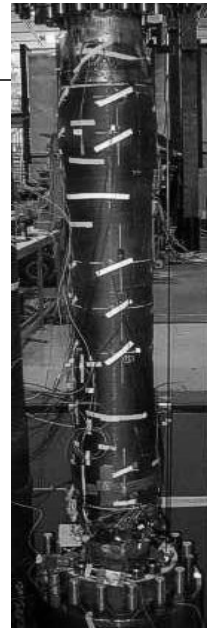
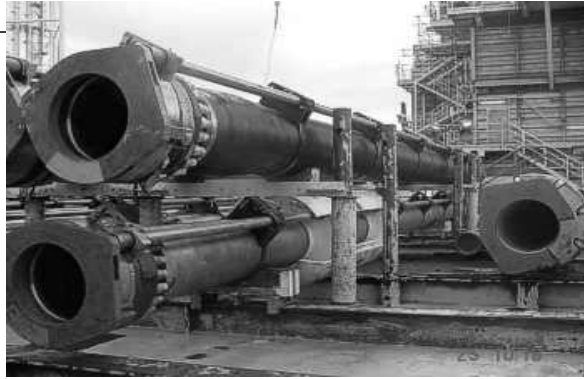
## 石油開採機具之應用

- **Oil riser pipes**
- **Umbilicals and Anchor Cables**
- **Sea-Bed Pipelines**
- **Composite Reinforcing of Design Deficient Steel Structures**



<http://www.smartfibres.com/SmartPages/off.html>

單秋成

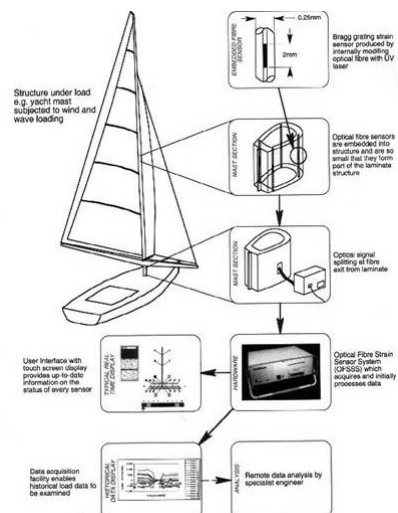


複合材料riser與鈦合金riser 相接處，  
以光纖光柵監測複材部份之應力及變  
形及結構完整性

單秋成

SMART FIBRES and their partners Carbospars, DAL Ltd & Aston  
University

Structural monitoring system for composite materials  
(fibre optic smart composites)

