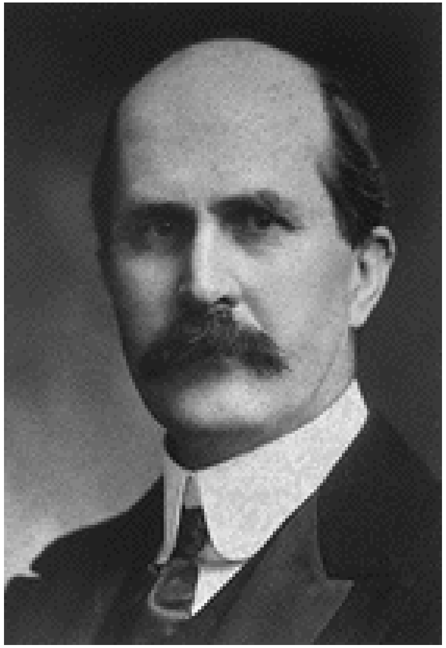
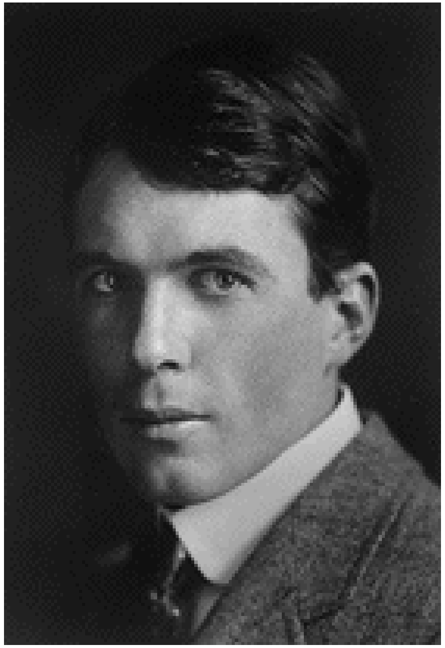
The Braggs

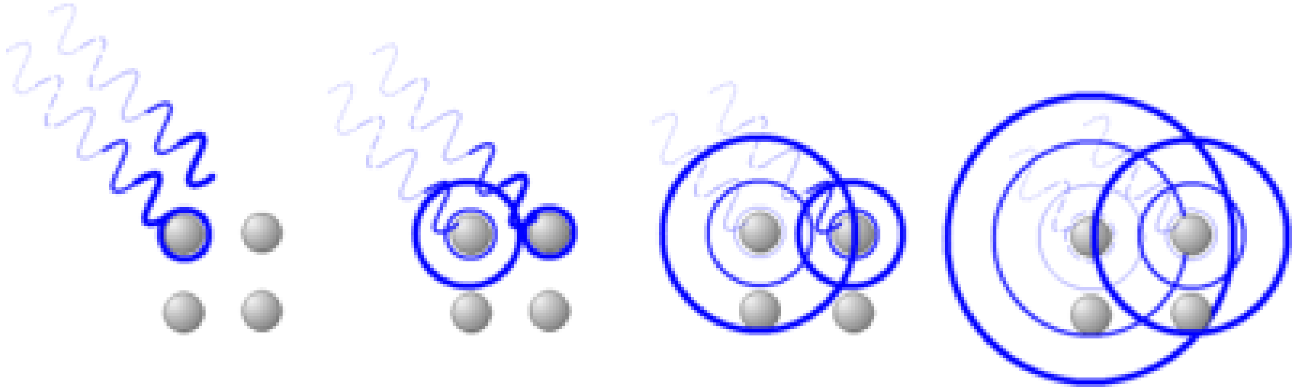
The Nobel Prize in Physics 1915
"for their services in the analysis of crystal structure by means of X-rays"

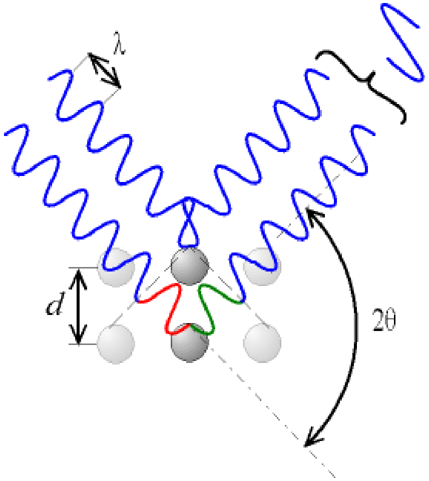


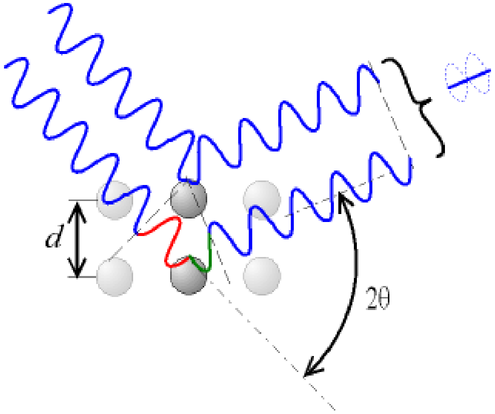


Sir William Henry Bragg
(1862-1942)

