

광계측

이병호

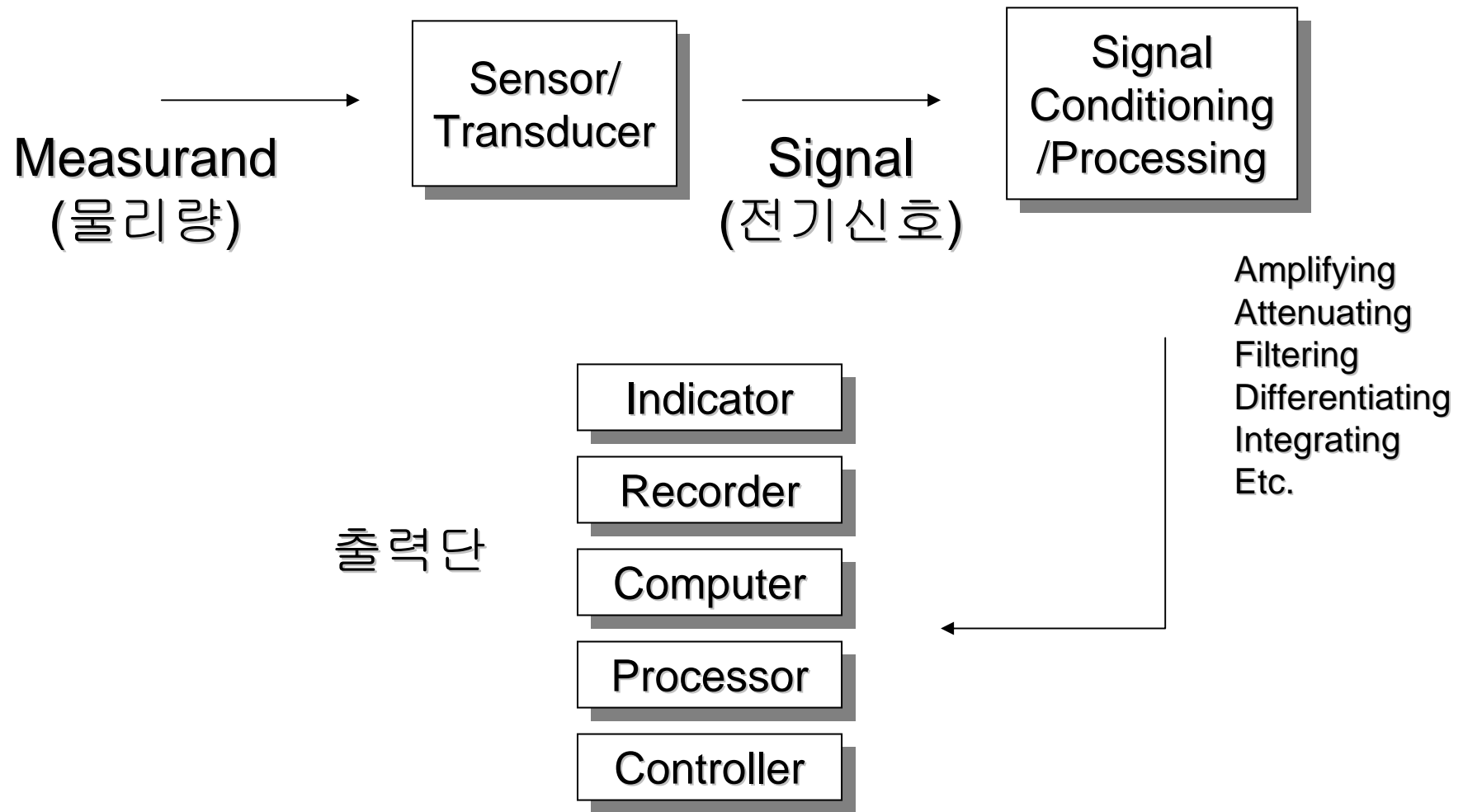
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계측 시스템



좋은 센서의 요구조건

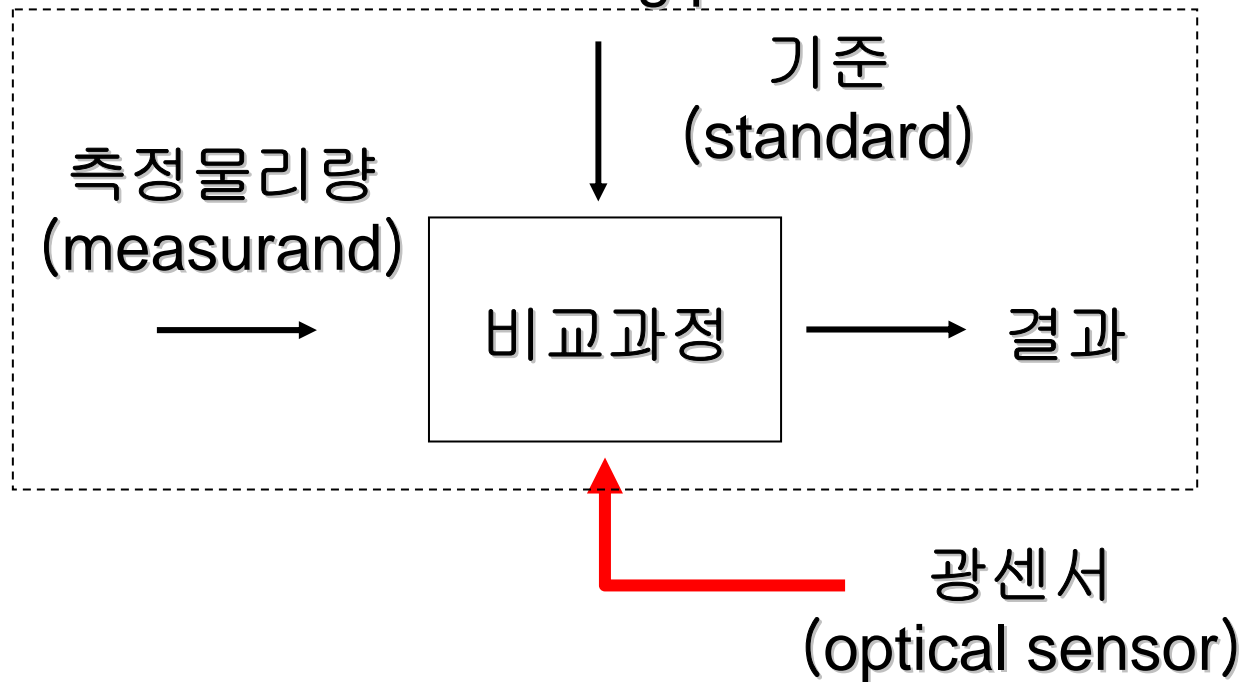
- 민감하게 반응 (Sensitivity)
- 선형적으로 반응 (Linearity)
- 선택적으로 반응 (Selectivity)
- 폭 넓은 측정범위 (Dynamic Range)
- 빠른 응답속도 (Bandwidth)
- 기타 (외란에 대한 안정성, 내충격성, 방폭성, etc.)



광계측이란?

빛 (**laser** 또는 기타 광)을 이용하는 계측

Fundamental measuring process



광계측의 장점

- **EMI Immunity**
- 비접촉 방식
- 비파괴 검사
- 고정밀도
- 분포센서
- 원격측정
- 잠재적 경제성
- 거의 모든 물리량 측정가능

Temperature	Chemical Species
Pressure	Force
Flow	Radiation
Liquid Level	pH
Displacement	Humidity
Vibration	Strain
Rotation	Velocity
Magnetic Fields	Electric Fields
Acceleration	Acoustic Fields

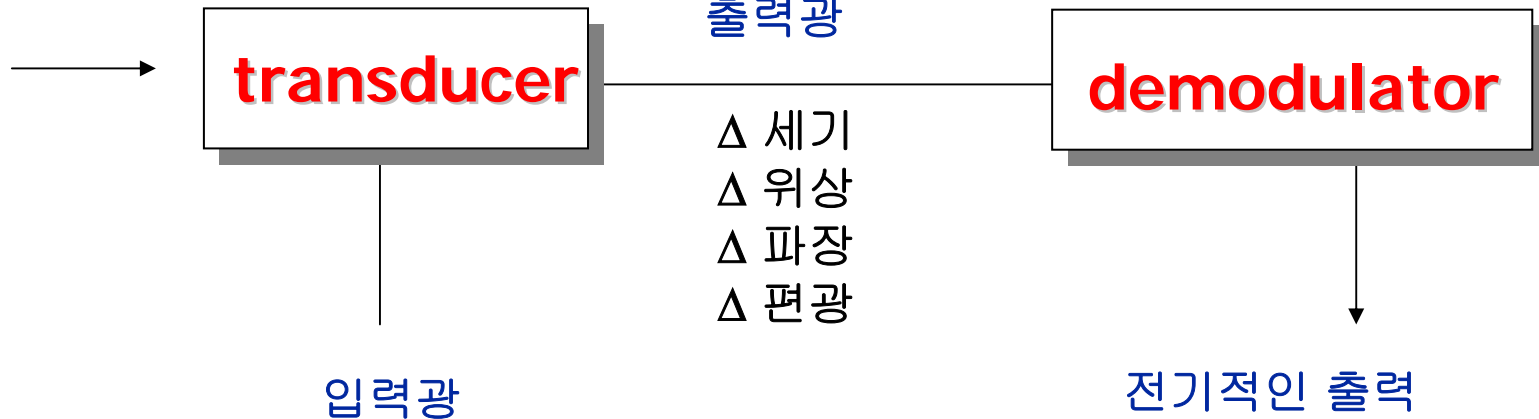
& many others.