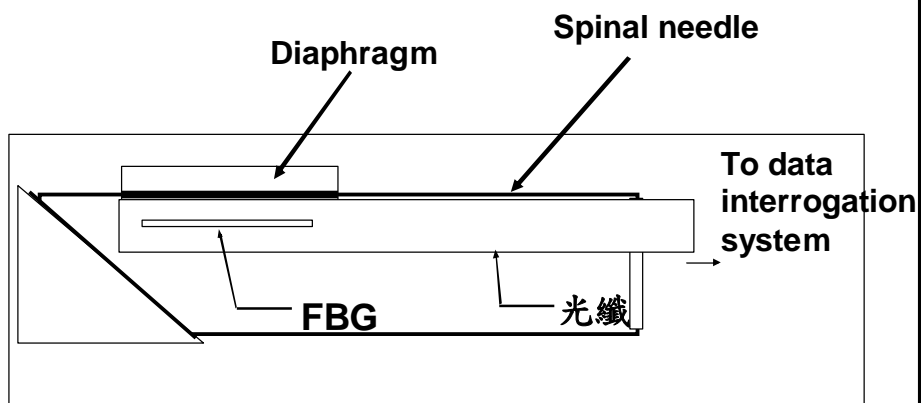


火成

# 生醫監測之應用

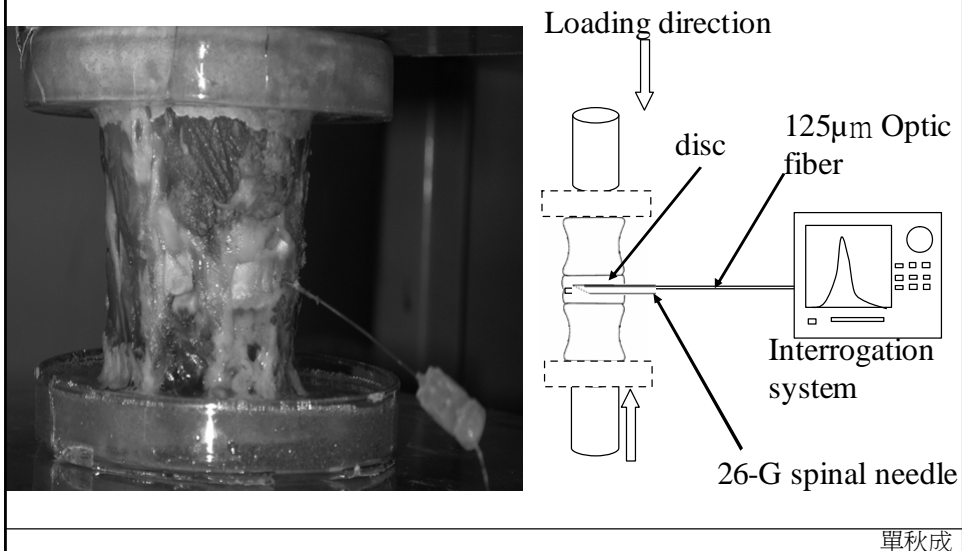
單秋成

## 光纖壓力探針



單秋成

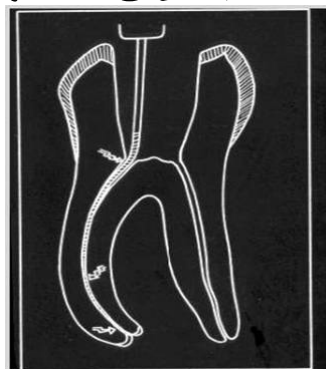
## 光纖壓力探針在椎間盤內壓力量測的應用



## 根管治療器械之疲勞斷裂防治

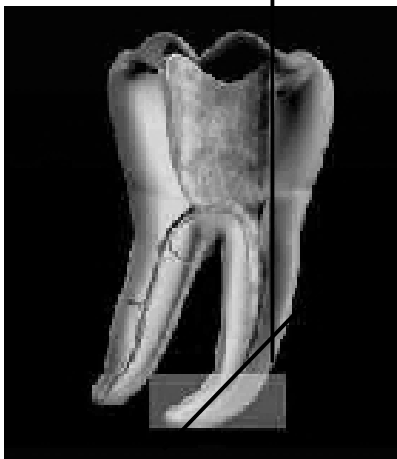
牙齒根管具有一定彎度，進行根管治療時，旋轉器械之面臨旋轉彎曲疲勞破壞的危險。

### 如何評估旋轉器械之完整性？



單秋成

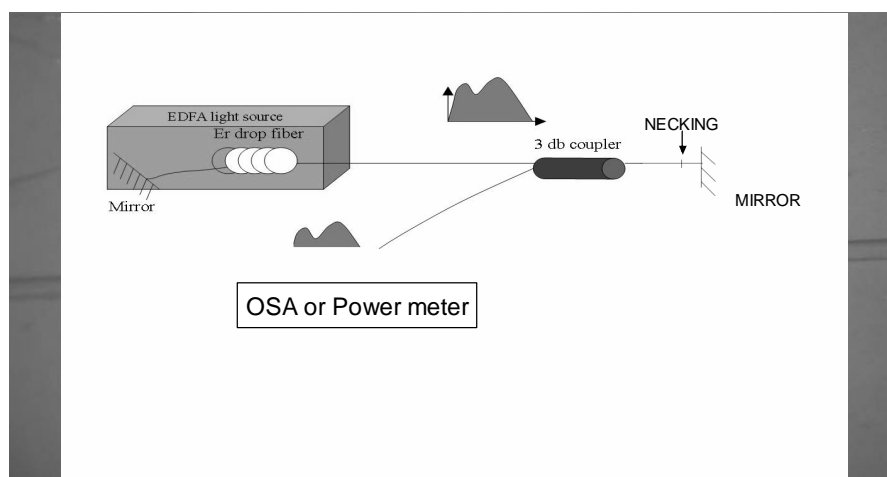
## 疲勞壽命預估



- 如能掌握根管彎曲度，可據以評估疲勞壽命。
- 根管直徑在  $100\sim 200\ \mu m$ 。
- X-ray 照相費時且不一定可行。

單秋成

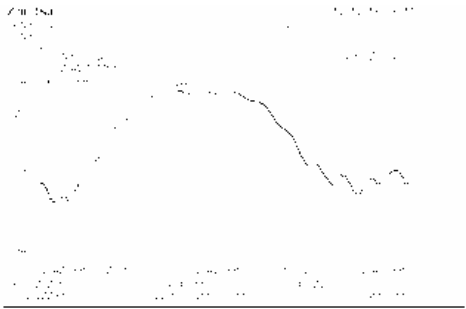