William Lawrence Bragg
(1890-1971)

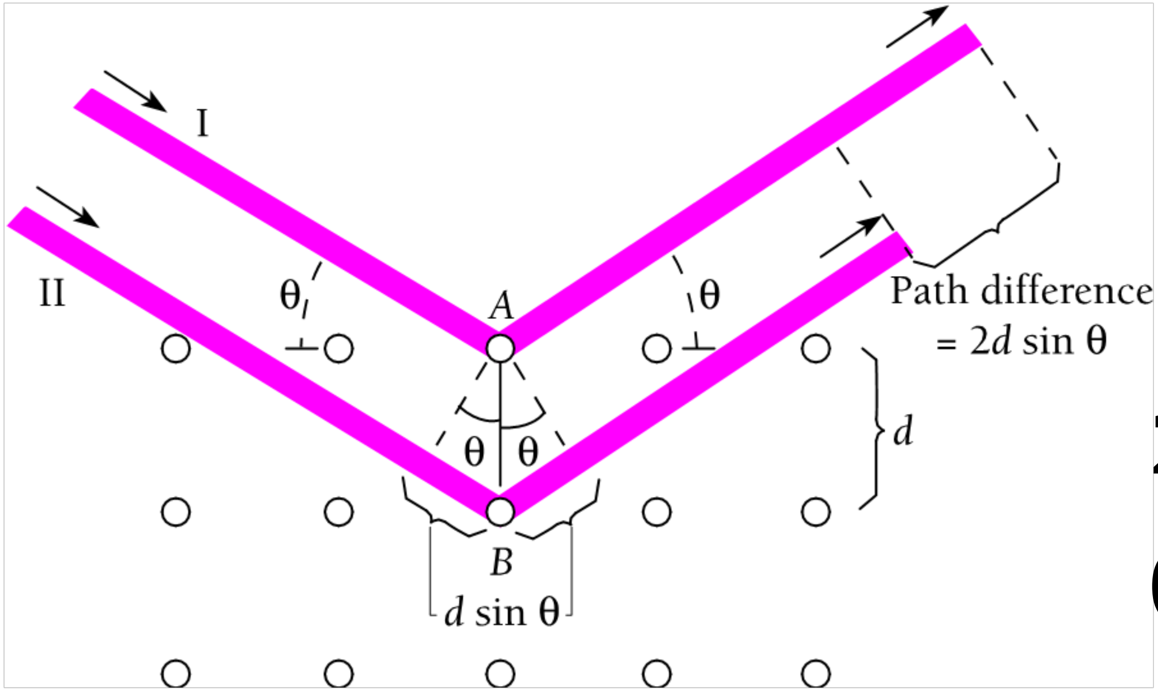






http://en.wikipedia.org/wiki/Bragg%27s_law

Bragg's Law


I
II
θ
A
θ
Path difference
= 2d sin θ
θ
θ
d
B
d sin θ

$$2d\sin\theta = n\lambda$$

$$(n = 1, 2, 3, \cdots)$$

입방체 결정에서의 x-선 산란

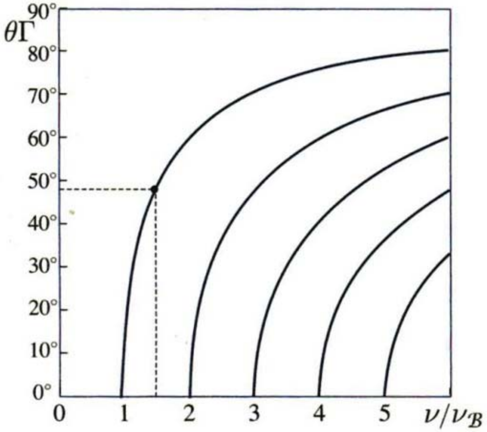
Bragg grating

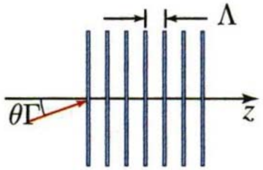
$$\mathcal{R}_N = \frac{\sin^2 N\varphi}{\sin^2 \varphi} R$$

$$\cos\theta = q\frac{\lambda}{2\Lambda} = q\frac{\omega_{\mathcal{B}}}{\omega} = q\frac{\nu_{\mathcal{B}}}{\nu}$$

$$\nu_{\mathcal{B}} = \frac{c}{2\Lambda}, \quad \omega_{\mathcal{B}} = \frac{\pi c}{\Lambda}$$