광계측 메카니즘

물리량

- 변위
- (가)속도
- 온도
- 스트레인
- 압력
- 전류
- 전압
- ...



광센서 = **transducer(modulator) + demodulator**

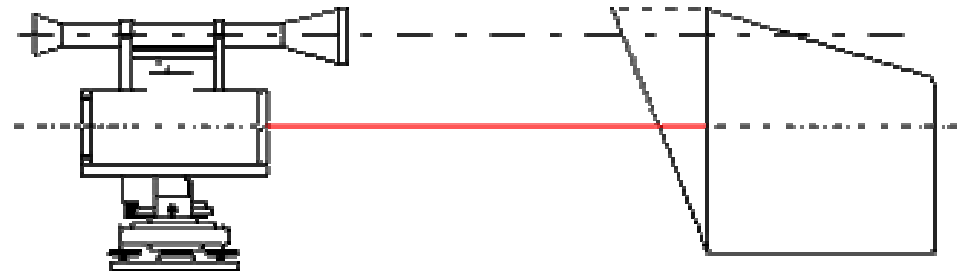
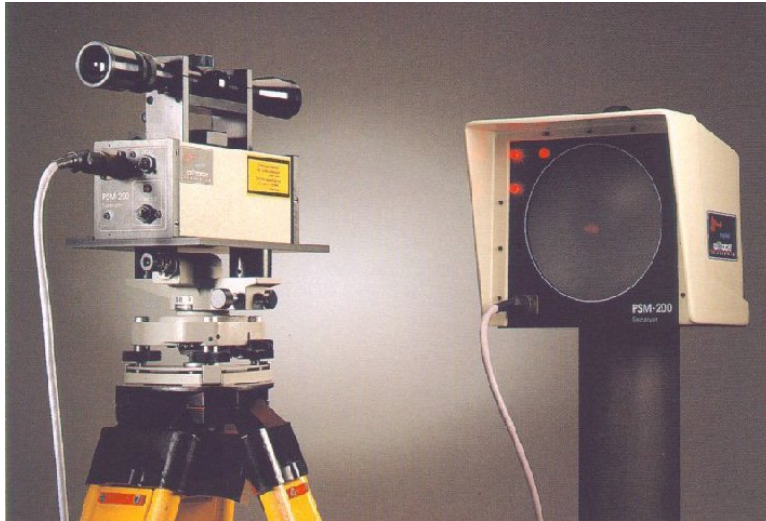


Transducer/Demodulator Combination

- 세기 → Photo Detection
 - 가시도, gas, 레벨 등
- 위상 → 간섭계(Interferometer)
 - 온도, 진동, 변위, 속도, 스트레인, 음파, 경보신호 등
- 파장 → 파장필터, Grating based 파장분석기
 - 온도, 스트레인, 압력 등
- 편광 → 편광분석기(polarization analyzer)
 - 전류, 전압, 광통신소자의 편광의존 특성 등



