레이저의 응용

이병호

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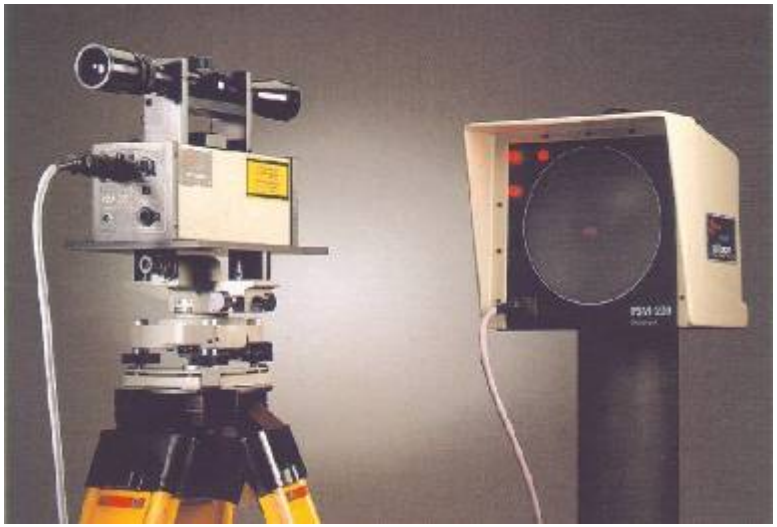
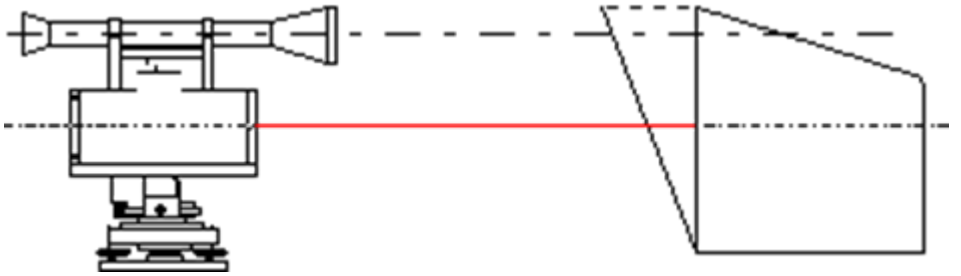
레이저의 직진성을 이용한 변위 센서



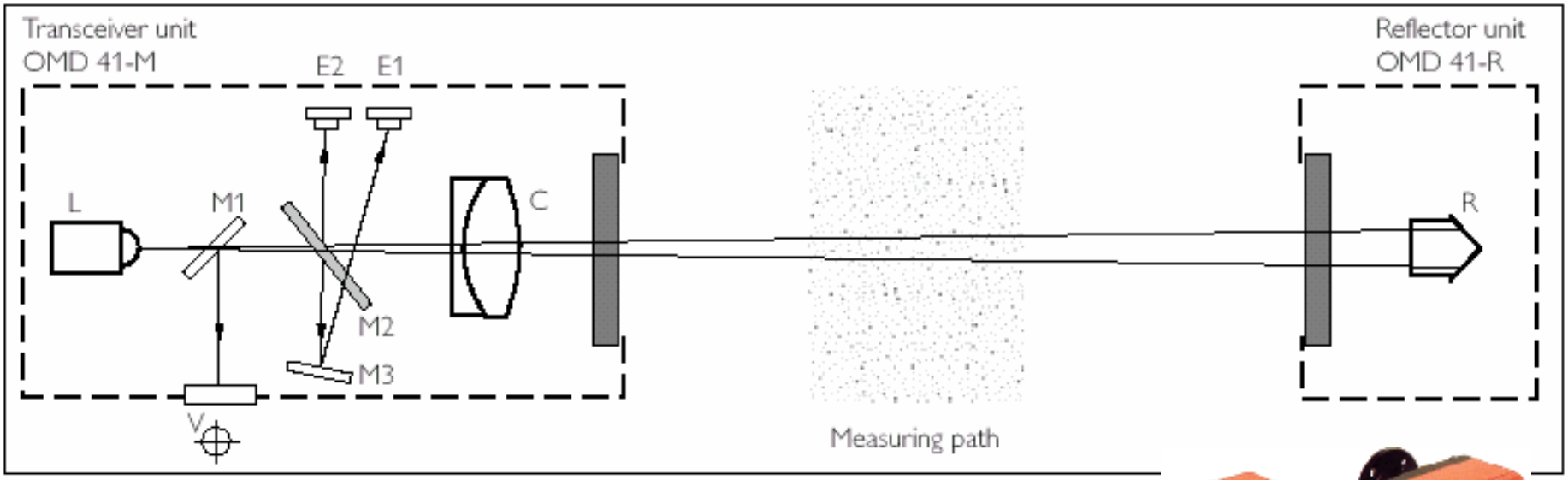


- 교량, 빌딩 등의 변형도, 진동, 구부러짐 측정
- 구조물의 정렬
- 목표물의 변위측정

펄스 레이저를 이용한 거리 센서

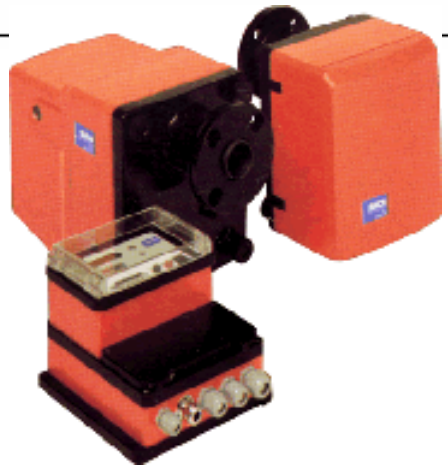
- Laser diode transmits 40 pulses in 1/3 second.
- Light pulse hits target and reflects back to instrument.
- Crystal controlled time base measures flight time.
- Distance = Time x Speed of Light