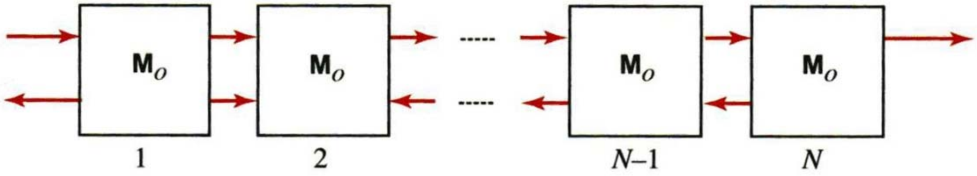
$$\theta_{\mathcal{B}} = \sin^{-1}(\lambda/2\Lambda)$$





Bragg grating

$$\mathbf{M}_o = \begin{bmatrix} 1/t^* & r/t \\ r^*/t^* & 1/t \end{bmatrix}$$



$$\mathbf{M}_o^N = \Psi_N \mathbf{M}_o - \Psi_{N-1}\mathbf{I}$$

$$\Psi_N = \frac{\sin N\Phi}{\sin \Phi}$$

$$\cos\Phi = \mathrm{Re}\{1/t\}$$

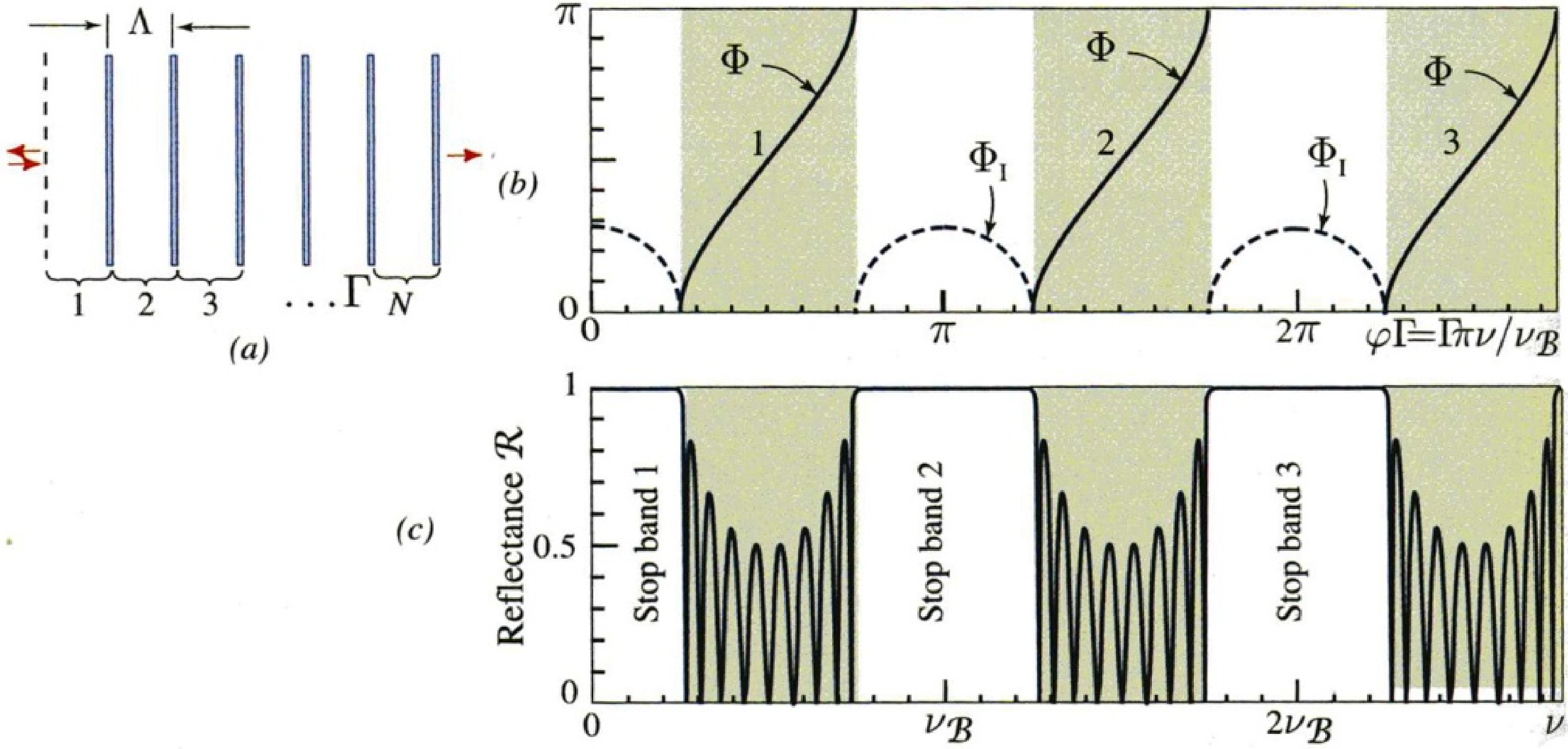