레이저의 직진성을 이용한 변위 센서

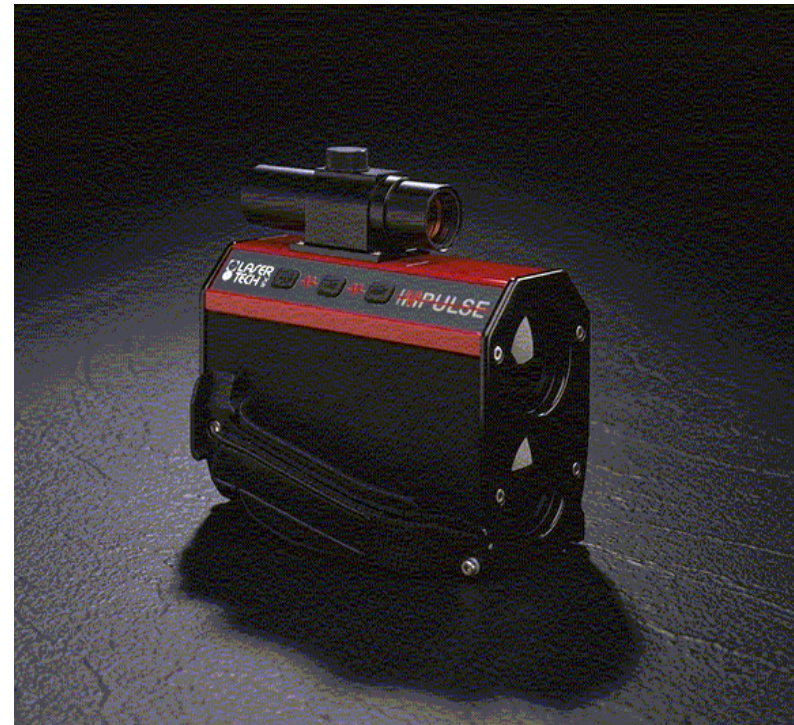


- 교량, 빌딩 등의 변형도, 진동, 구부러짐 측정
- 구조물의 정렬
- 목표물의 변위 측정

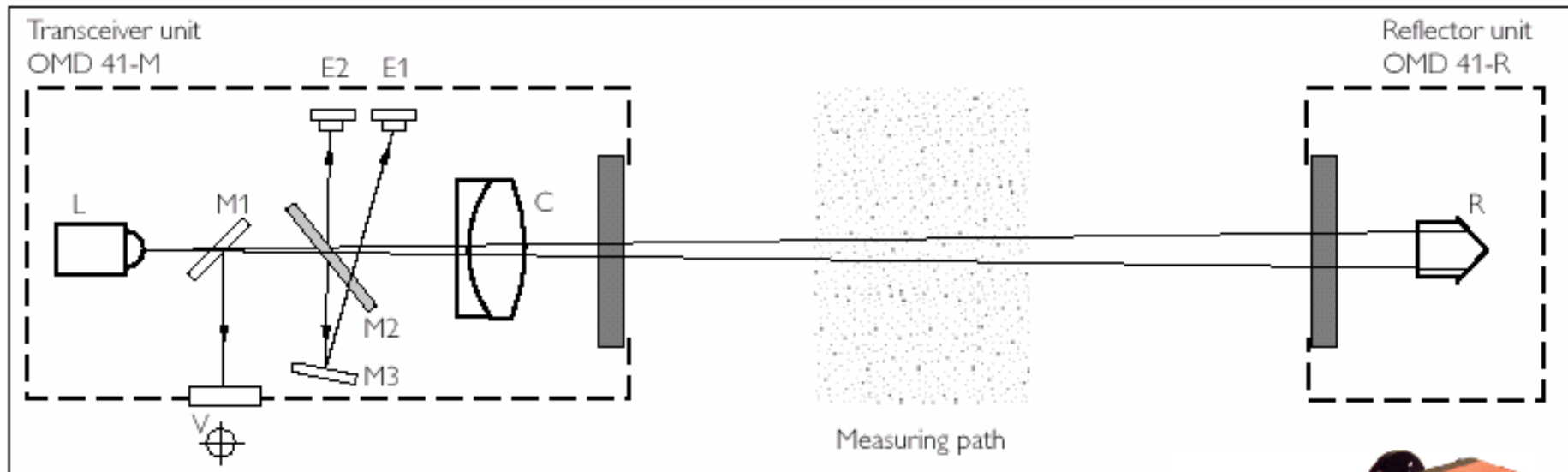


펄스 레이저를 이용한 거리 센서

- 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

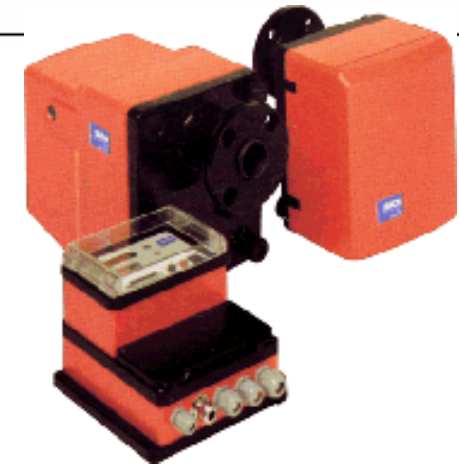


산란을 이용한 가시도의 측정

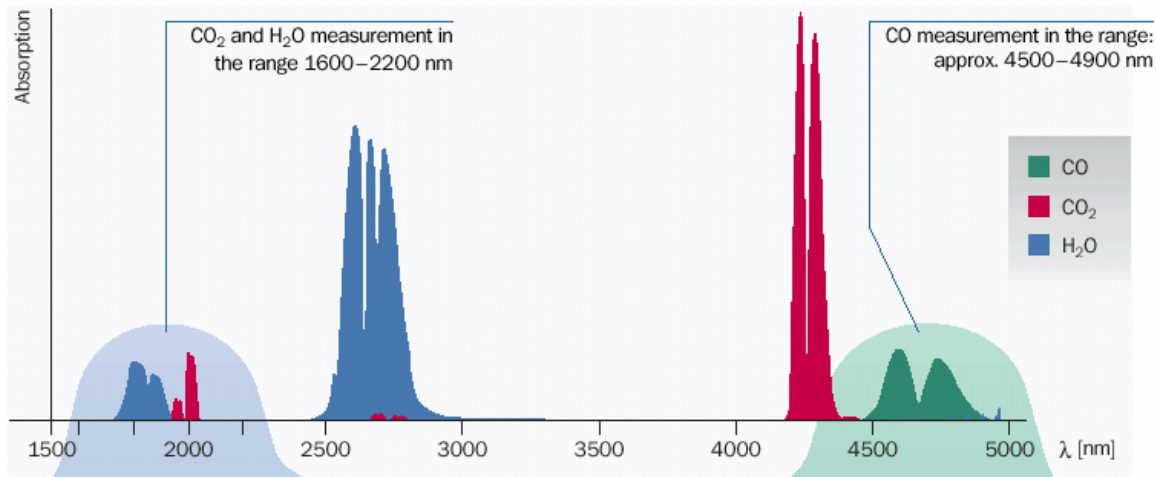
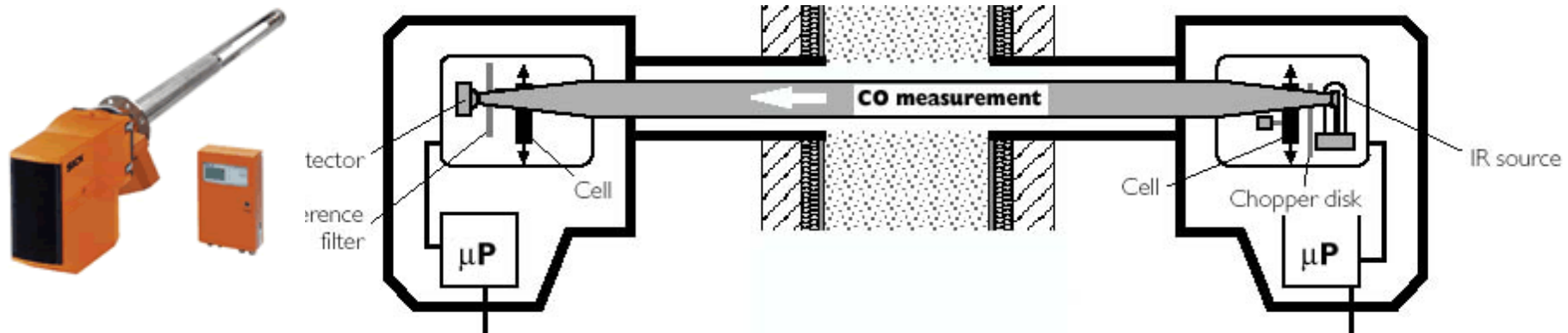


$$I_{out} = I_{in} \cdot e^{-ckx}$$

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



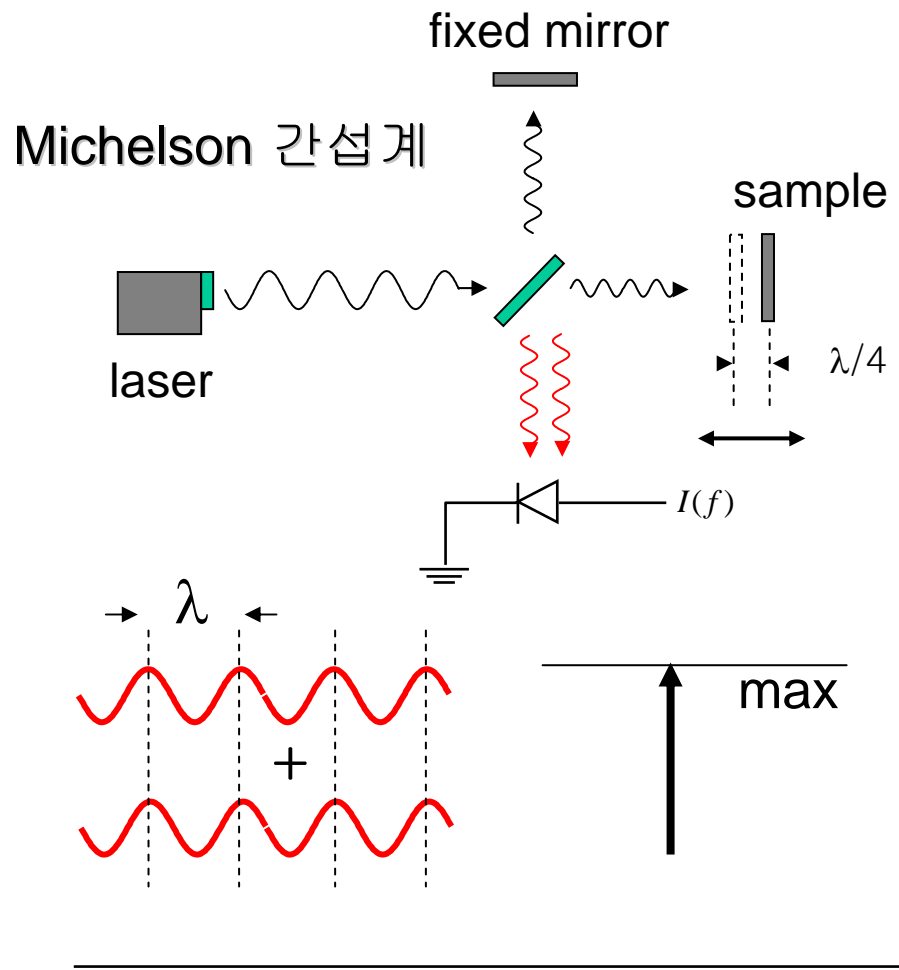
흡수를 이용한 Gas의 측정



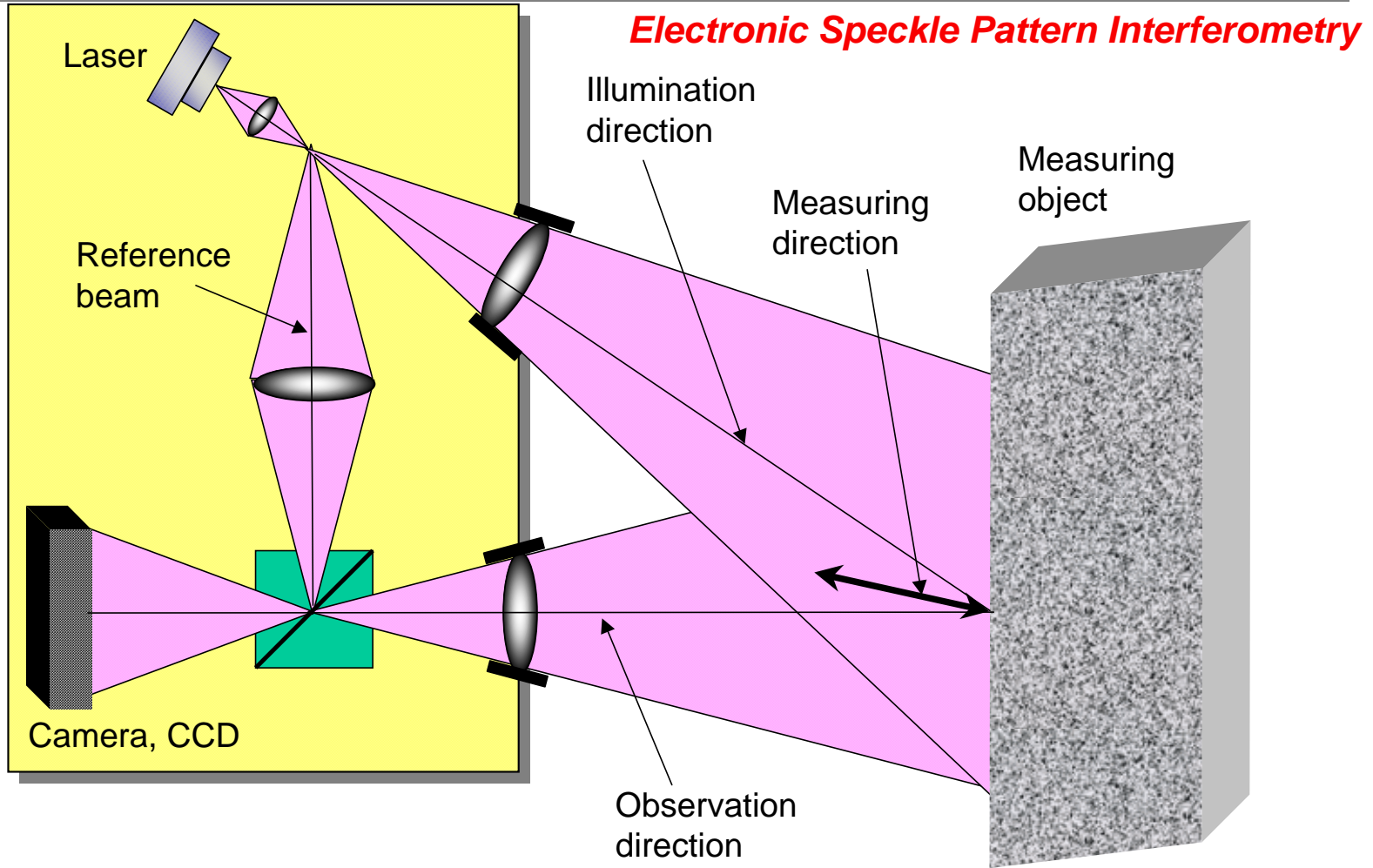
Gas duct monitoring
Emission monitoring
Process controlling