산란을 이용한 가시도의 측정

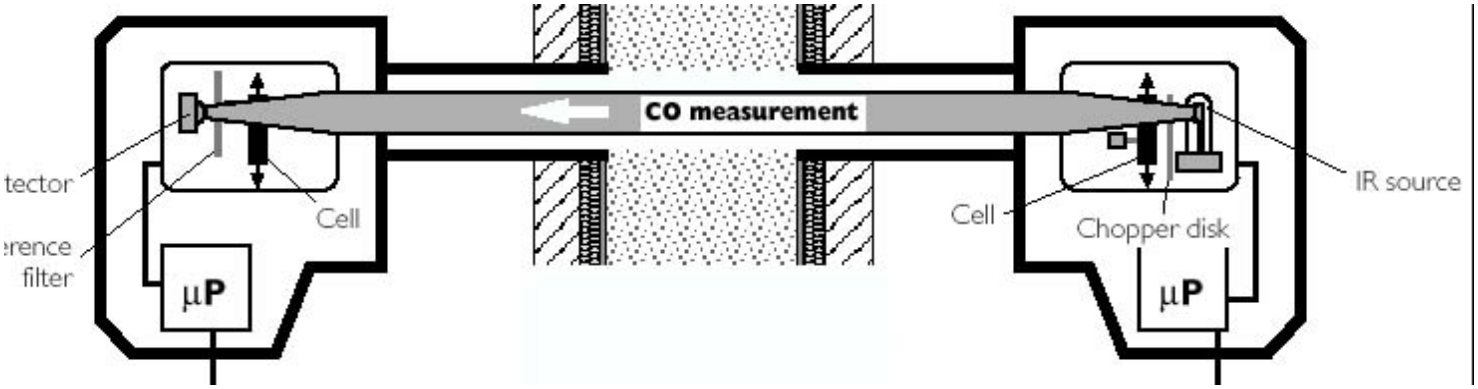


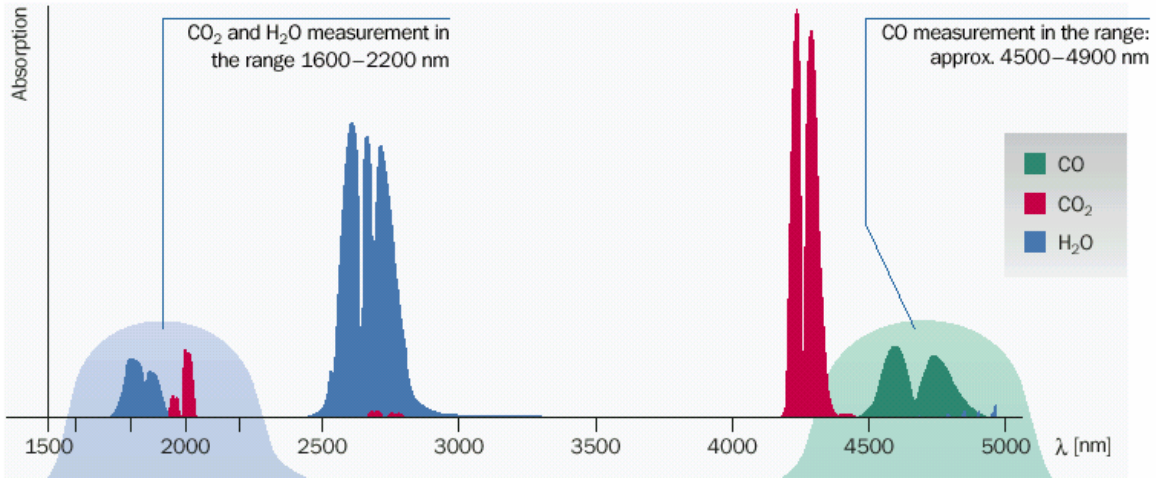
$$I_{out} = I_{in} \cdot e^{-ckx}$$

c: dust concentration
k: extinction coefficient
x: measurement path



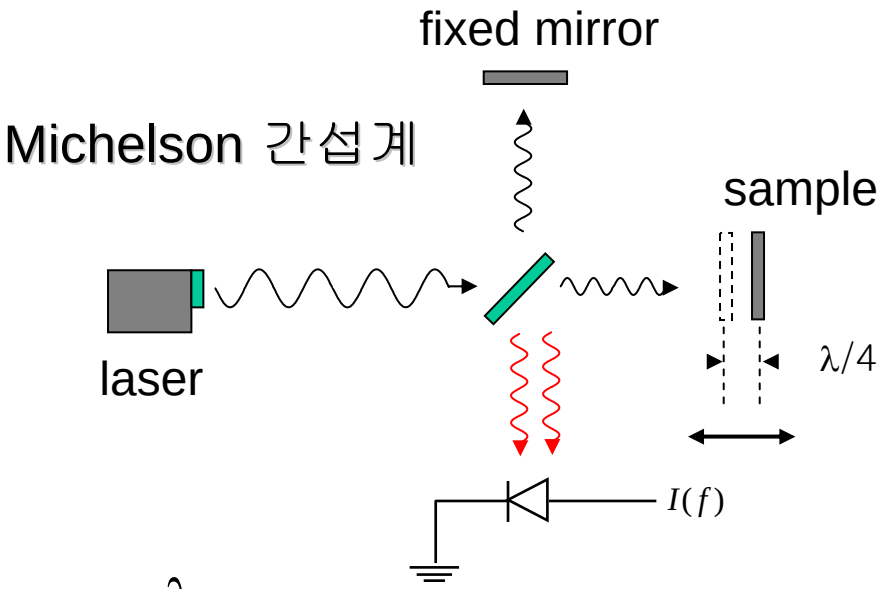
흡수를 이용한 **Gas**의 측정

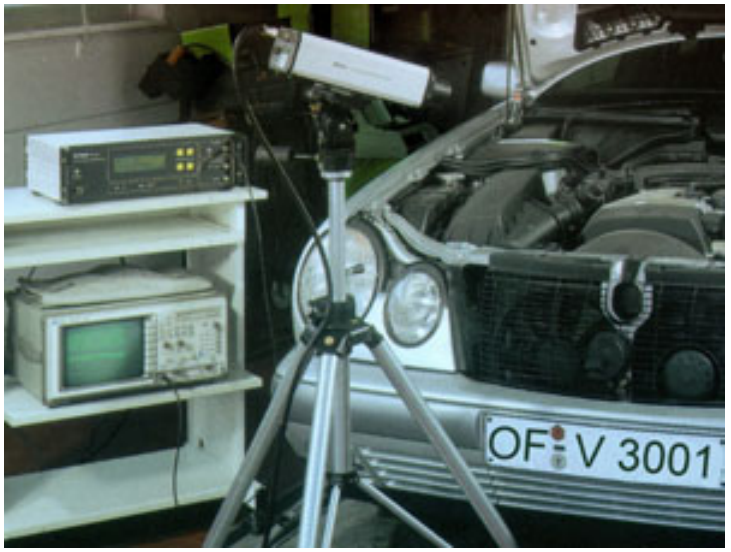


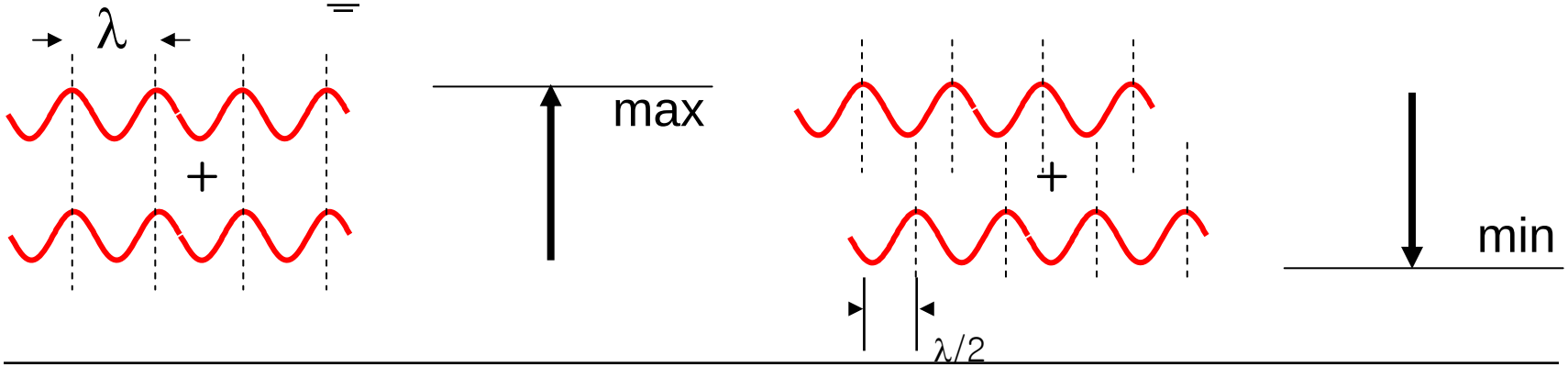


Gas duct monitoring
Emission monitoring
Process controlling

간섭계를 이용한 진동 해석

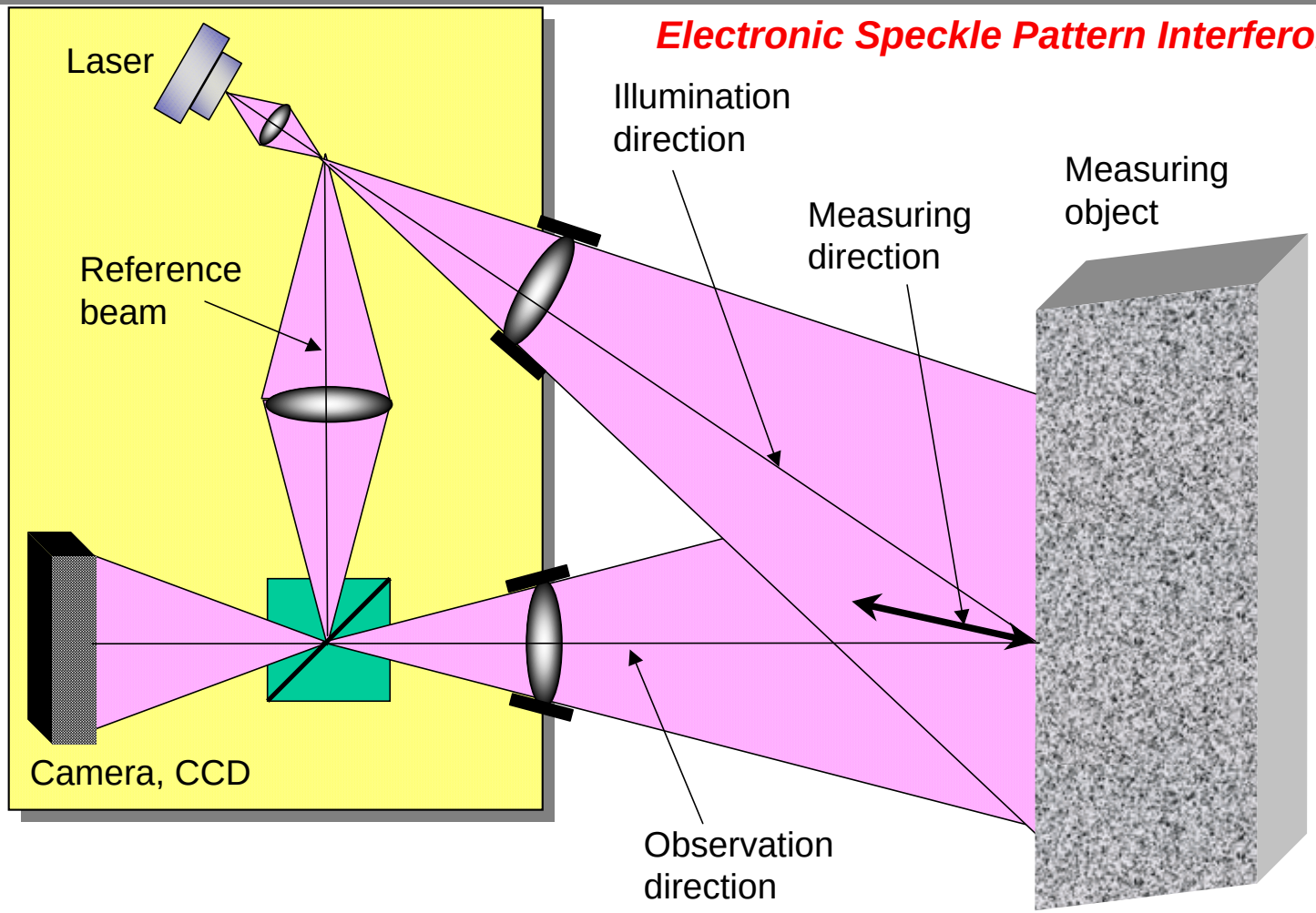




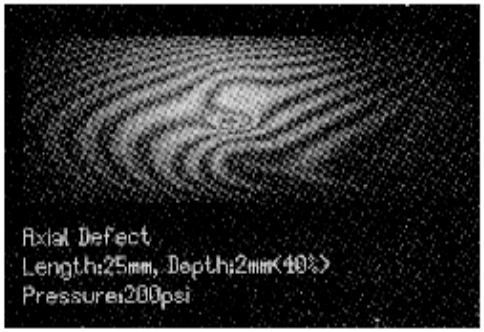


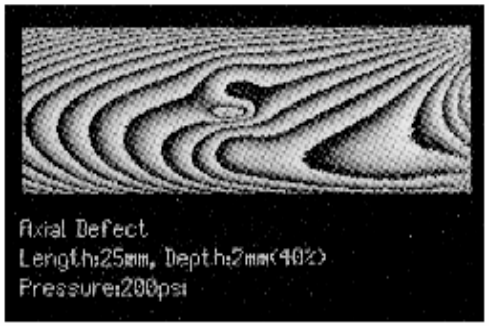
ESPI

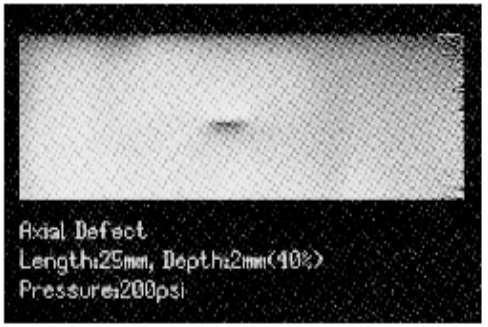
Electronic Speckle Pattern Interferometry

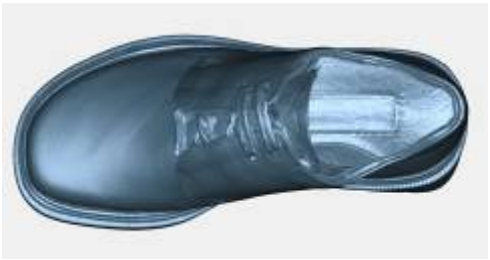


간섭 패턴을 통한 3차원 형상 및 진동의 측정 (ESPI, Shearography 등)

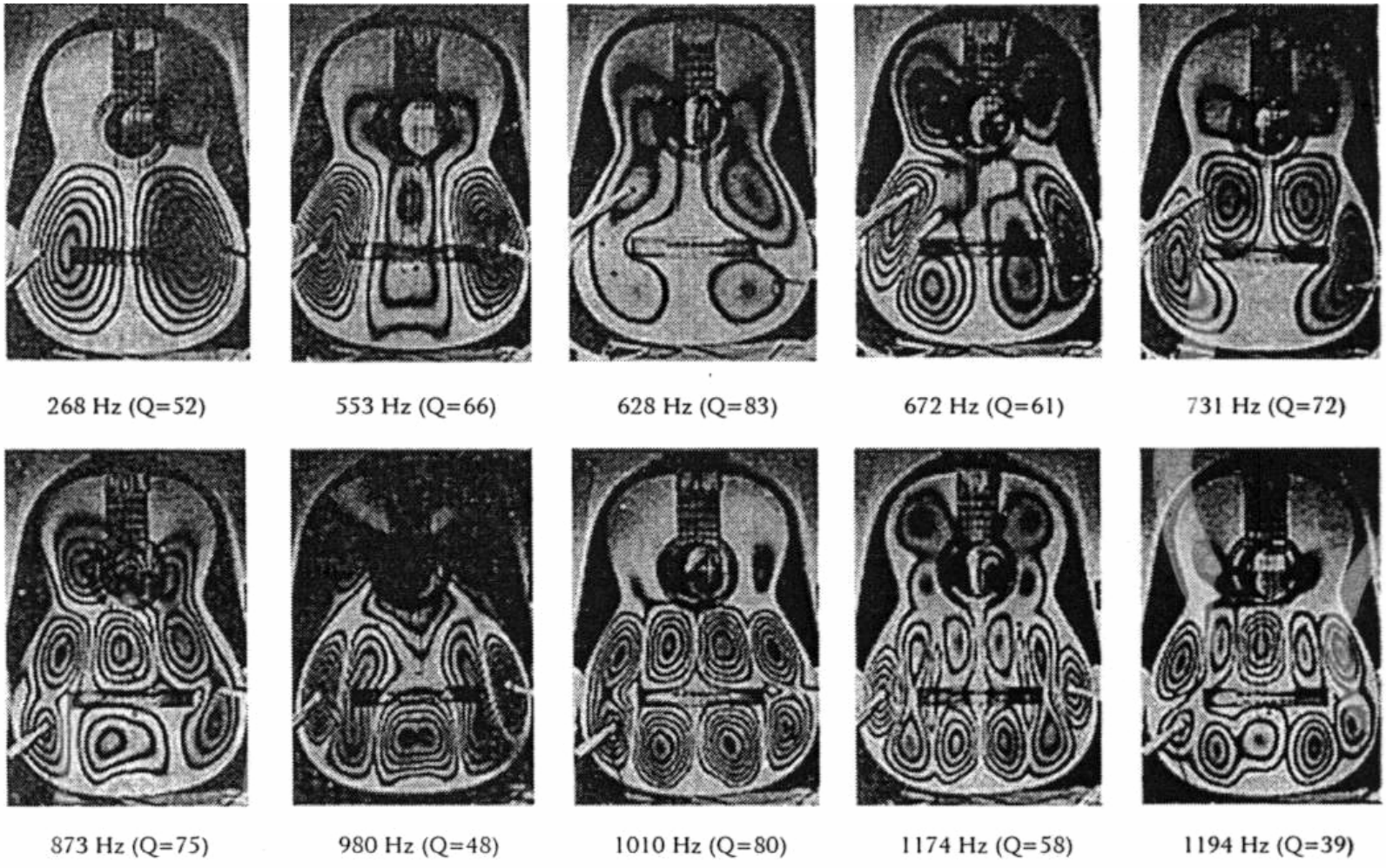






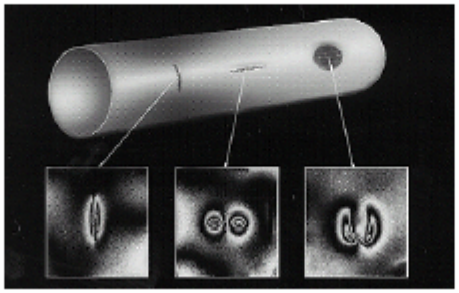


진동 모드 측정의 예


268 Hz (Q=52)
553 Hz (Q=66)
628 Hz (Q=83)
672 Hz (Q=61)
731 Hz (Q=72)
873 Hz (Q=75)
980 Hz (Q=48)
1010 Hz (Q=80)
1174 Hz (Q=58)
1194 Hz (Q=39)