Total-reflection regime

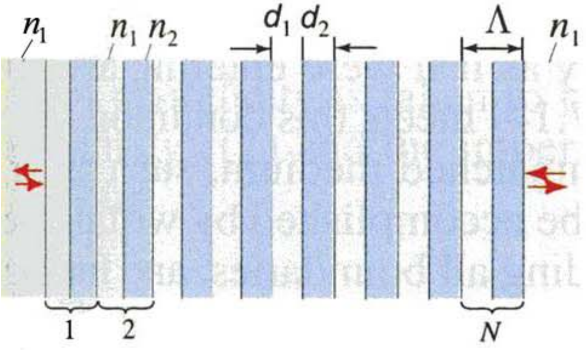
$$\cosh \Phi_{\mathrm{I}} = |\,\mathrm{Re}\{1/t\}|$$

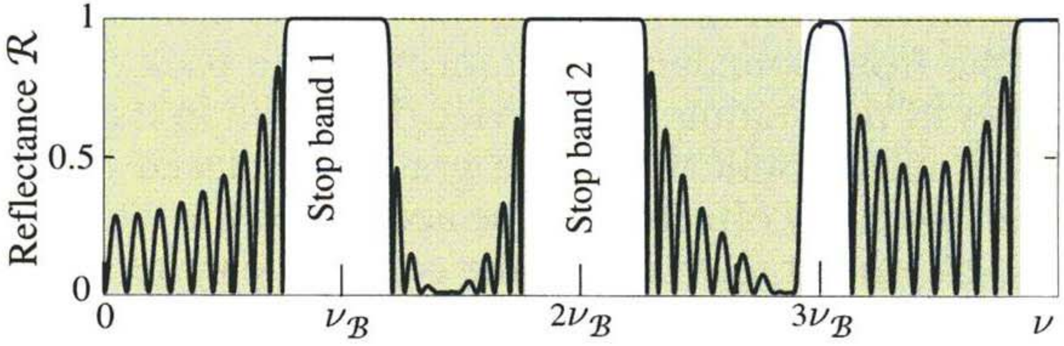
$$\mathbf{M}_o^N = \begin{bmatrix} 1/t_N^* & r_N/t_N \\ r_N^*/t_N^* & 1/t_N \end{bmatrix}$$

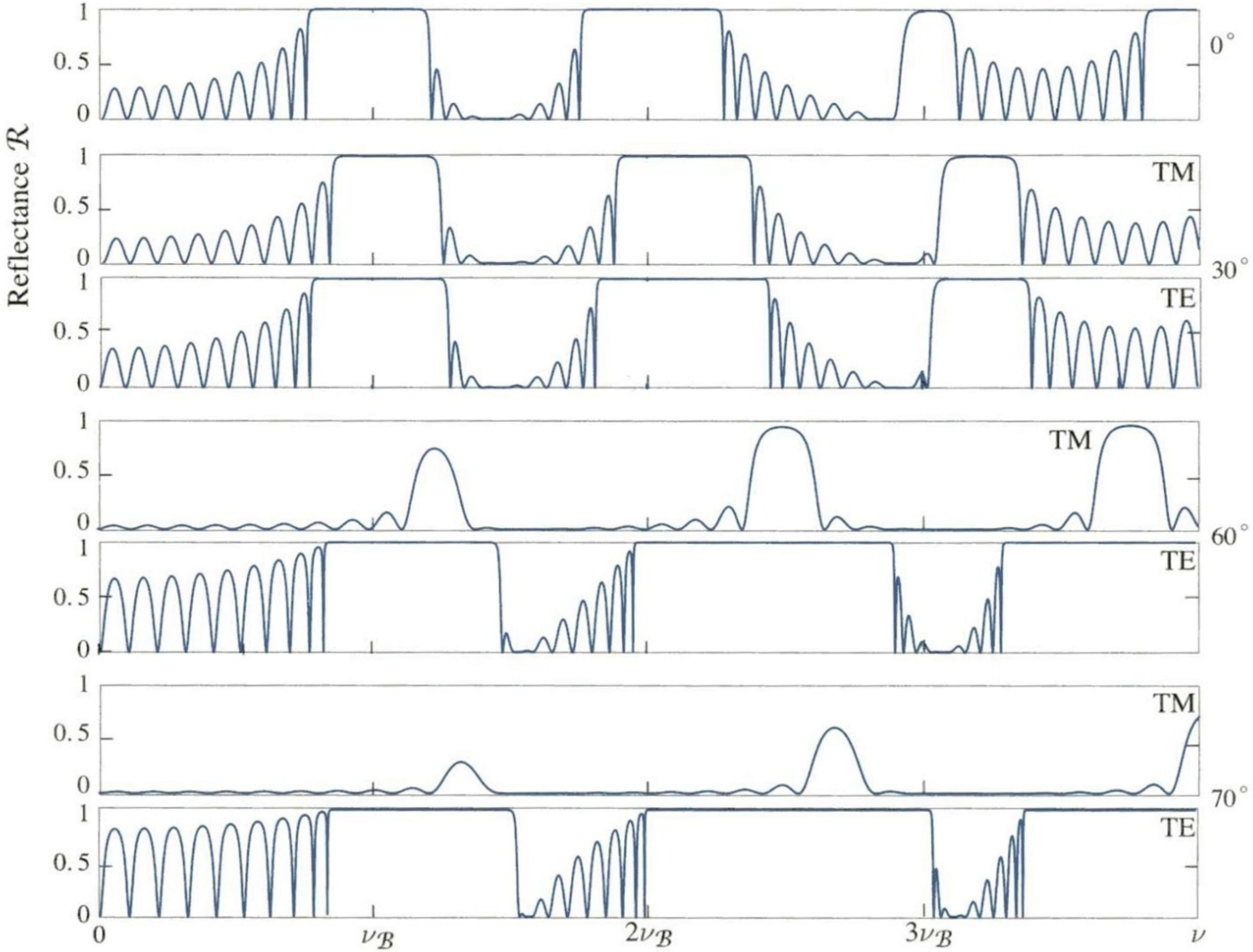
$$\Psi_N = \pm \frac{\sinh N\Phi_{\mathrm{I}}}{\sinh \Phi_{\mathrm{I}}}$$