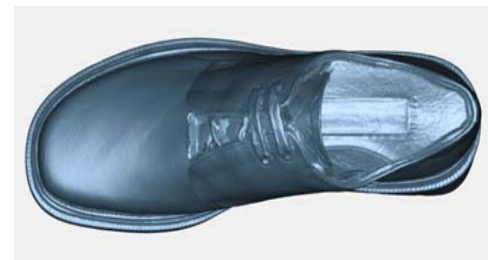
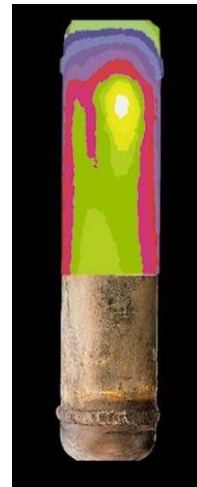
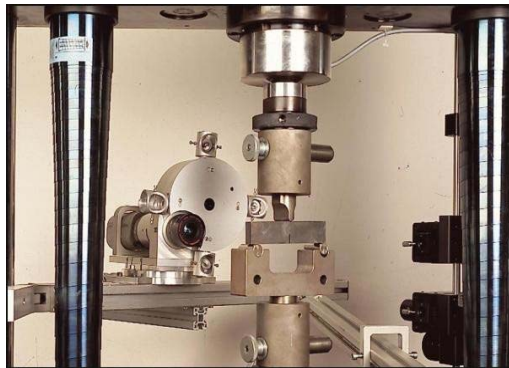
간섭계를 이용한 진동 해석



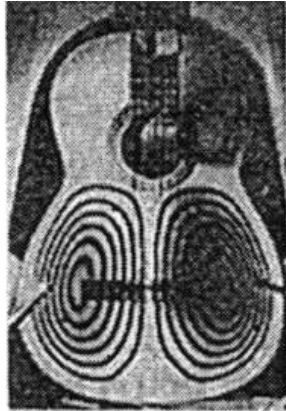
ESPI



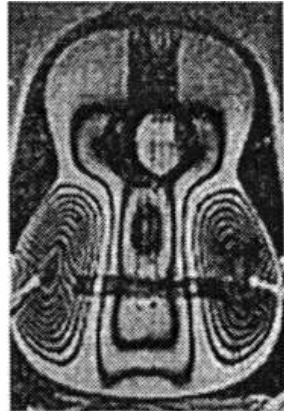
간섭 패턴을 통한 3차원 형상 및 진동의 측정 (ESPI, Shearography 등)



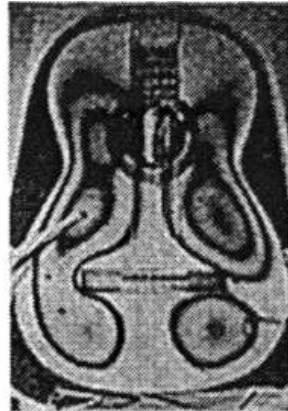
진동 모드 측정의 예



268 Hz (Q=52)



553 Hz (Q=66)



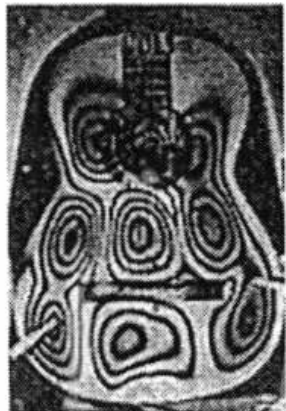
628 Hz (Q=83)



672 Hz (Q=61)



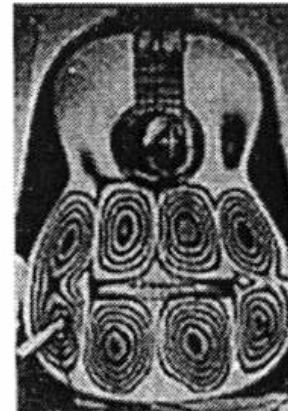
731 Hz (Q=72)



873 Hz (Q=75)



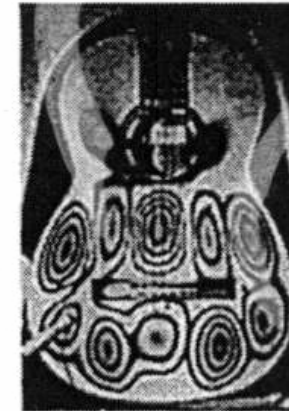
980 Hz (Q=48)



1010 Hz (Q=80)



1174 Hz (Q=58)

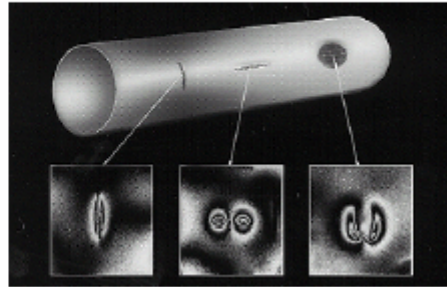


1194 Hz (Q=39)



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 – $0.1 \mu\text{m}$ (3.9×10^{-6} in.)
- Sensitivity – $0.05 \mu\text{m}$ (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

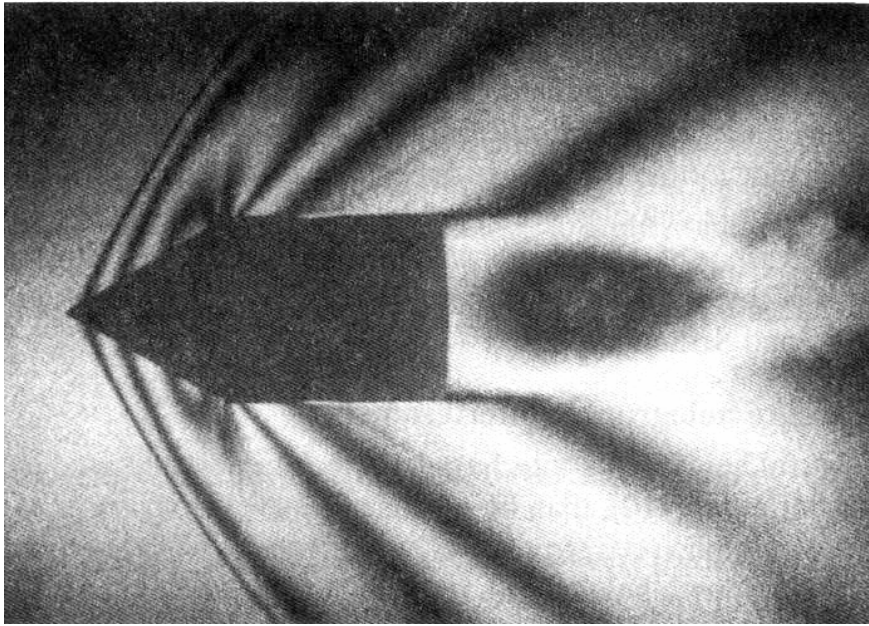
*Specifications may be enhanced or modified for specific setup options and custom requirements.