Shearography 시스템 예

Shearography from Steinbichler Optotechnik GmbH

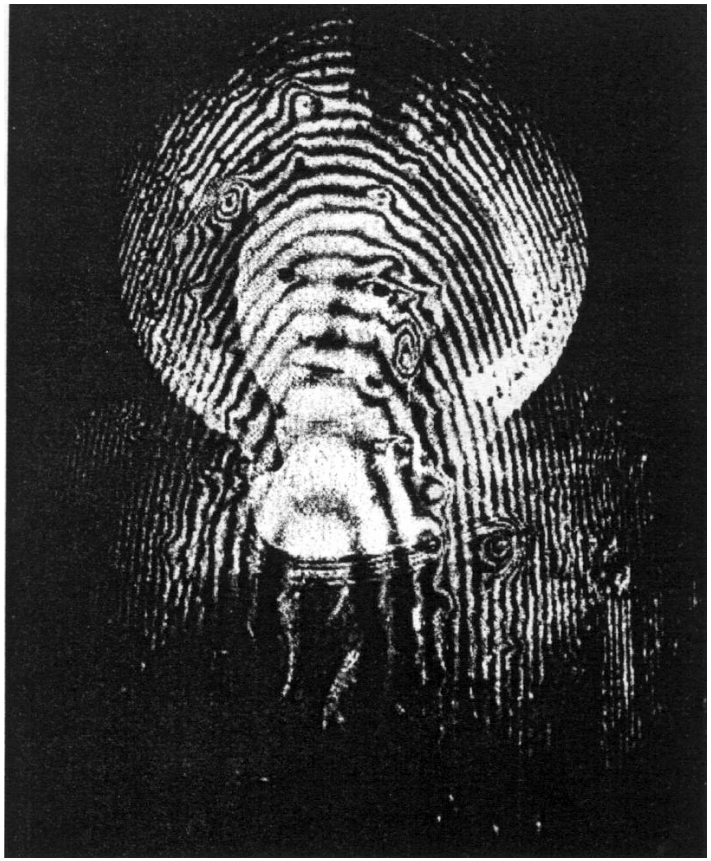


Typical Specifications*:

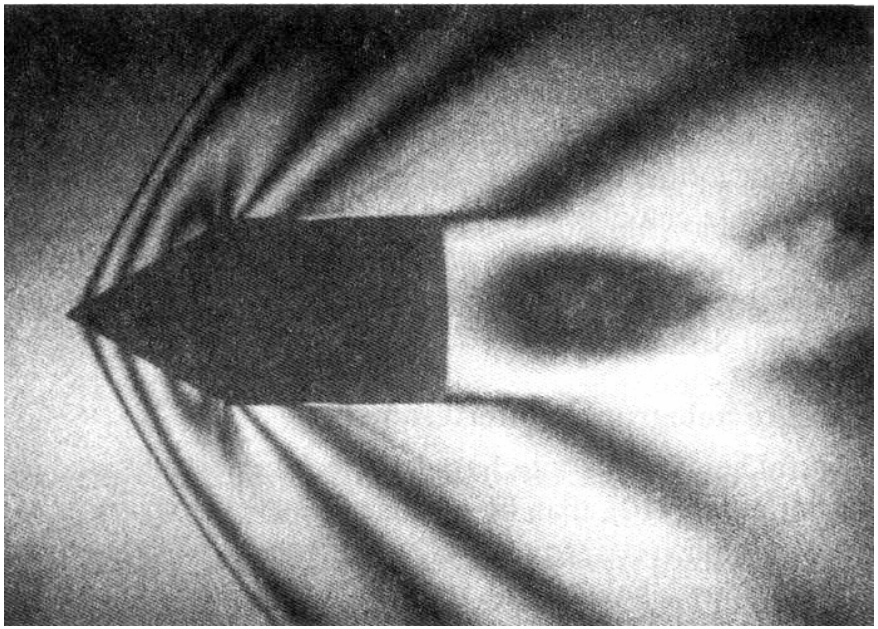
- Patented high-speed, high resolution shearography technology
- Measurement method – direct and temporal phase shift
- Electrical Power - 110 V / 220V
- Detectable defect size – 0.1 µm (3.9×10^{-6} in.)
- Sensitivity – 0.05 µm (1.9×10^{-6} in.)
- Shearing head size – 88 mm x 150 mm x 180 mm (3.5 in. x 6 in. x 7 in.)
- Shearing head weight – 3.5 kg (7.7 lb.)
- Laser – IR diode laser array
- Processor - Pentium III or higher; 1.1 GHz, 40 GB HDD, Frame Grabber board PCVision
- Software - FRAMESplus with Free Boundary
- Camera – high resolution CCD; 1024 x 1280 pixel; 12 bit
- Optics - variable zoom objectives, Nikon interface
- Measurement Field of View Range – 3 mm x 3 mm to 1.0 m^2, unlimited with superposition

*Specifications may be enhanced or modified for specific setup options and custom requirements.

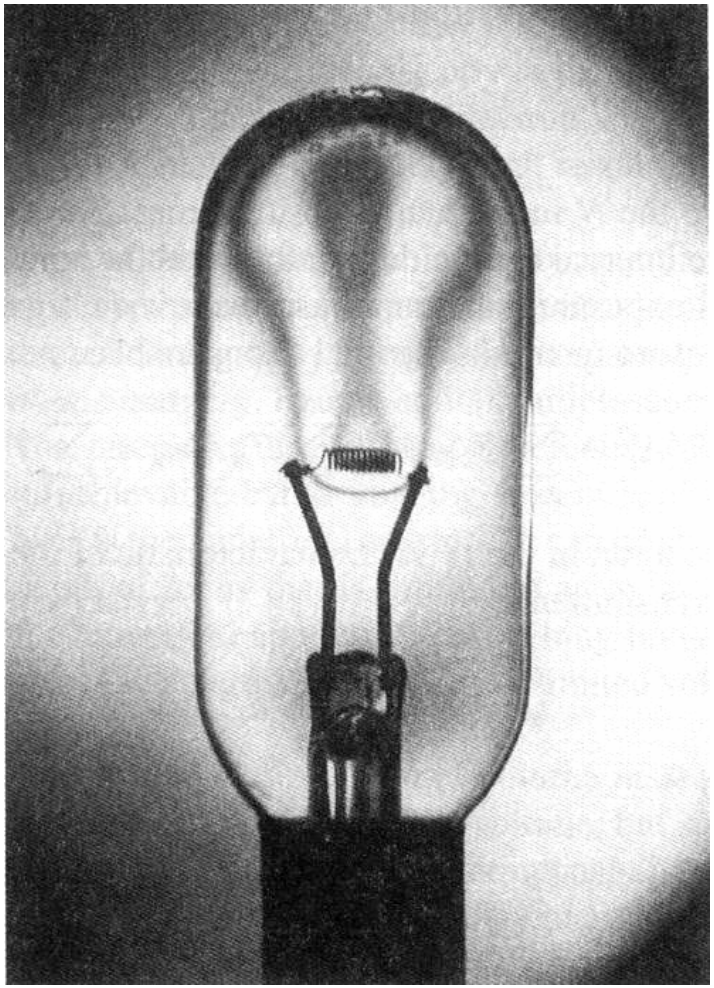
Interferometry



Double-Exposure Holographic Interferometry

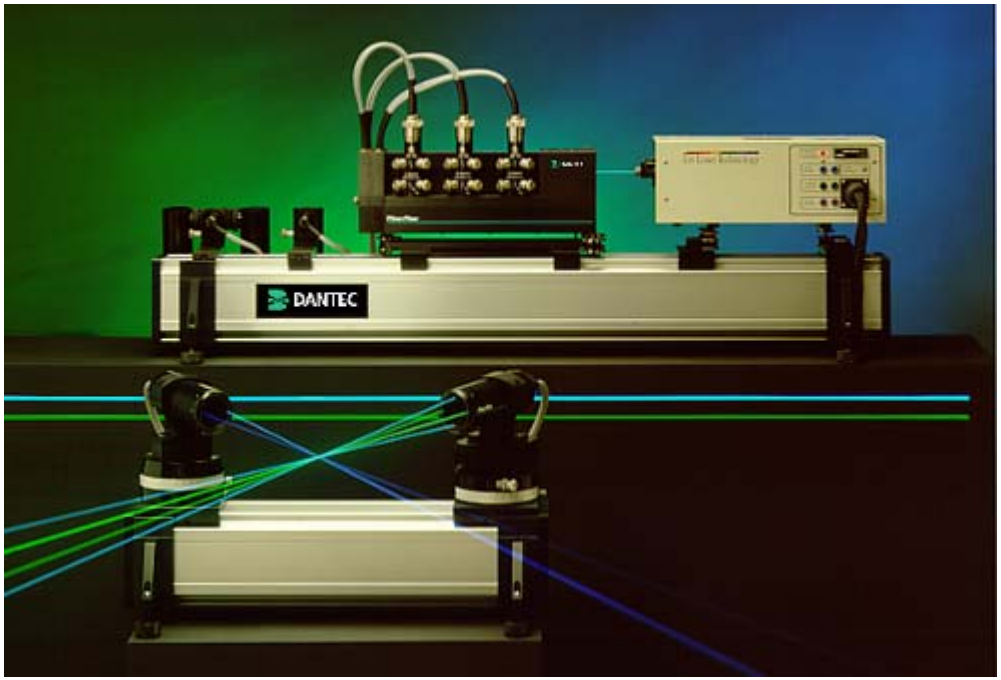


(a)



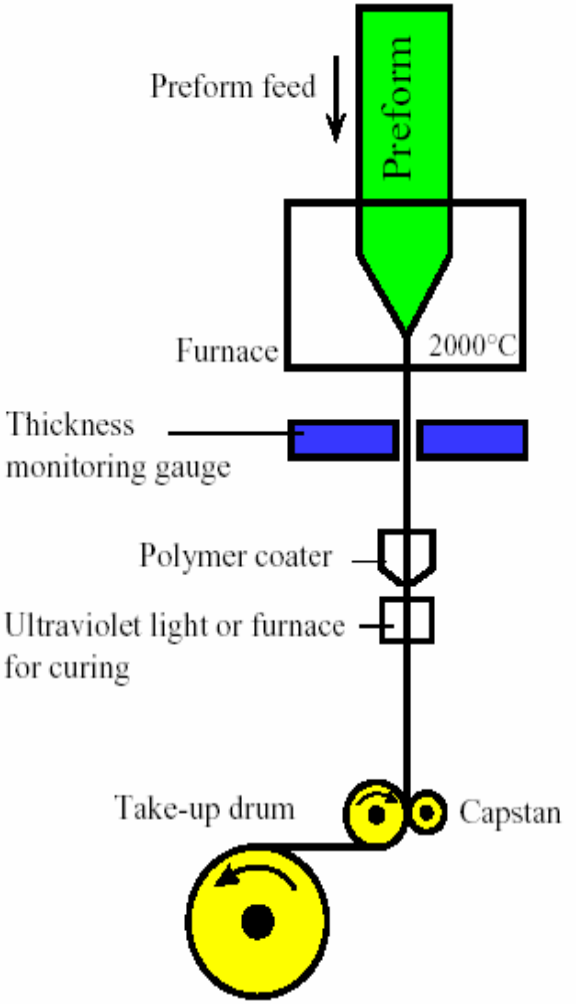
(b)

레이저 도플러 유속계

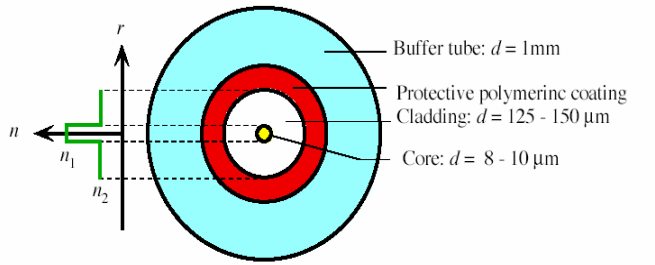


- 비접촉식 3차원 측정
- 난류유동의 해석
- 공기역학적 응용
- 표면 속도, 진동 측정

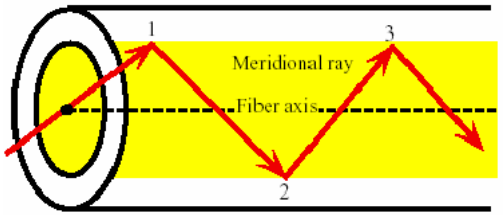
광섬유 (Optical Fiber)



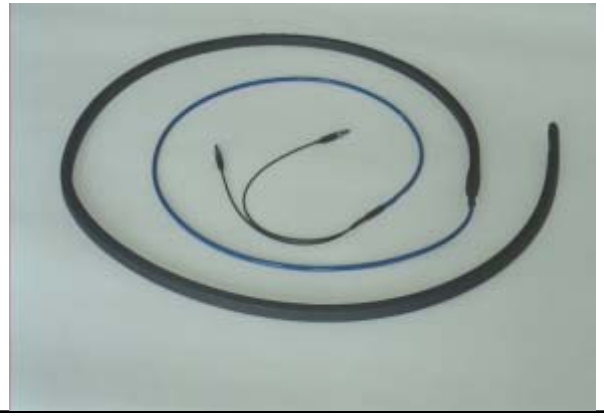
- 센서와 신호전달의 역할을 동시수행
- 분배형 센서의 실현이 용이
- 원격측정가능 (~0.2 dB/km loss)
- 기존 센서기술로 불가능한 부분을 커버