## 光纖彎度感測器



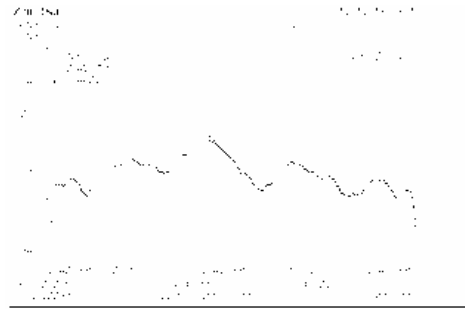
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## 光纖彎度感測器

進入根管前

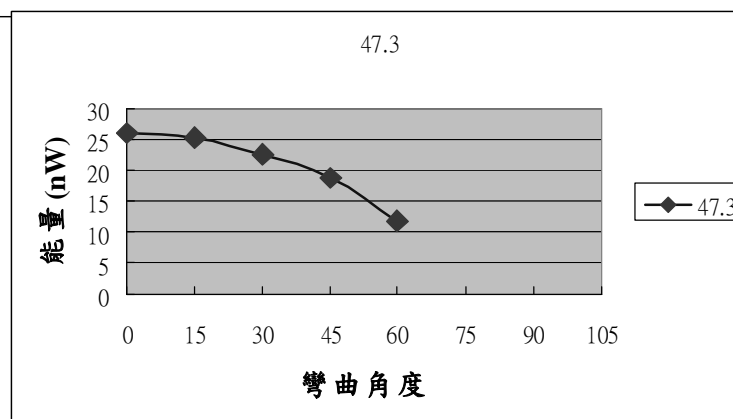


進入根管後



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## 光纖彎度感測器

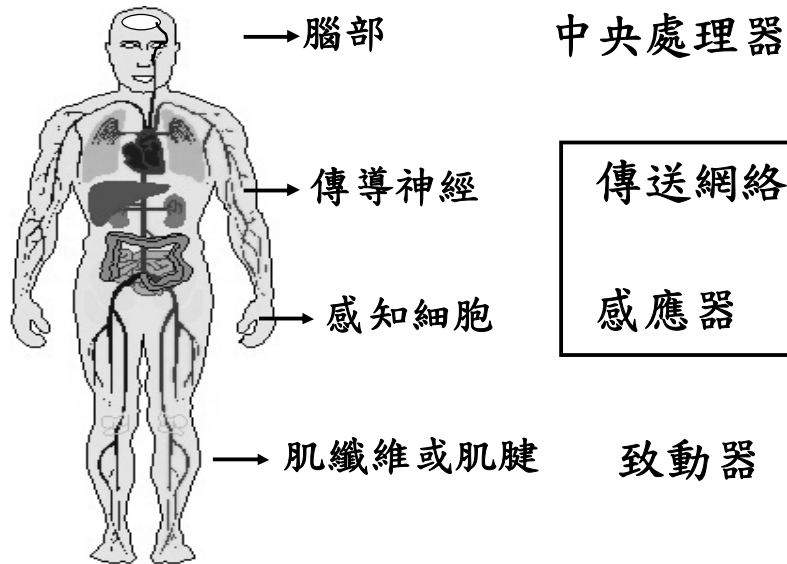


藉由光能量掌握根管彎曲度，可據以評估疲勞壽命。

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模擬人類智慧的機械

智慧型材料/結構



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光纖感測系統同時包括:

傳送網絡

光纖網路

感應器

光纖感測器

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