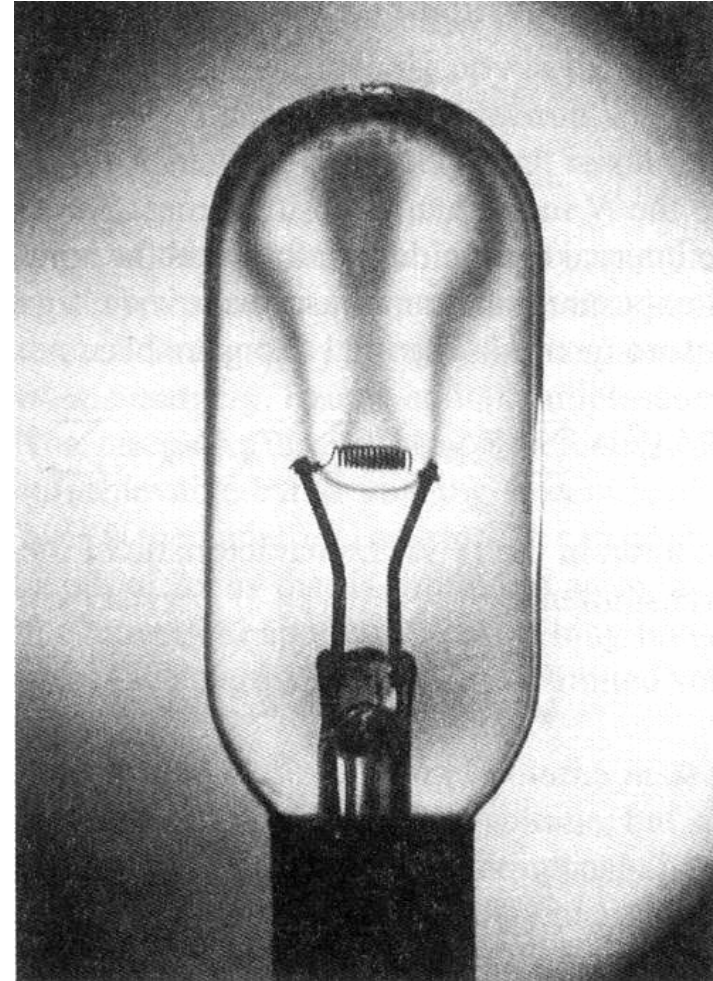
Interferometry



Double-Exposure Holographic Interferometry



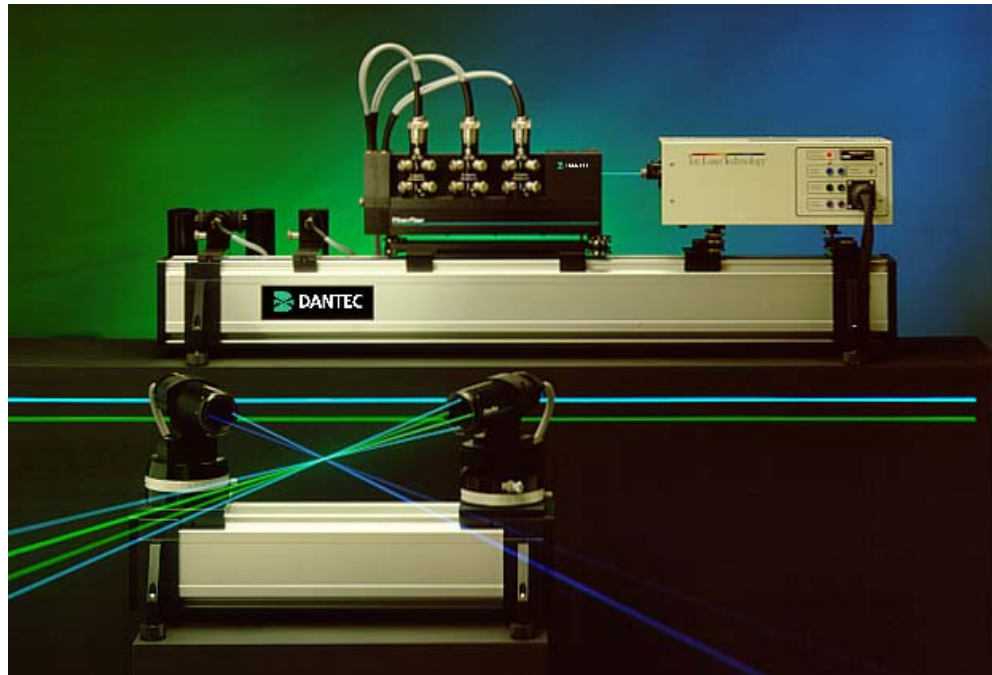
(a)



(b)



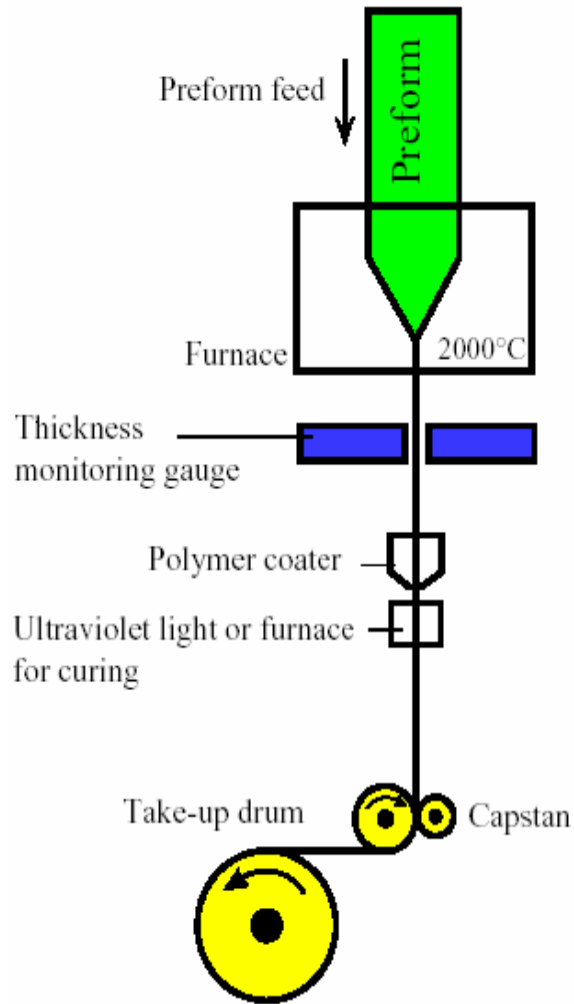
레이저 도플러 유속계



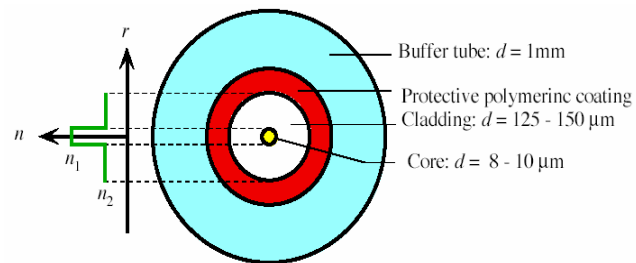
- 비접촉식 3차원 측정
- 난류유동의 해석
- 공기역학적 응용
- 표면 속도, 진동 측정



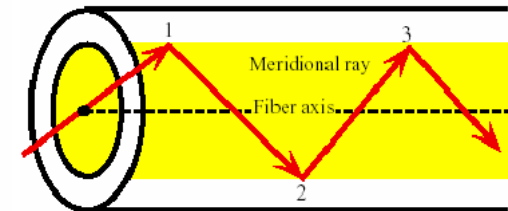
광섬유 (Optical Fiber)



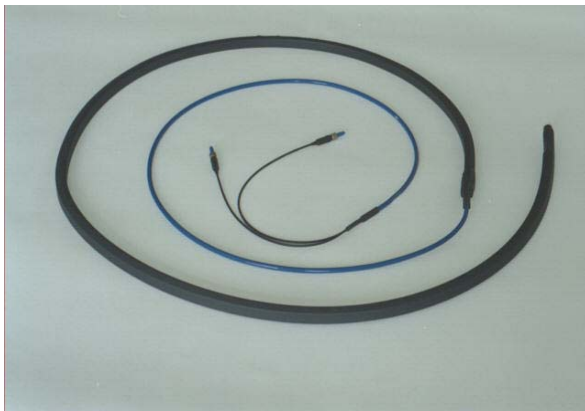
- 센서와 신호전달의 역할을 동시에 수행
- 분배형 센서의 실현이 용이
- 원격측정가능 (~ 0.2 dB/km loss)
- 기존 센서기술로 불가능한 부분을 커버