The cross section of a typical single-mode fiber with a tight buffer tube. (*d* = diameter)



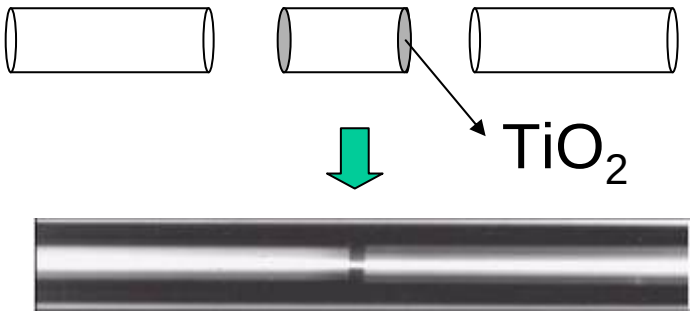
광섬유 센서

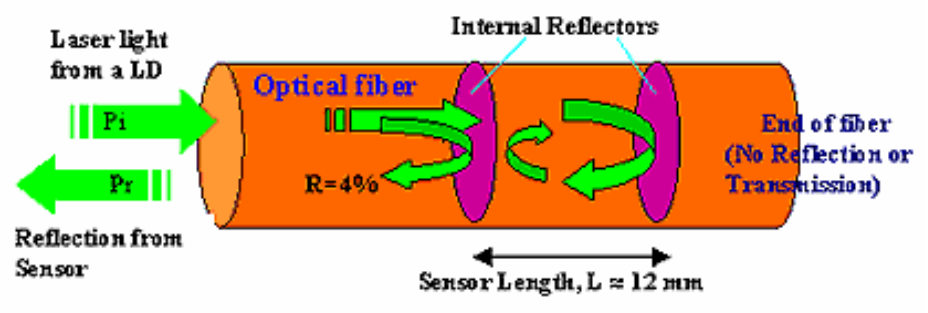


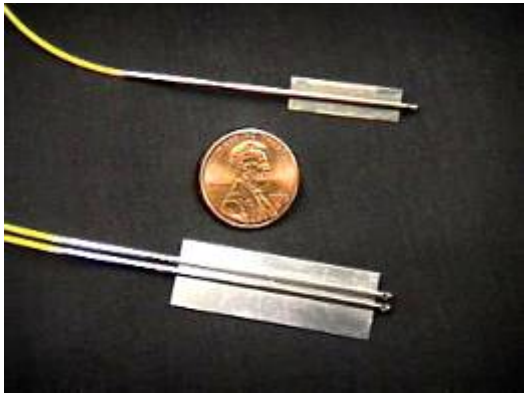
Fabry-Perot 간섭계 센서

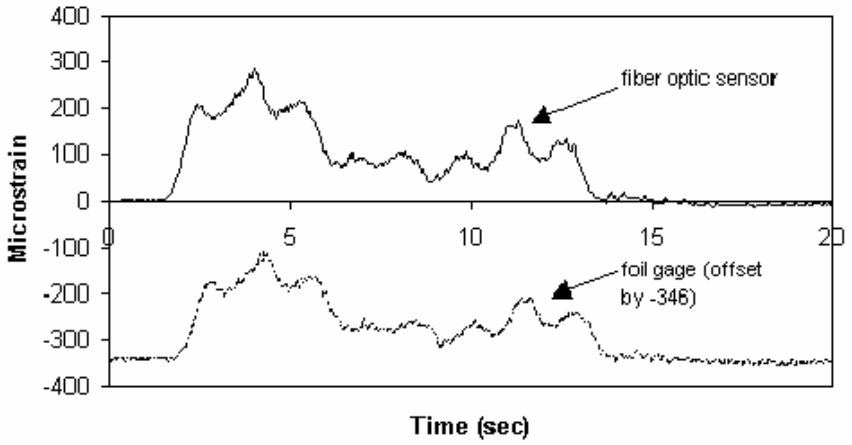
$$\Delta\phi = \frac{4\pi\Delta(nL)}{\lambda}$$

In-line FP sensor

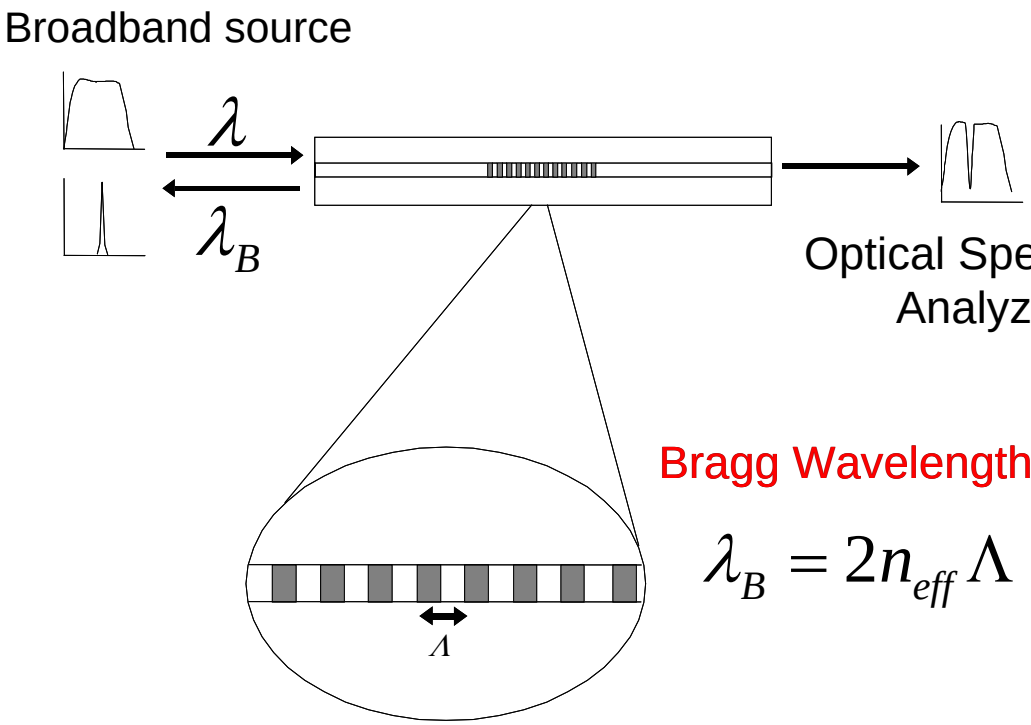








광섬유 격자 (fiber Bragg grating) 센서



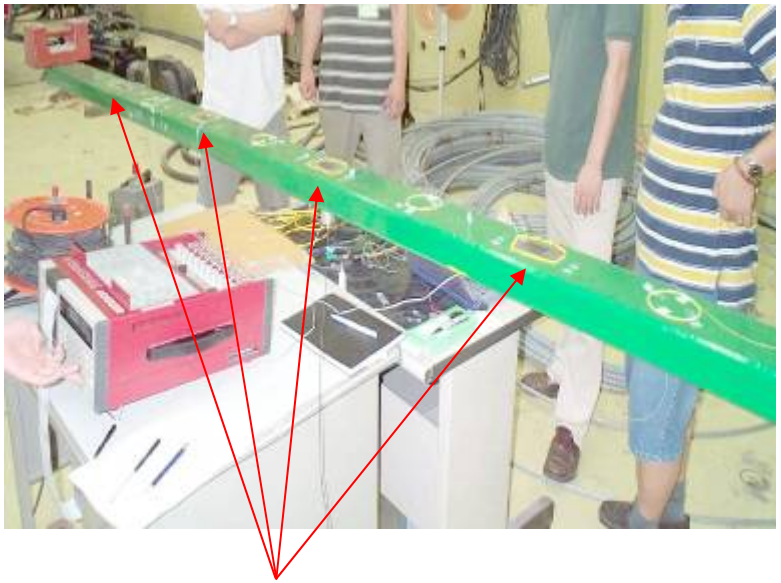
Bragg Wavelength

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

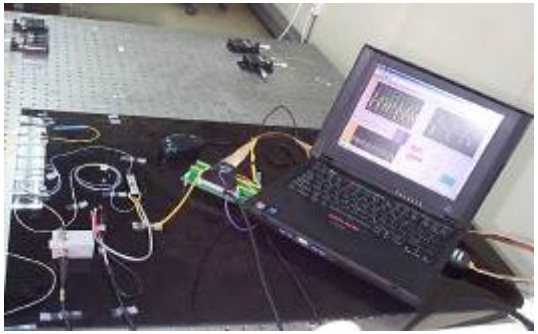
- 특정 파장만을 반사
- 반사파장의 변화로부터 물리량을 측정
- 측정점의 위치, 크기가 고정 → 준분포센서

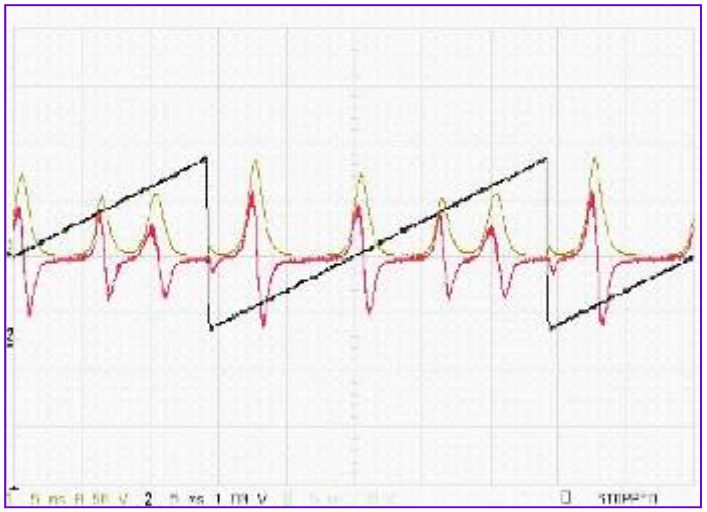
다중점 광섬유 격자 센서의 측정 예

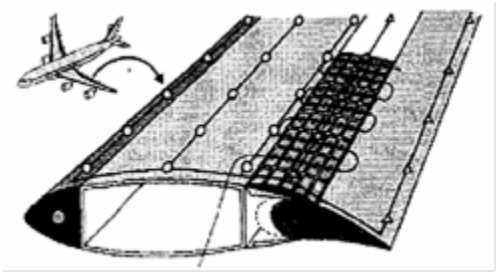
Load measurement based on multiplexed FBG sensor system