$$\mathcal{R}_N = \frac{\Psi_N^2 \mathcal{R}}{1 - \mathcal{R} + \Psi_N^2 \mathcal{R}} \qquad \mathcal{R}_N \approx \Psi_N^2\,\mathcal{R} = \frac{\sin^2 N\Phi}{\sin^2 \Phi}\mathcal{R}$$

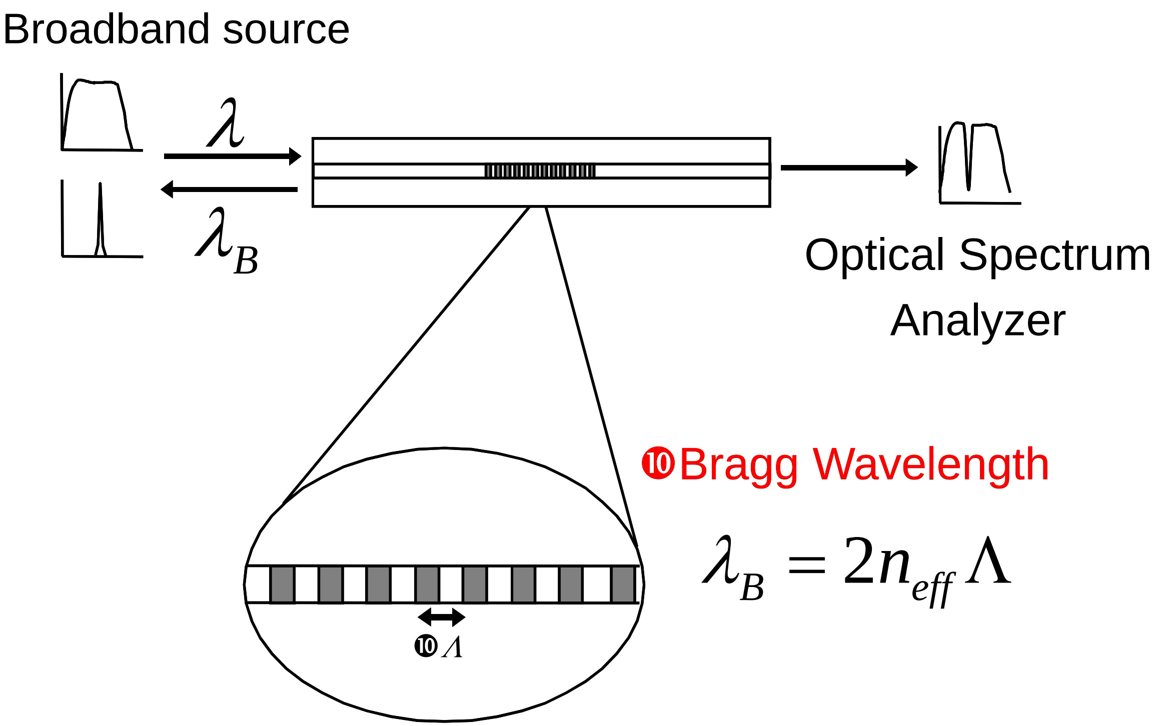

Λ
1
2
3
. . . Γ
N
(a)
(b)
π
0
Φ
1
2
3
Φ_I
0
π
2π
φΓ=Γπν/ν_B
(c)
1
0.5
0
Reflectance ℛ
Stop band 1
Stop band 2
Stop band 3
0
ν_B
2ν_B
ν


n_1
n_1 n_2
d_1 d_2
Λ
n_1
1
2
N


Reflectance $\mathcal{R}$
1
0.5
0
Stop band 1
Stop band 2
0
$\nu_\mathcal{B}$
$2\nu_\mathcal{B}$
$3\nu_\mathcal{B}$
ν