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

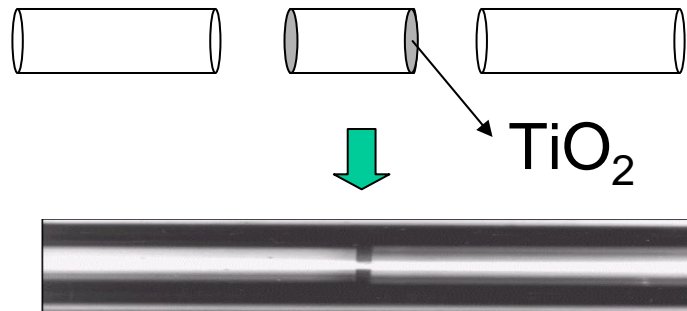


광섬유 센서

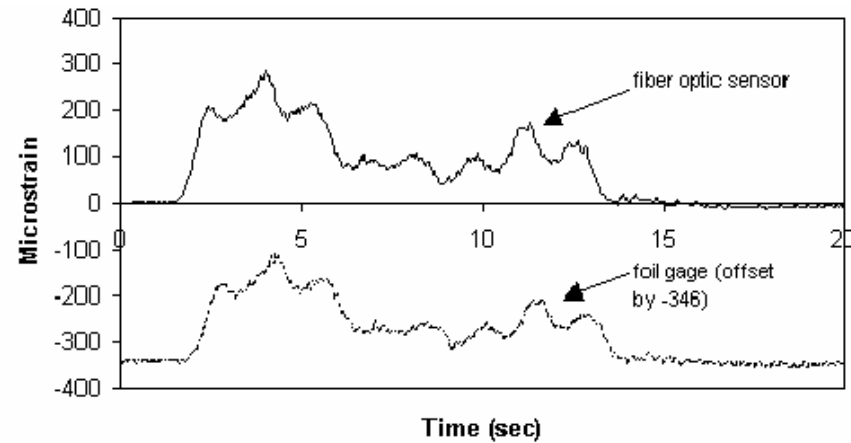
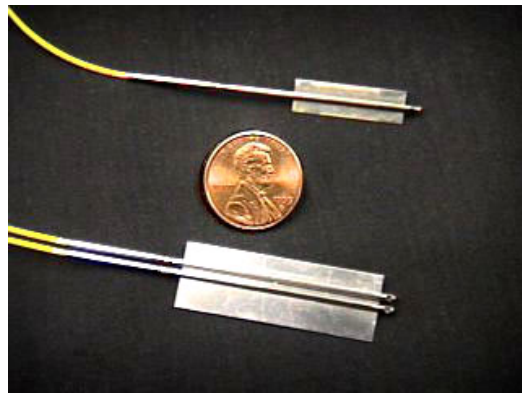
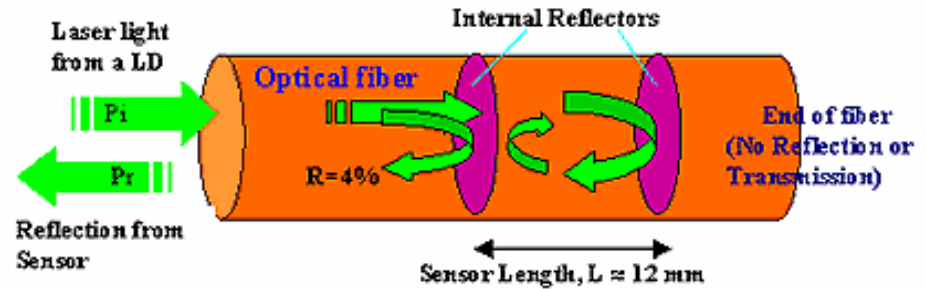


Fabry-Perot 간섭계 센서

In-line FP sensor

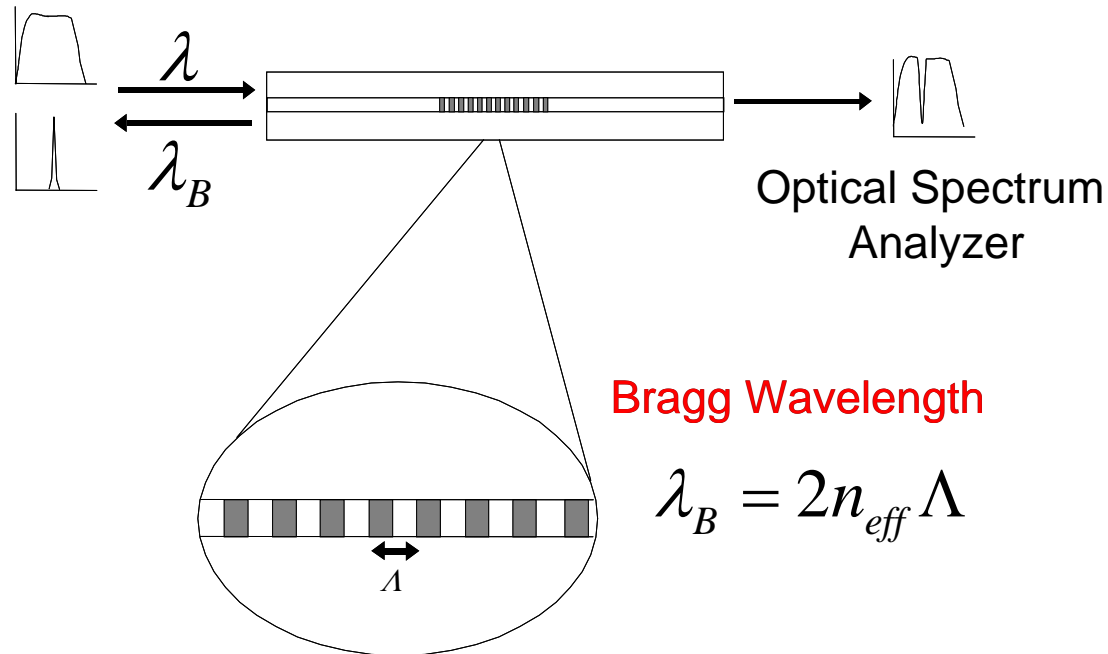


$$\Delta\phi = \frac{4\pi\Delta(nL)}{\lambda}$$



광섬유 격자 (fiber Bragg grating) 센서

Broadband source

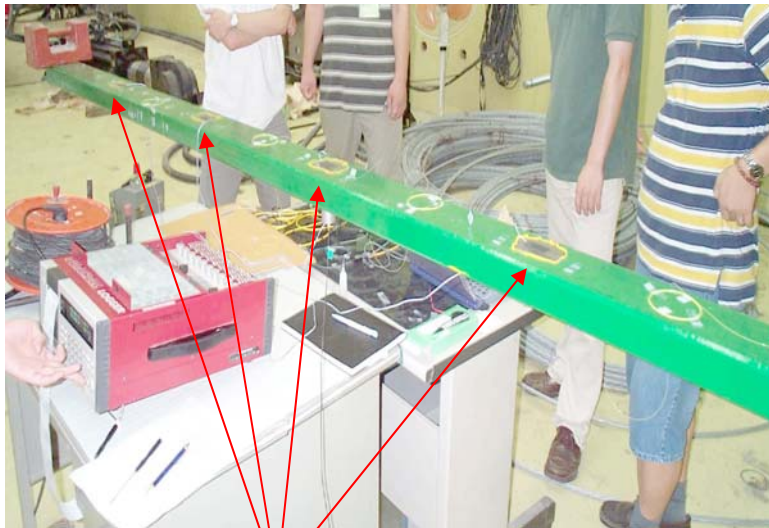


- 특정 파장만을 반사
- 반사파장의 변화로부터 물리량을 측정
- 측정점의 위치, 크기가 고정 → 준분포센서

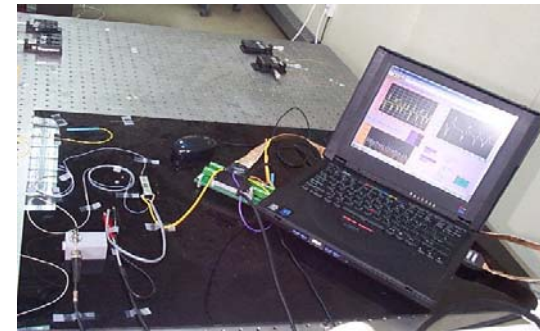


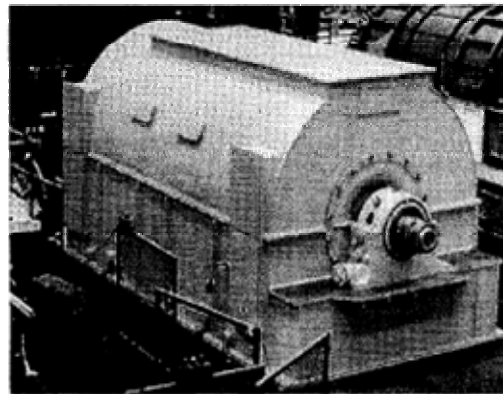
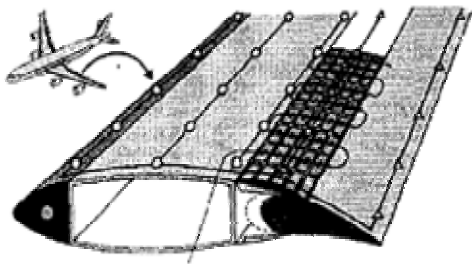
다중점 광섬유 격자 센서의 측정 예