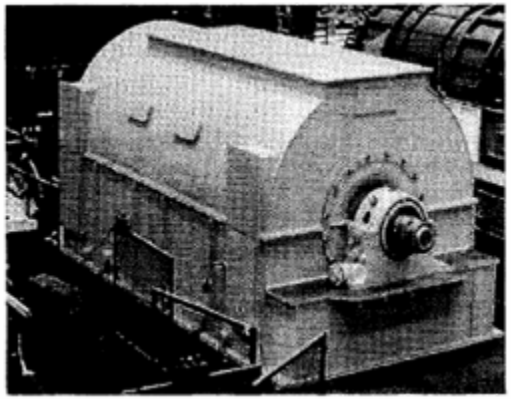


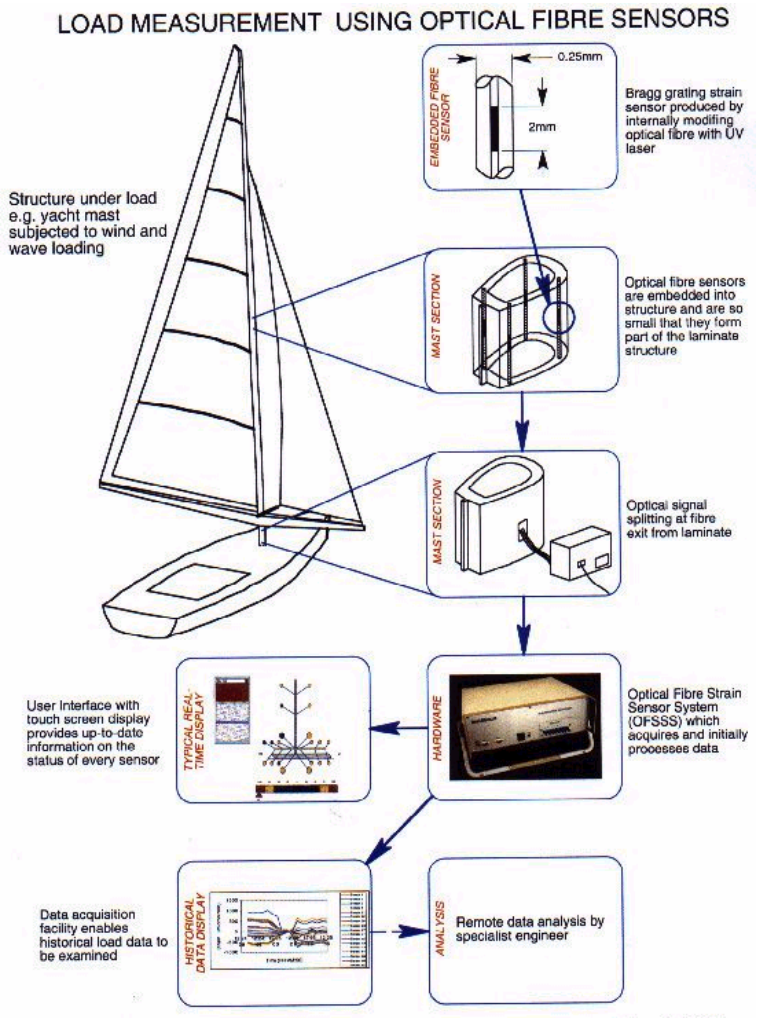
FBGs










LOAD MEASUREMENT USING OPTICAL FIBRE SENSORS
Structure under load e.g. yacht mast subjected to wind and wave loading
EMBEDDED FIBRE SENSOR
0.25mm
2mm
Bragg grating strain sensor produced by internally modifing optical fibre with UV laser
MAST SECTION
Optical fibre sensors are embedded into structure and are so small that they form part of the laminate structure
MAST SECTION
Optical signal splitting at fibre exit from laminate
HARDWARE
Optical Fibre Strain Sensor System (OFSSS) which acquires and initially processes data
TYPICAL REAL-TIME DISPLAY
User Interface with touch screen display provides up-to-date information on the status of every sensor
HISTORICAL DATA DISPLAY
Data acquisition facility enables historical load data to be examined
ANALYSIS
Remote data analysis by specialist engineer