Reflectance $\mathcal{R}$
1
0.5
0
0°
TM
TE
30°
60°
70°
0
$\nu_{\mathcal{B}}$
$2\nu_{\mathcal{B}}$
$3\nu_{\mathcal{B}}$
ν

Fiber Bragg grating sensor


Broadband source
λ
λ_B
Optical Spectrum Analyzer
⑩Λ

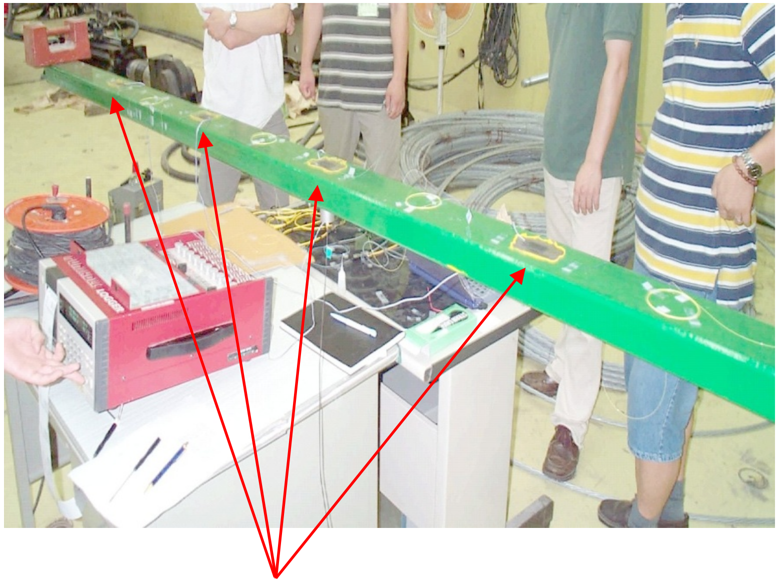
⑩Bragg Wavelength

$$\lambda_B = 2n_{eff}\Lambda$$

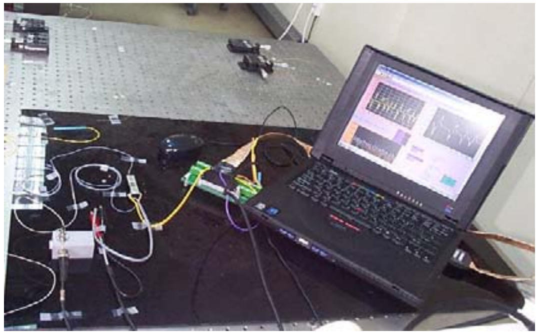
- 특정 파장만을 반사
- 반사파장의 변화로부터 물리량을 측정
- 측정점의 위치, 크기가 고정 → 준분포센서