Load measurement based on multiplexed FBG sensor system



FBGs

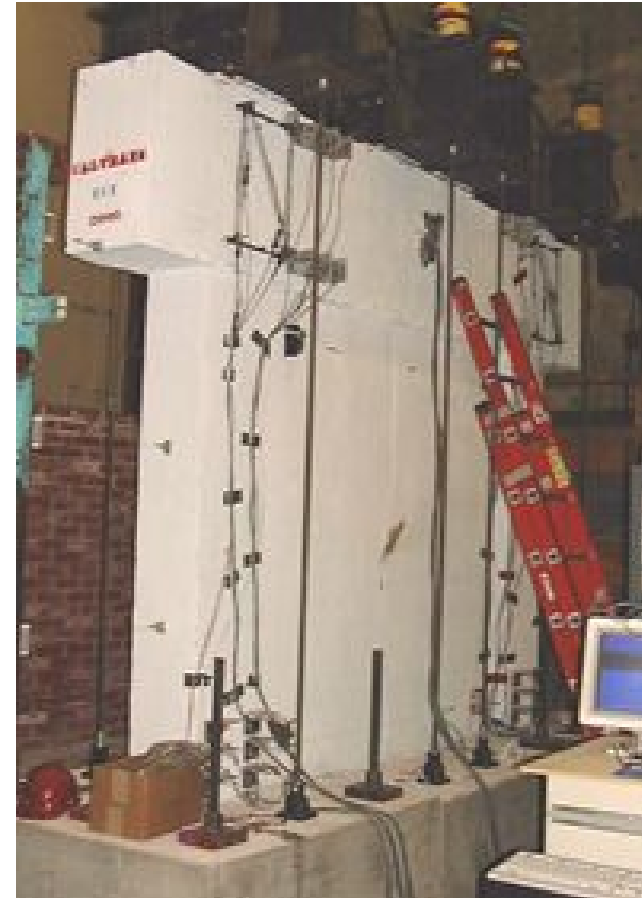
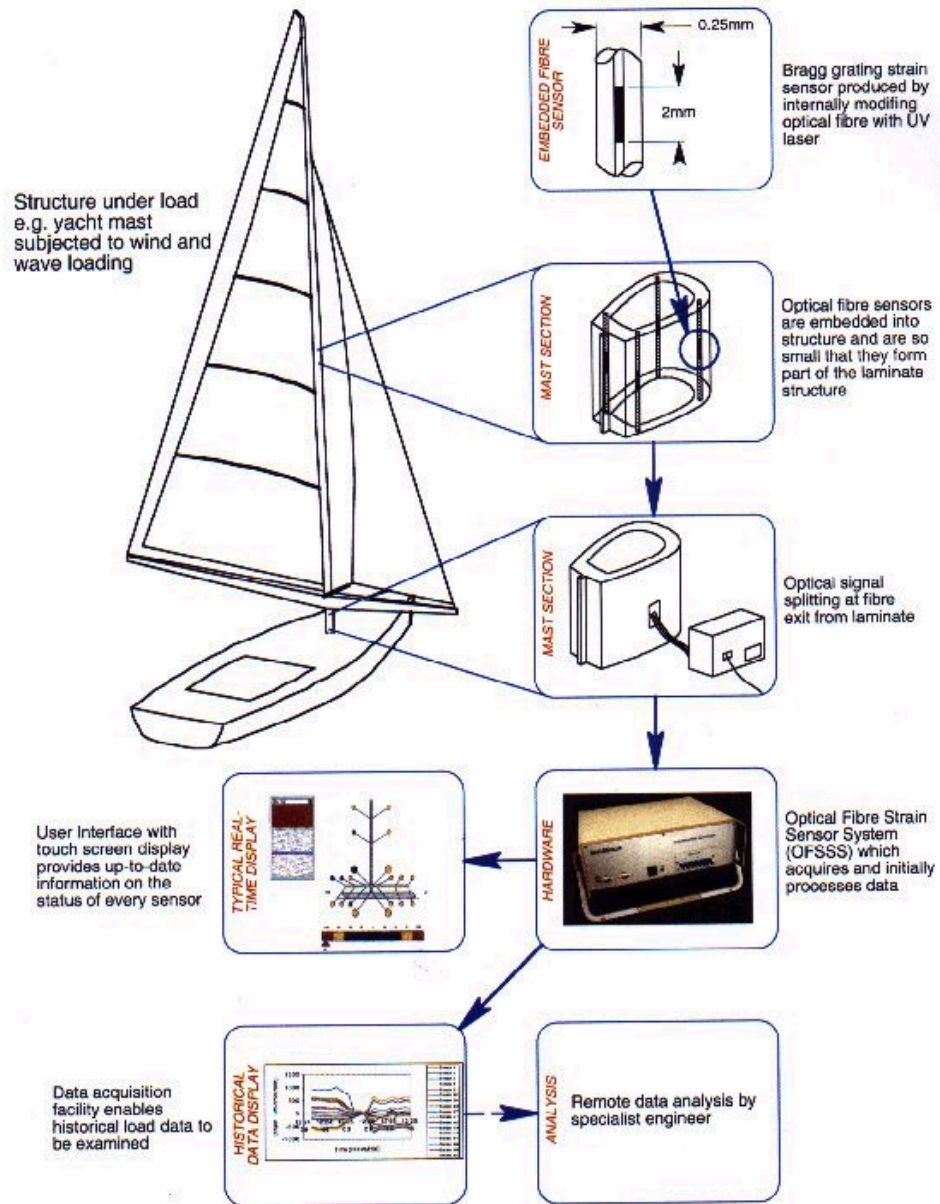




- Wavelength encoding
 - Noise에 매우 강함
 - 다중점 센서
- Intrinsic structure
 - Easily embedded
 - Easily locatable
- Cost-effective



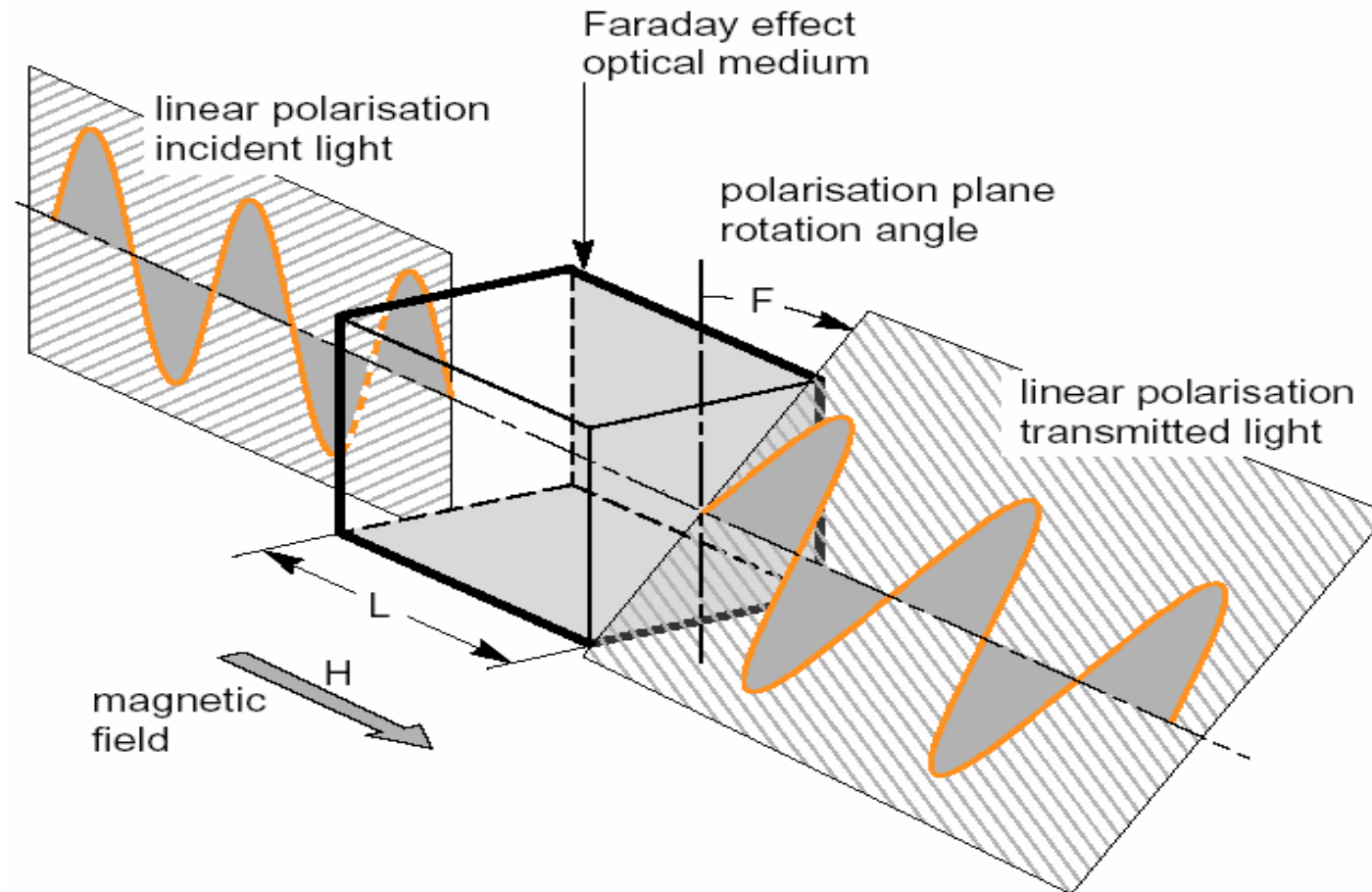
LOAD MEASUREMENT USING OPTICAL FIBRE SENSORS