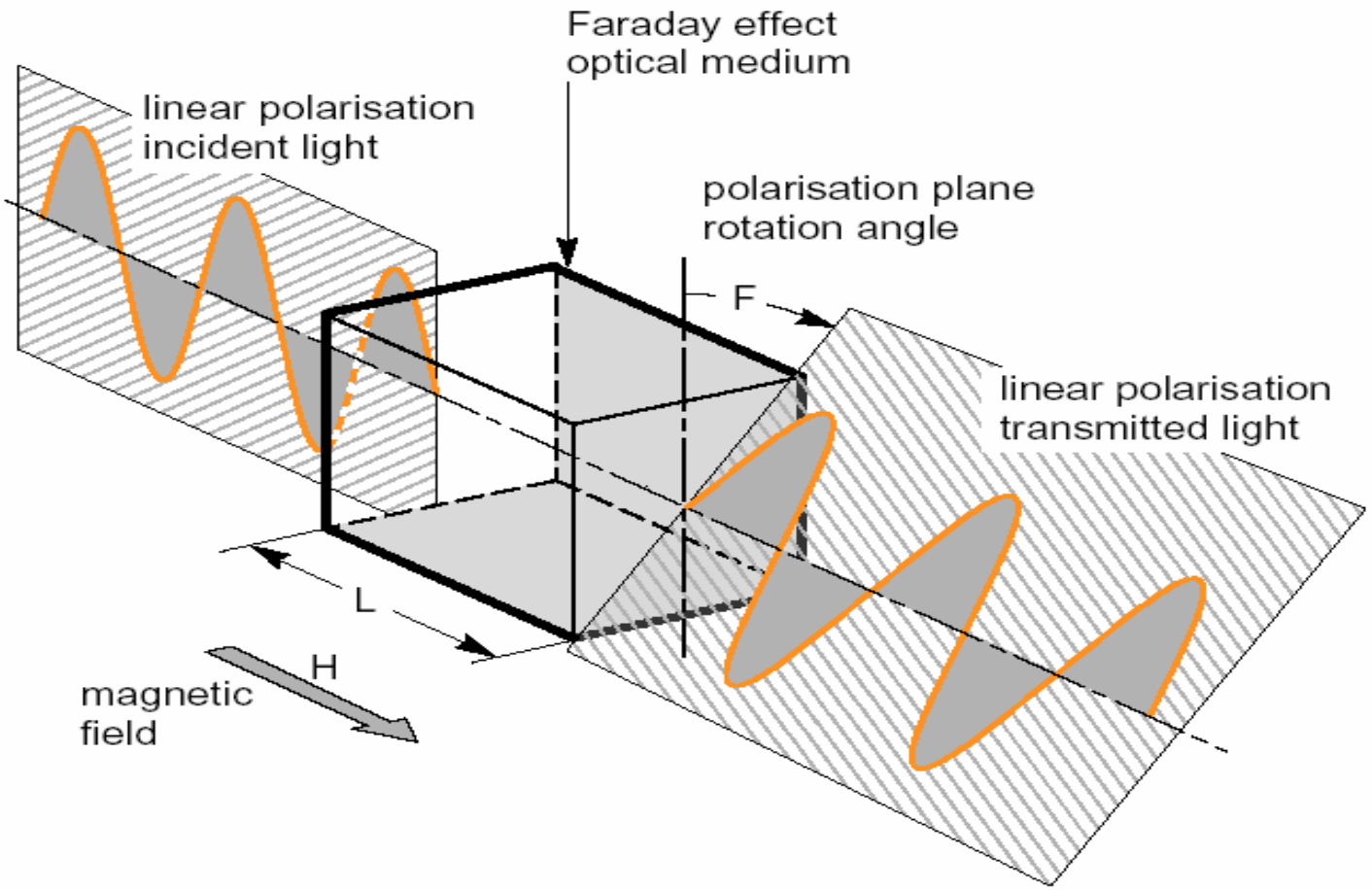
광섬유 센서 설치 작업



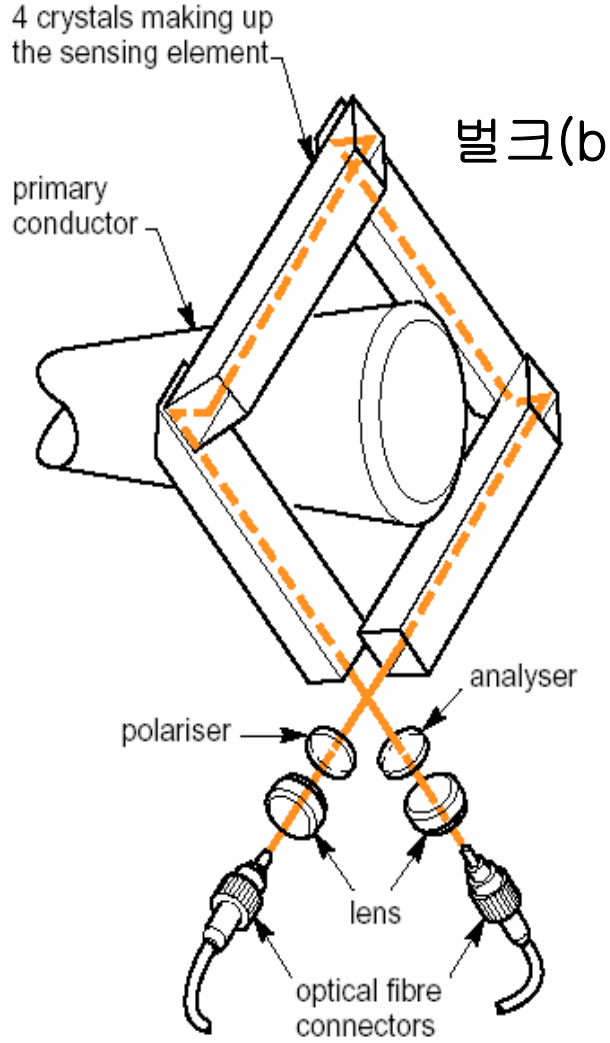




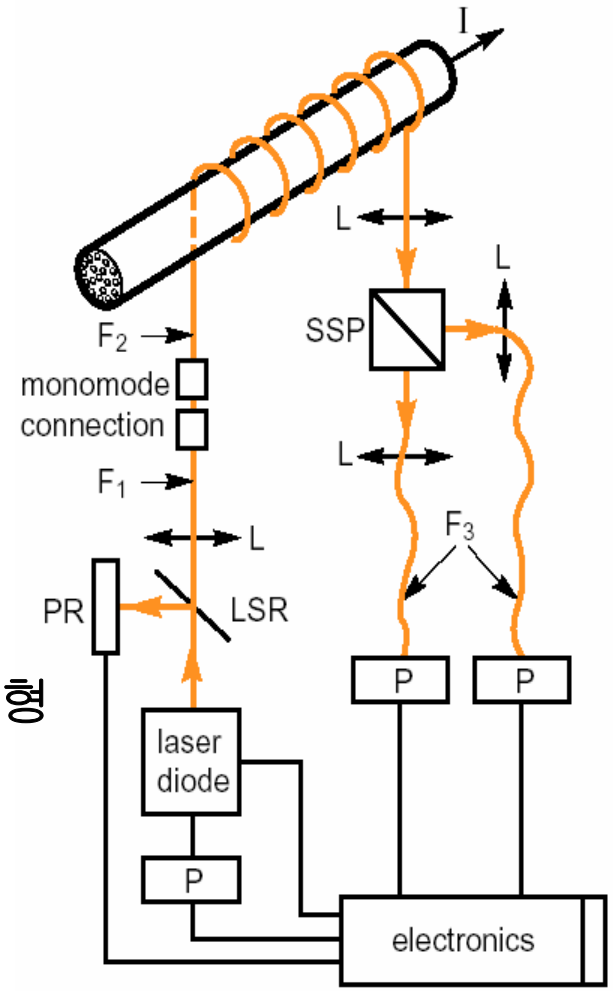

편광 변화를 이용한 전류의 측정



광 CT의 종류

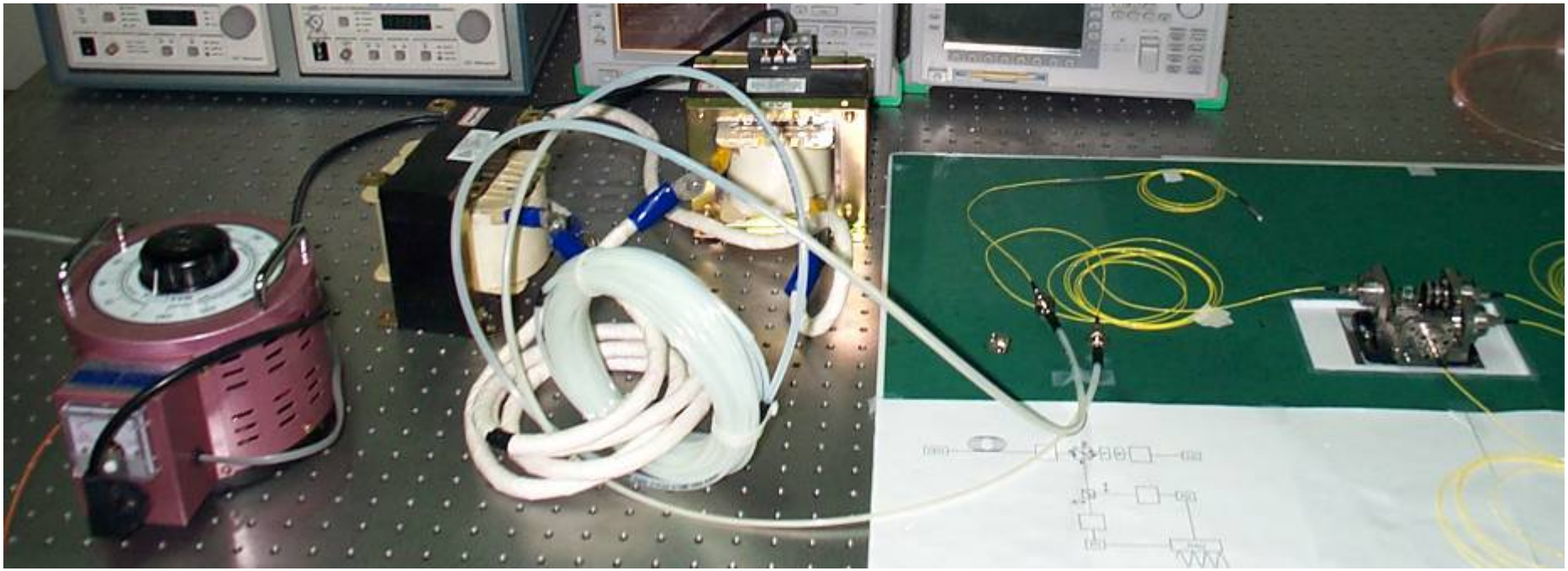


벌크(bulk)형



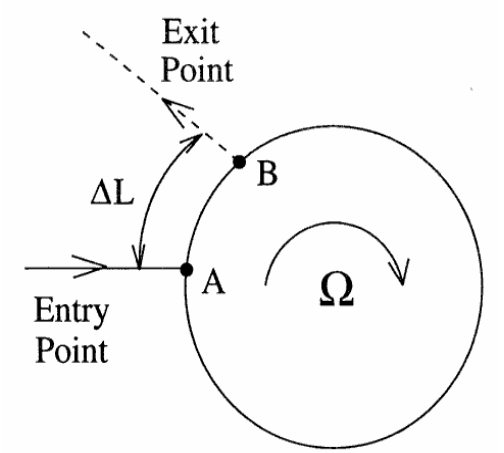
광섬유형

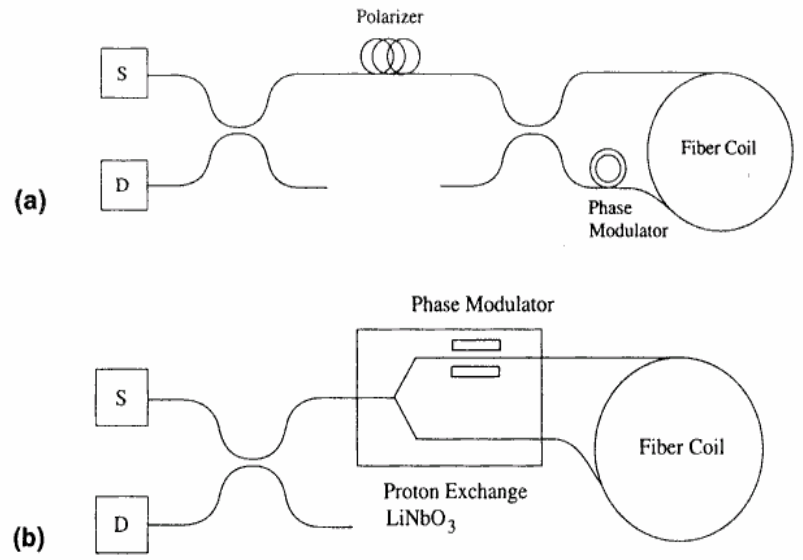
광 CT의 실험 Setup



측정전류: 0~200 Ampere·Turns 광섬유 코일 회전 수 N = 53
56 twist/meter

광을 이용한 자이로스코프 (Gyroscope)



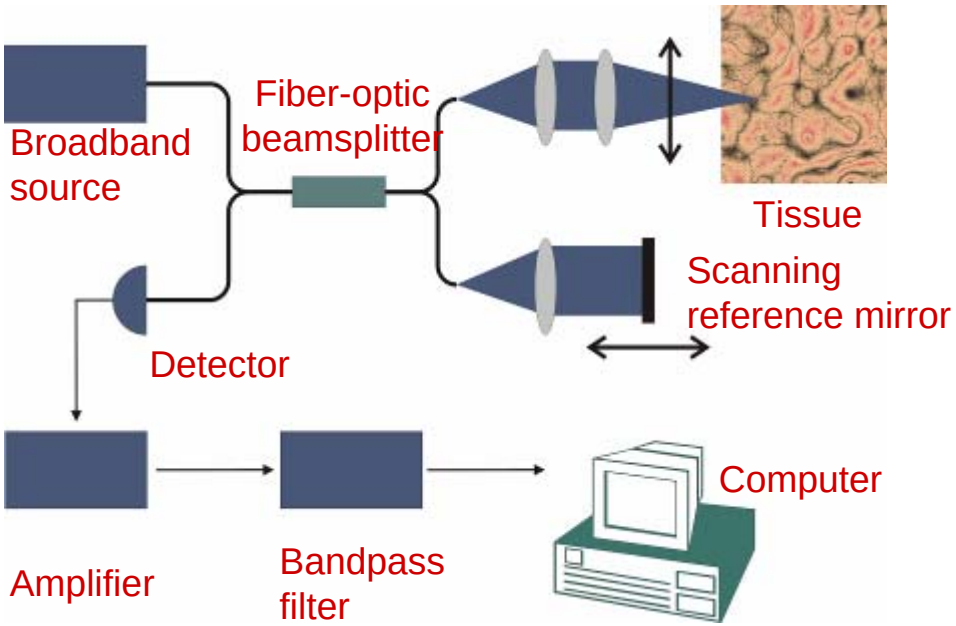


회전에 의한 위상차 발생 → 위상차의 측정

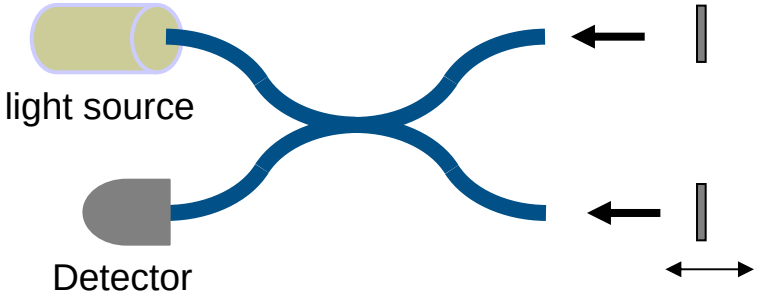
- 회전각을 초정밀측정(100년에 1회전도 측정가능)
- 가격, 안정성, 내구성, 빠른 기동 시간 등이 우수
- 비행기, 미사일, 우주선, 잠수함 등의 항법장치, 무인자동화 기기의 자세제어, 자이로 콤파스 등의 응용범위를 가짐

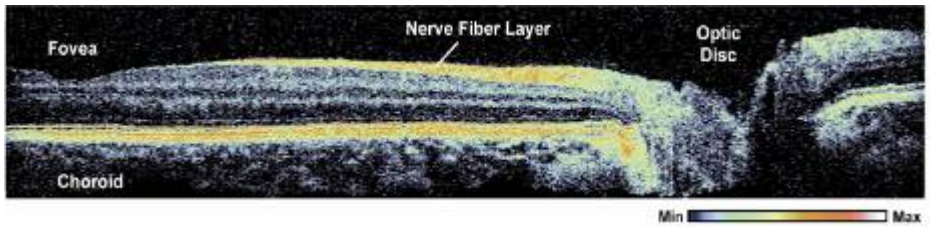
Optical Coherence Tomography

❑ Experimental Set-up of OCT and Results



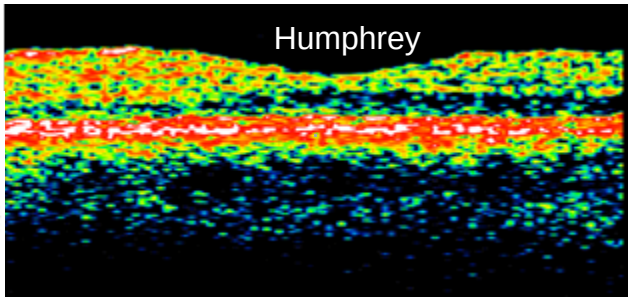
Michelson interferometer





W. Drexler *et al*., "Ultrahigh-resolution ophthalmic optical coherence tomography", Nature Medicine **7**, 502-507 (2001)

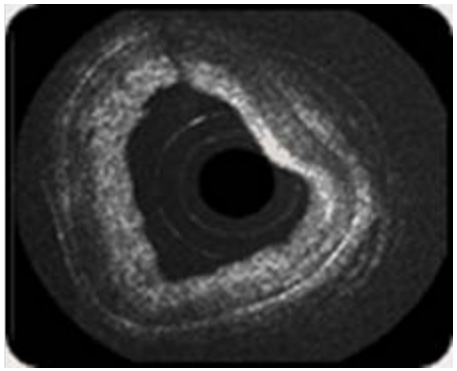
Normal Eye scaned image



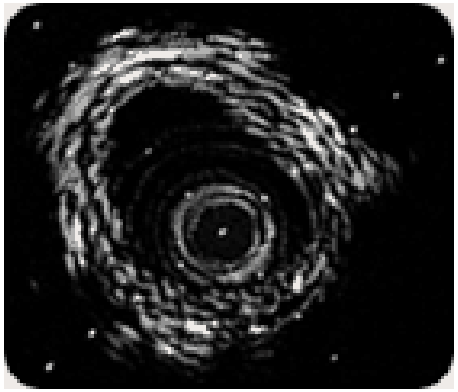
Nominal width of scan: 2.8 mm

OCT

- Some Examples of OCT
  - ✓ Imaging inside Veins

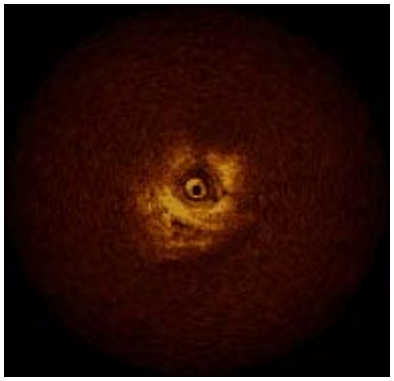


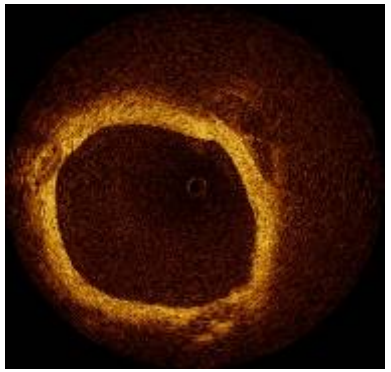
OCT



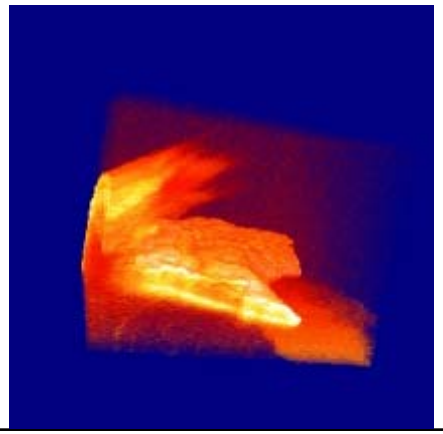
Ultrasound

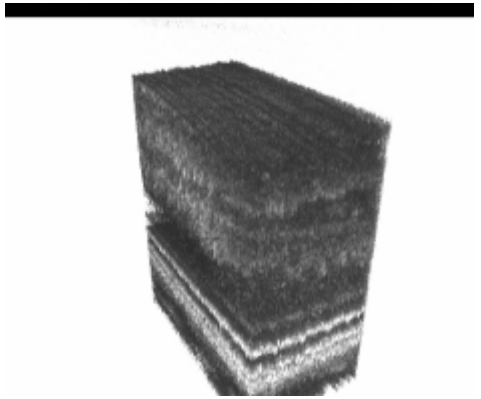
Real-time cardiology





In-vivo human anterior eye segments





통신의 역사

- 1830년대 --- Morse : 전신기술의 발명
  (전송속도 : < 10b/s)
- 1866 --- 대서양 횡단 전신 케이블
- 1876 --- Bell : 전화의 발명
- 1940년경 --- 3MHz 동축케이블 전송기술
- 1950년대 --- Microwave 무선전송기술
  (전송속도 : < 100Mb/s)

광통신의 역사 I

- 1950년대 --- Townes, Schawlow, Basov, Prokhorov
  : Laser의 원리
- 1960 --- 최초의 laser 개발
- 1966 --- 광섬유 통신의 가능성 발표
- 1970 --- 저손실 광섬유의 가능성 (20dB/km)
  상온에서의 cw반도체레이저
- 1975 --- 1세대 광전송시스템:
  0.8μm GaAs 레이저, 다중모드 광섬유
  (BL ~ 500Mb/s·km)