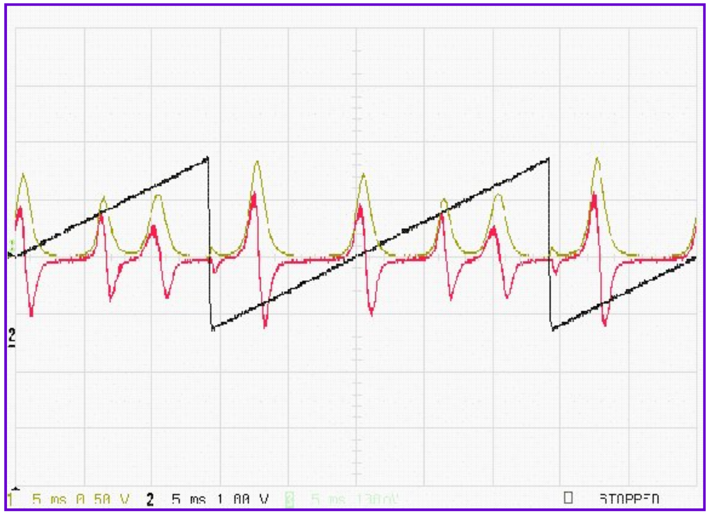
Example of FBG sensor

Load measurement based on multiplexed FBG sensor system



FBGs





- Wavelength encoding

→ Noise에 매우 강함

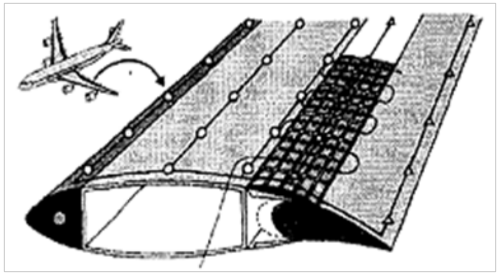
→ 다중점 센서

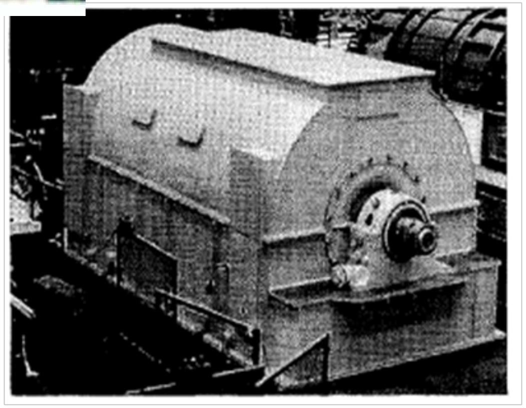
- Intrinsic structure

→ Easily embedded

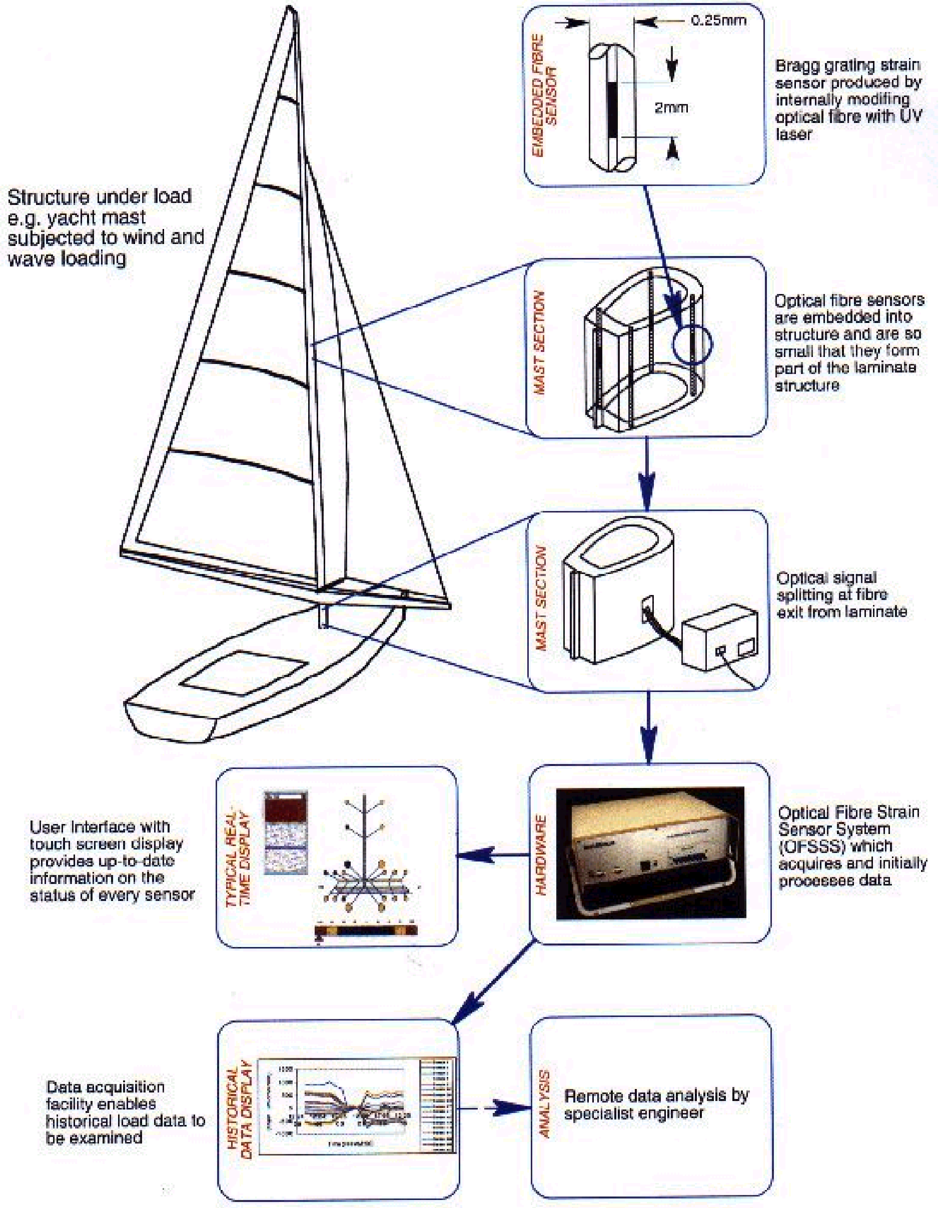
→ Easily locatable

- Cost-effective





LOAD MEASUREMENT USING OPTICAL FIBRE SENSORS


0.25mm
2mm
EMBEDDED FIBRE SENSOR
MAST SECTION
MAST SECTION
HARDWARE
TYPICAL REAL-TIME DISPLAY
HISTORICAL DATA DISPLAY
ANALYSIS