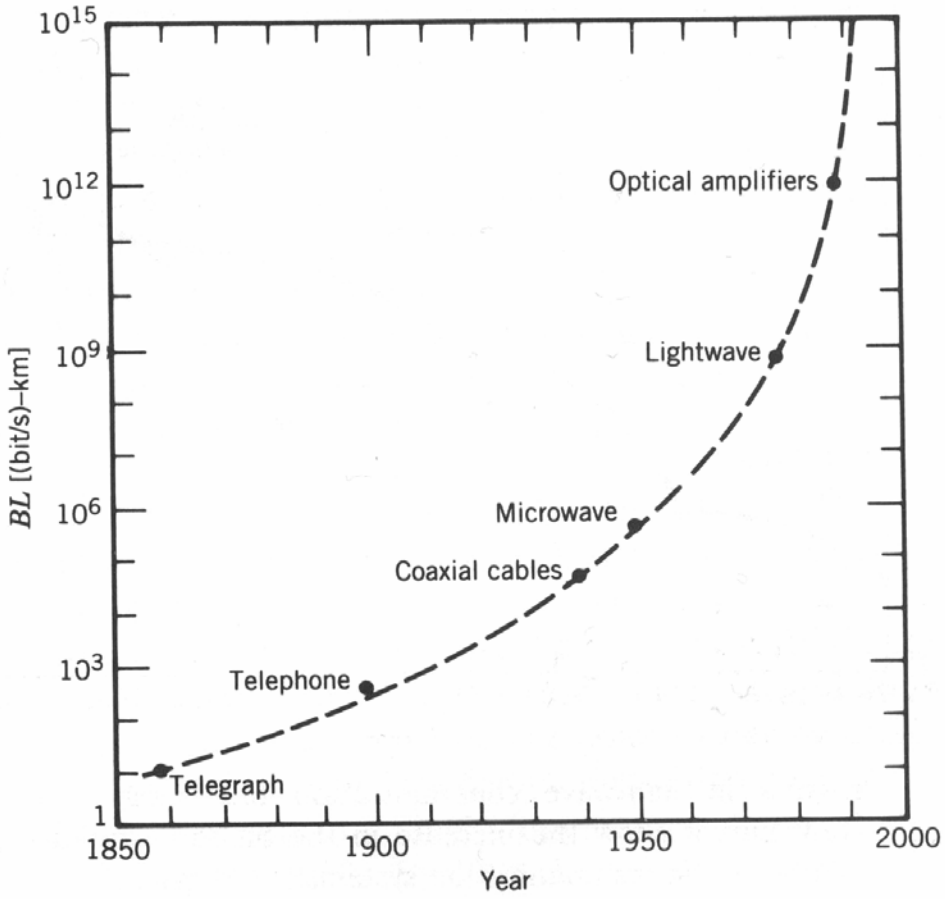
광통신의 역사 II

- 1976~1977 ---최초의 현장 적용시험 및 상업화 시도
- 1977 --- 2세대 광전송 시대의 개막:
  1.3μm InGaAsP 레이저
- 1980 --- 0.2dB/km 광섬유 개발
- 1981 --- 1.5μm InGaAsP 레이저 개발
- 1988 --- 최초의 대서양 횡단 광케이블
  1.55μm 양자우물레이저 개발
  3세대 광전송의 연구 (1.55μm ,~10Gb/s)
- 현재 --- 4세대: 파장분할다중화(WDM)방식, 광증폭기,
  Soliton 연구(5세대)

광통신의 장점

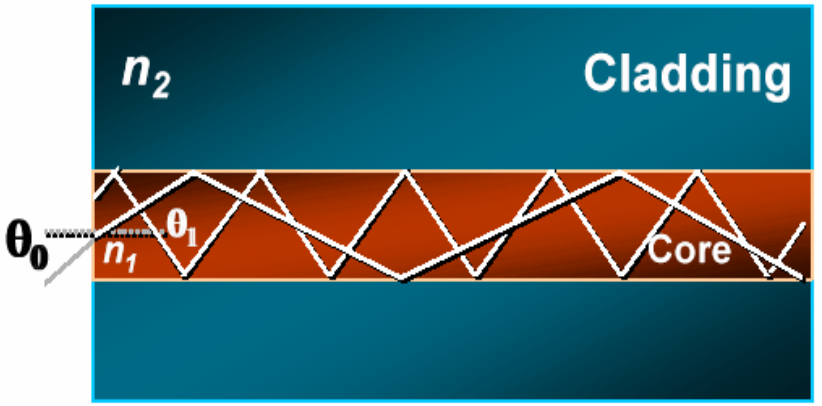
- 전송용량의 증대
- 고신뢰성
- 무중계 거리의 확대
- 보안성의 증대
- 크기 및 무게의 감소
- 무한한 성장 가능성
- 저가의 시스템

통신의 발전추세

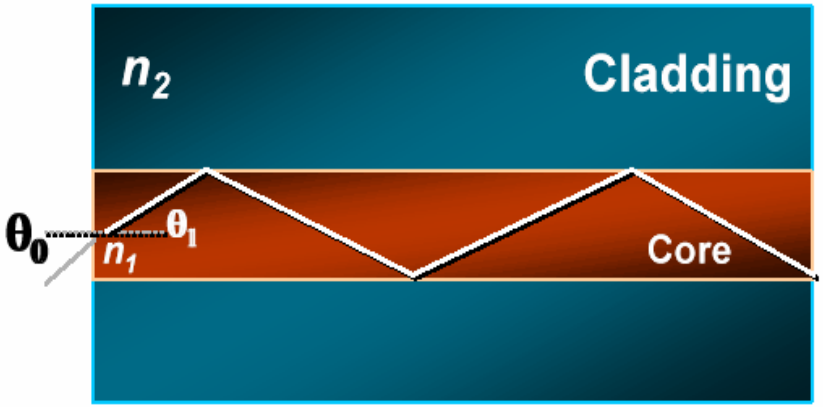

10^{15}
10^{12}
10^{9}
10^{6}
10^{3}
1
BL [(bit/s)–km]
Optical amplifiers
Lightwave
Microwave
Coaxial cables
Telephone
Telegraph
1850
1900
1950
2000
Year

광섬유의 종류

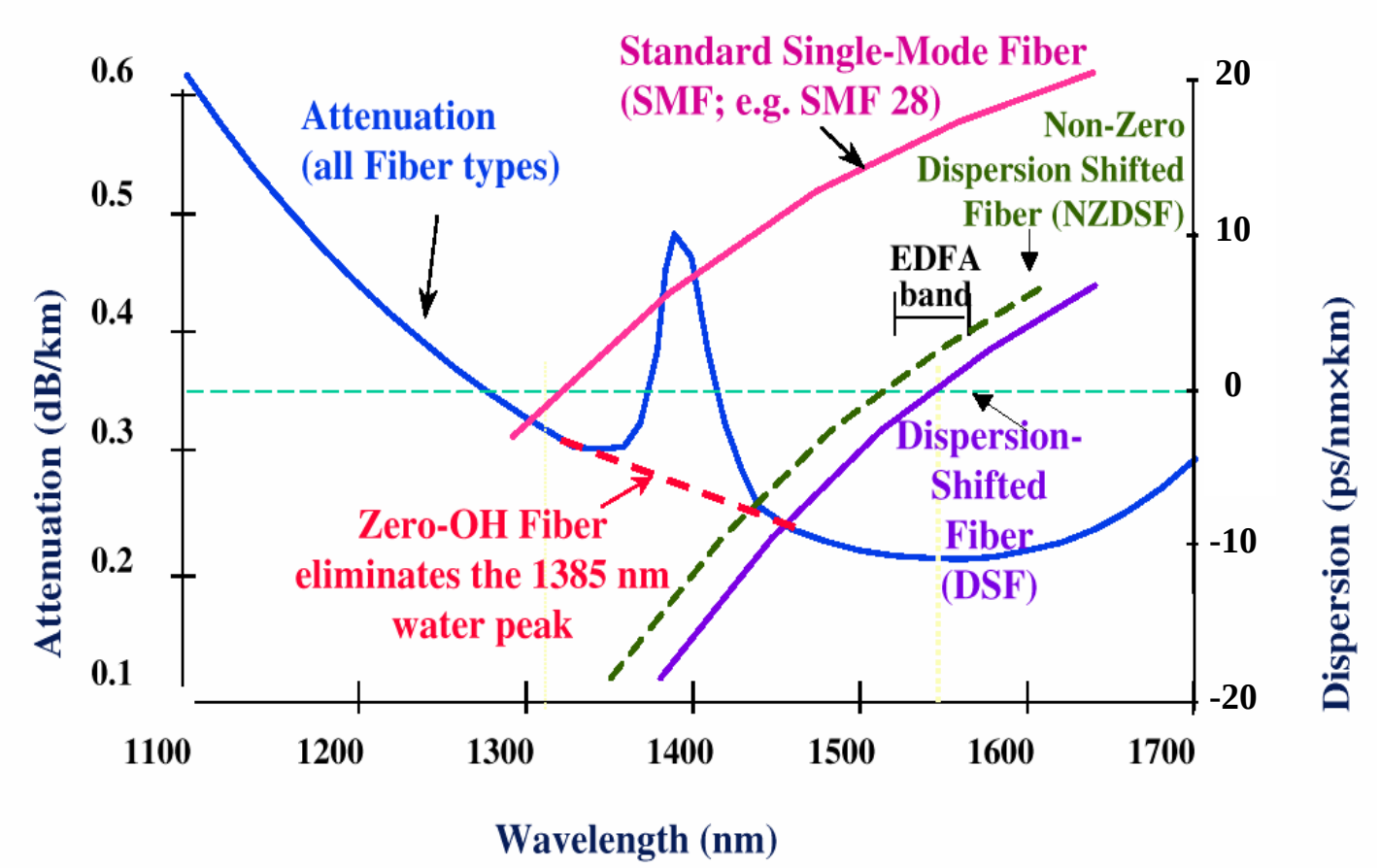
- 다중모드 광섬유 (MMF)
  - 코어 직경은 50μm
  - 모드간 분산에 의해 전송거리 제한



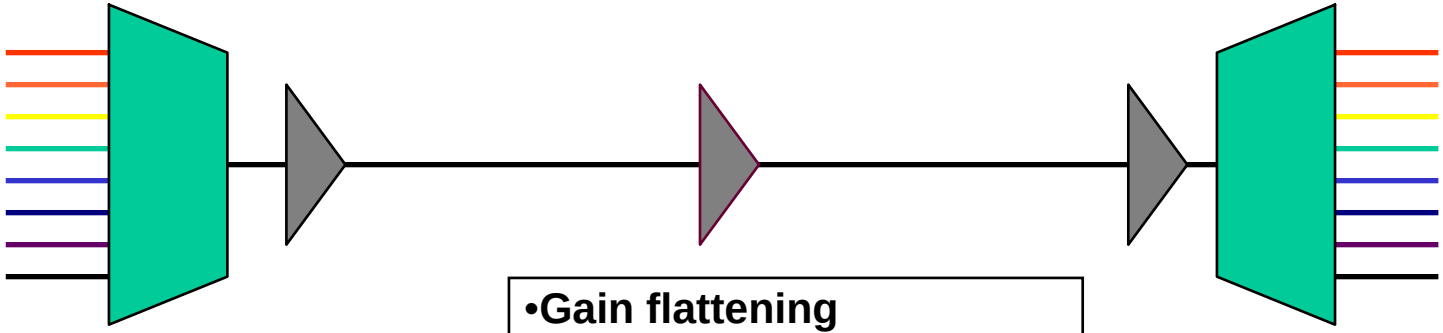
- 단일모드 광섬유 (SMF)
  - 코어 직경은 8μm
  - 색분산에 의해 전송거리 제한



단일 모드 광섬유의 종류


Standard Single-Mode Fiber
(SMF; e.g. SMF 28)
Attenuation
(all Fiber types)
Non-Zero
Dispersion Shifted
Fiber (NZDSF)
EDFA
band
Dispersion-
Shifted
Fiber
(DSF)
Zero-OH Fiber
eliminates the 1385 nm
water peak
Attenuation (dB/km)
0.6
0.5
0.4
0.3
0.2
0.1
20
10
0
-10
-20
Dispersion (ps/nm×km)
1100
1200
1300
1400
1500
1600
1700
Wavelength (nm)

WDM 전송에 요구되는 기술들



- Source types
- Laser λ control
- Laser aging
- Standard λ
- Channel spacing
- ⋮

- Gain flattening
- Dynamic gain control
- Gain bandwidth
- ⋮

- Dispersion compensation
- Nonlinearities
- ⋮

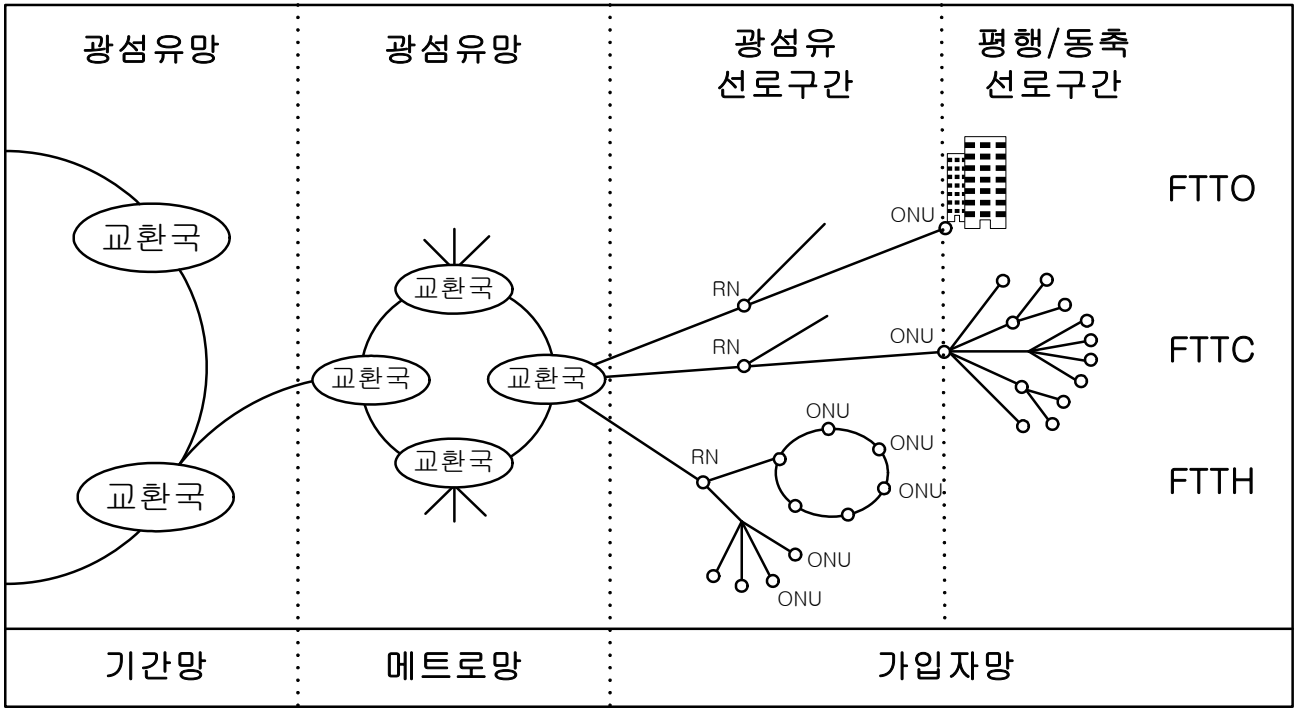
- Demultiplexer
- Demux λ control
- Bandwidth
- Crosstalk
- ⋮

Operation, Administration, Maintenance Issues...