Structure under load e.g. yacht mast subjected to wind and wave loading

Bragg grating strain sensor produced by internally modifing optical fibre with UV laser

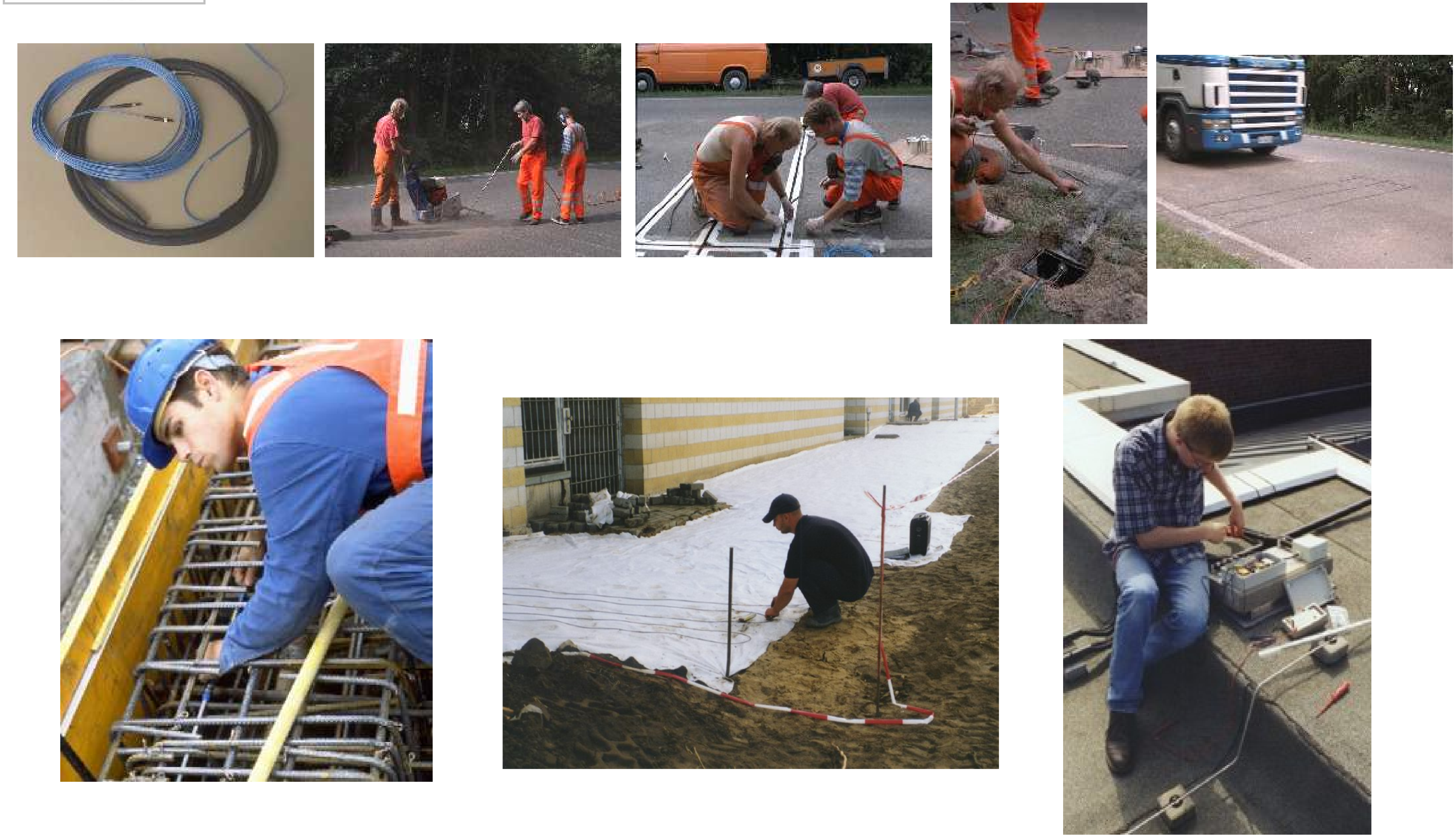
Optical fibre sensors are embedded into structure and are so small that they form part of the laminate structure

Optical signal splitting at fibre exit from laminate

Optical Fibre Strain Sensor System (OFSSS) which acquires and initially processes data

User Interface with touch screen display provides up-to-date information on the status of every sensor

Data acquisition facility enables historical load data to be examined

Remote data analysis by specialist engineer