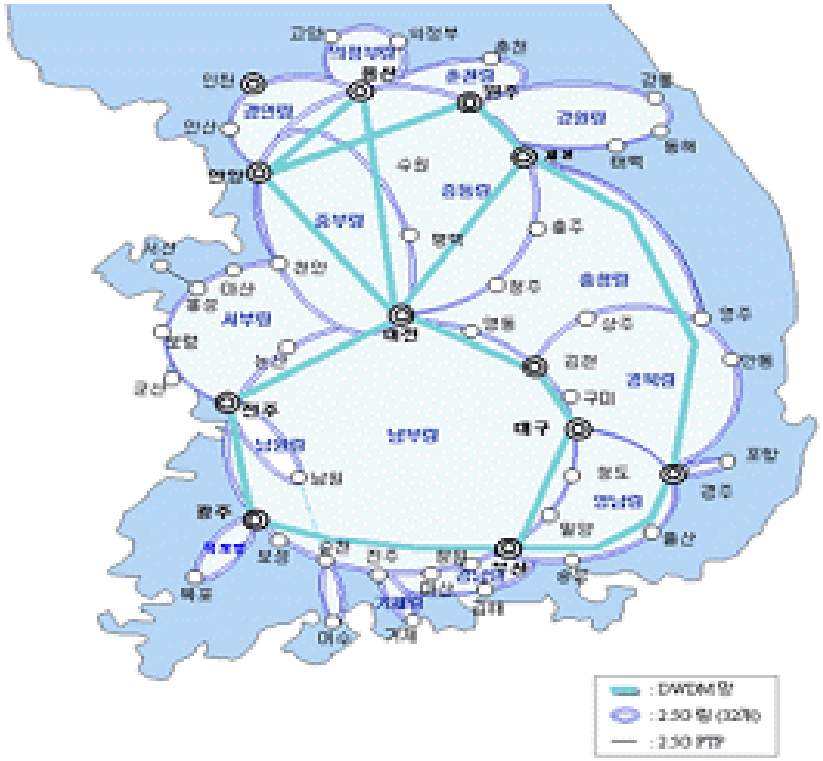
광통신의 주요 소자들

- 단일 모드 광섬유 (SMF: Single Mode Fiber)
- 광원 (DFB-LD)
- Photodiode (PIN, APD)
- 광 증폭기 (EDFA 등)
- 광 변조기 ($LiNbO_3$)
- 광 스위치, OXC, Optical Router ...

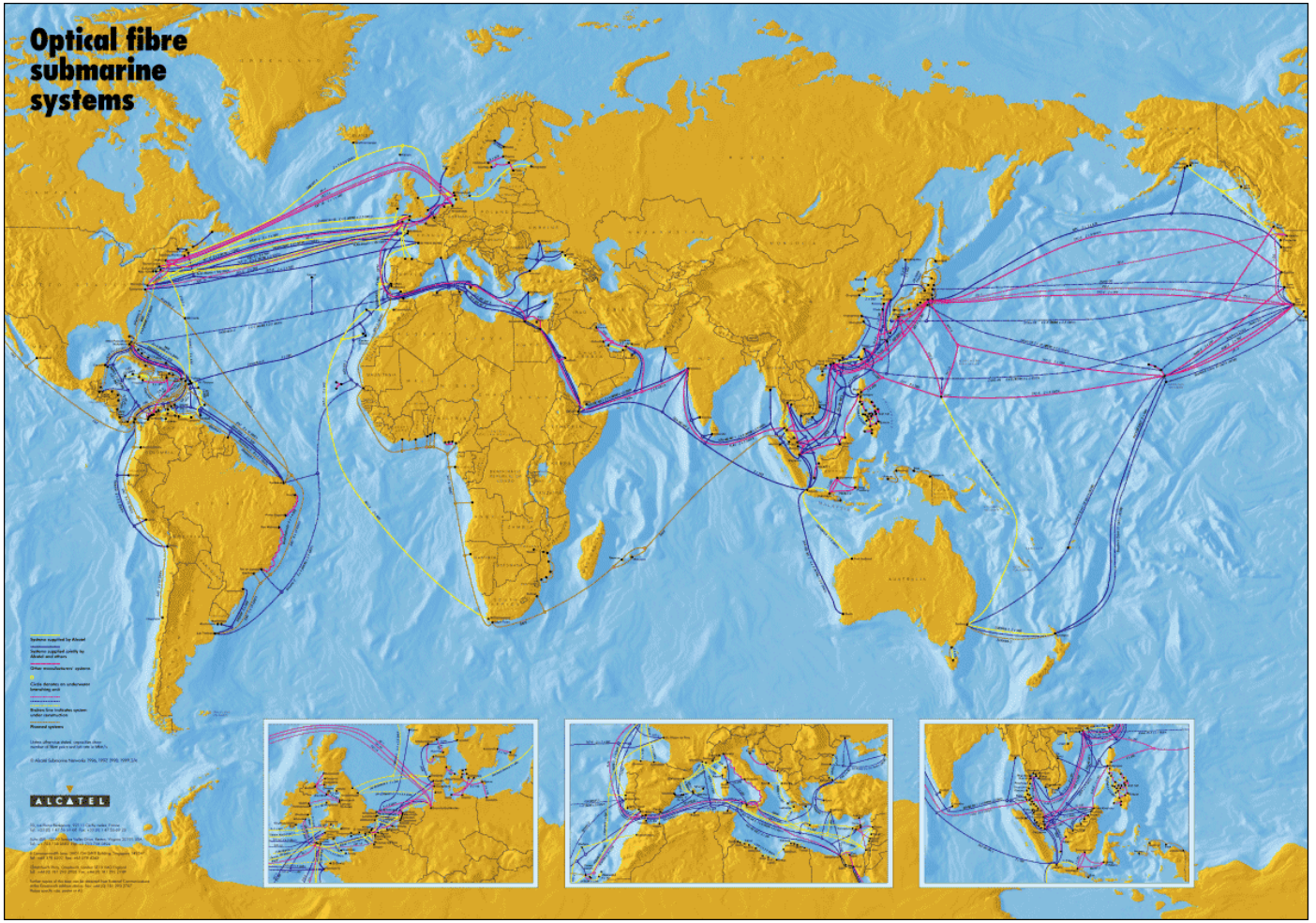
개략적인 계위별 망 구조


광섬유망
광섬유망
광섬유
선로구간
평행/동축
선로구간
교환국
교환국
교환국
교환국
교환국
RN
RN
RN
ONU
ONU
ONU
ONU
ONU
ONU
FTTO
FTTC
FTTH
기간망
메트로망
가입자망

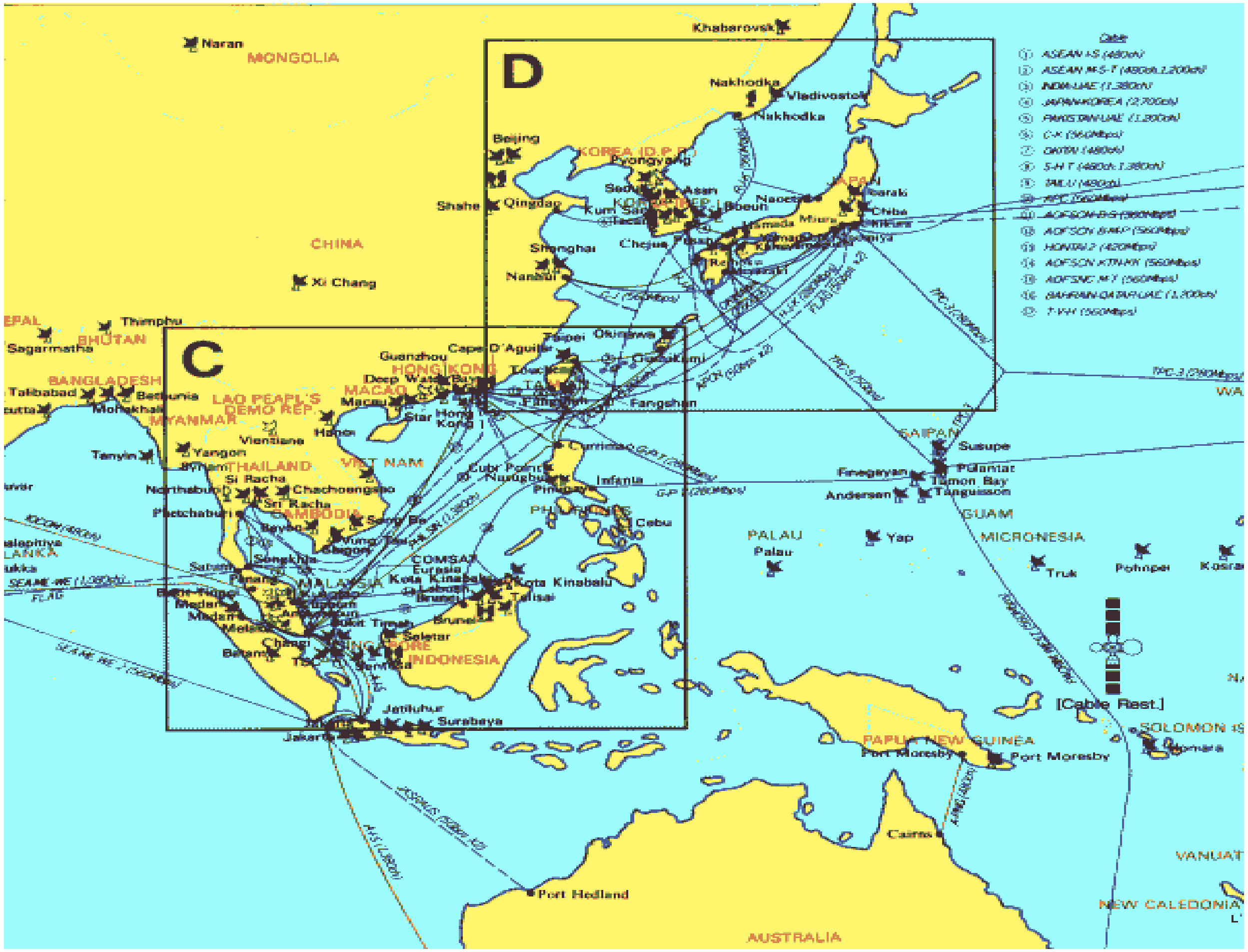
우리나라의 기간망



해저 광케이블 I



해저 광케이블 II



D
C
Khabarovsk
Naran
MONGOLIA
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Qingdao
Shanghai
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Xi Chang
JAPAN
Thimphu
BHUTAN
BANGLADESH
Okinawa
Taipei
HONG KONG
MACAO
Hanoi
Yangon
THAILAND
VIET NAM
Chachoengsao
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Kota Kinabalu
COMSAT
Brunei
INDONESIA
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Surabaya
Jakarta
[Cable Rest.]
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Port Moresby
SOLOMON IS
Cairns
Port Hedland
AUSTRALIA
VANUATU
NEW CALEDONIA