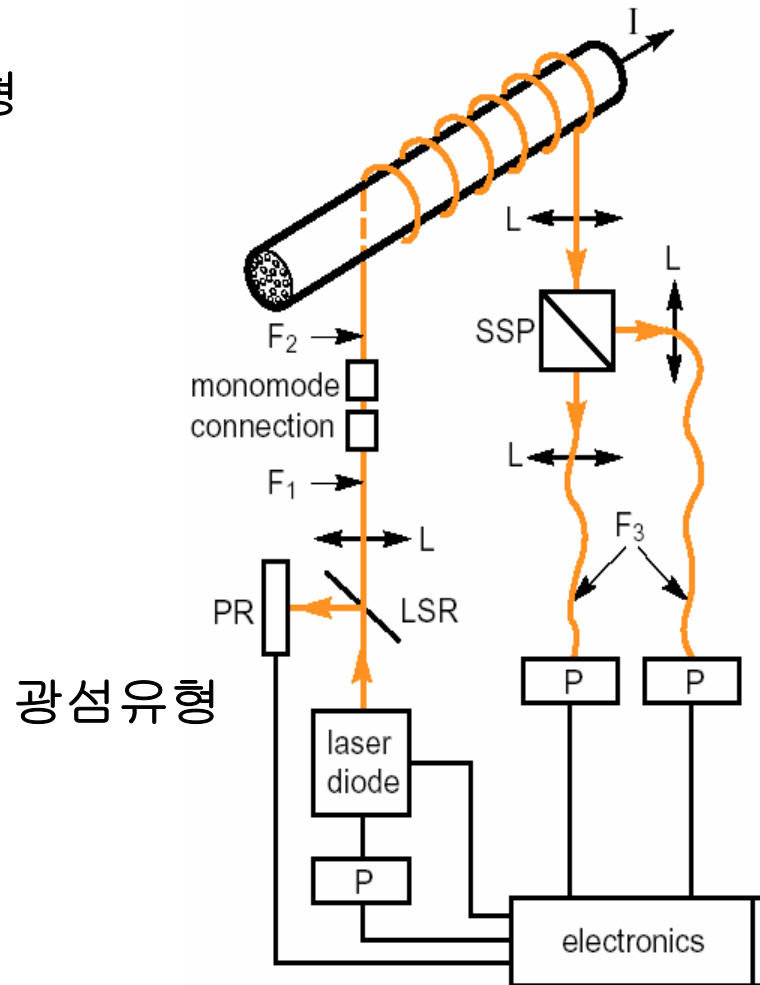
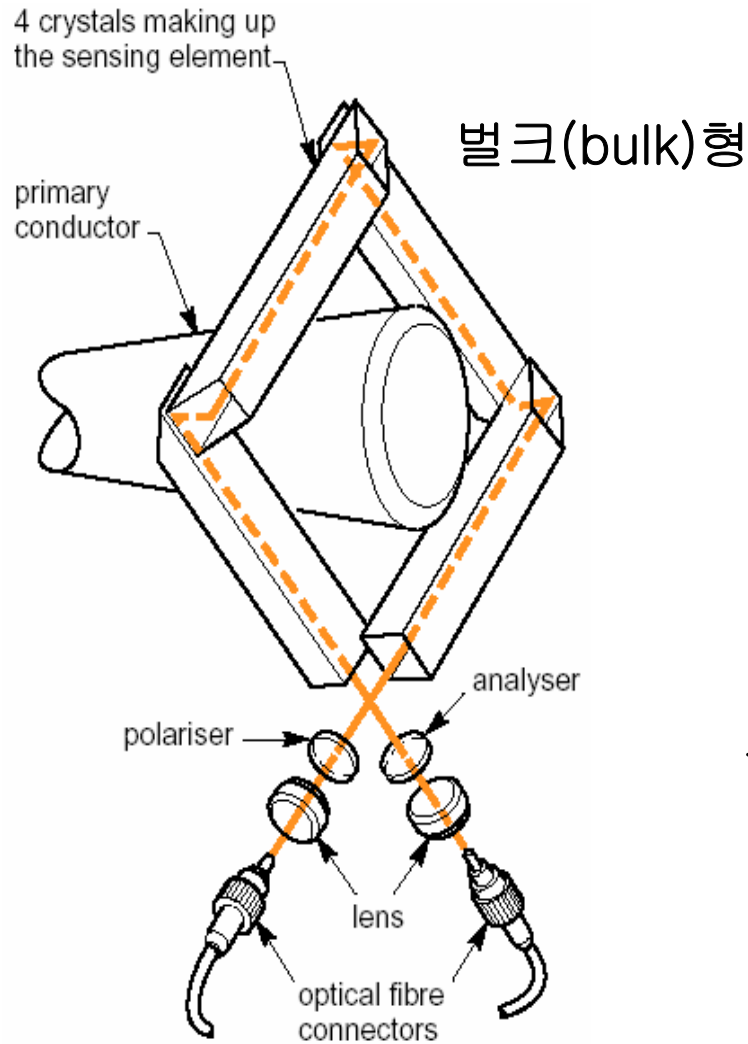
광섬유 센서 설치 작업



편광 변화를 이용한 전류의 측정



광 CT의 종류

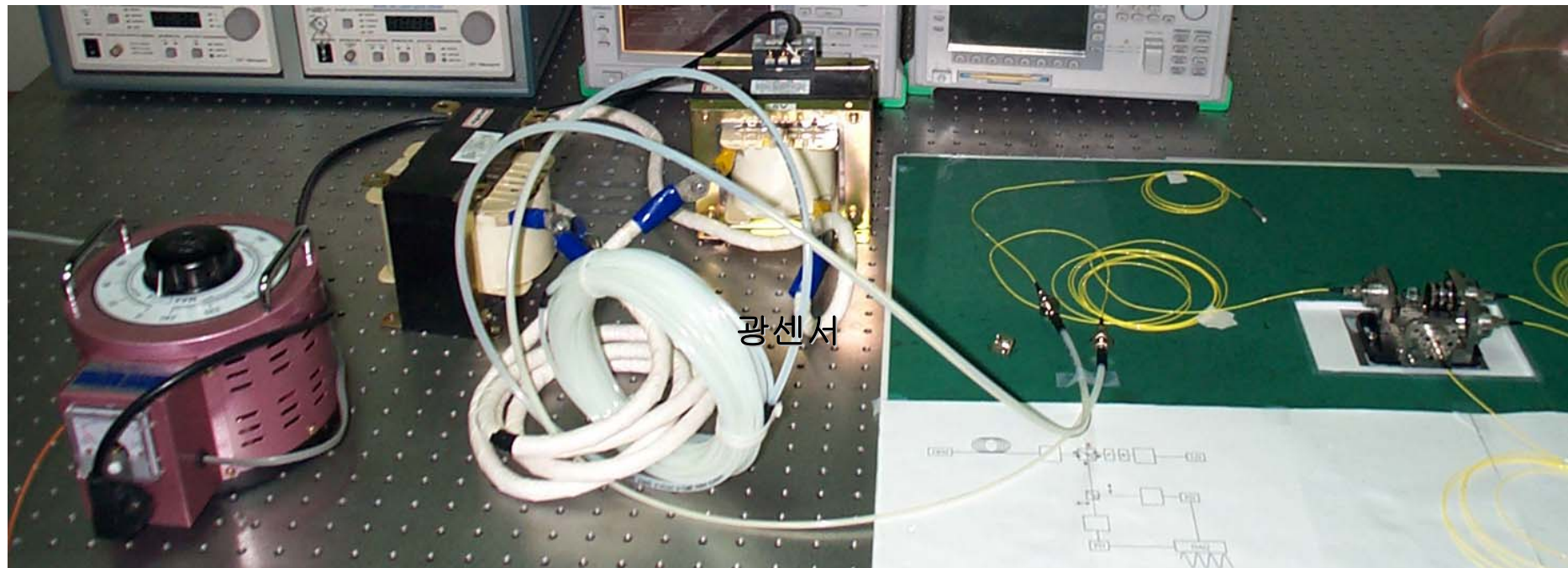


광 CT의 장점

- 전력계통으로부터 전자기적으로 완전히 분리
 - 시스템 해석이 쉬움 (여자전류, 철손, 잔류자속, 2차부담,...X)
 - 2차 개방에 의한 파손 및 안전성 문제가 없음
- 1차 전류 정보의 실시간 파악이 가능
 - 자기포화 (磁氣飽和) 없음 → 신호처리 간단 및 비용 절감
 - 빠른 반응속도 ($\sim 10^{-9}$ sec)
 - 써지나 주변 전자기장에 의한 잡음 없음
- 환경 친화적 (SF6 gas, Oil 등 불필요)
- 절연비용 절감 및 소형화로 초고전압, 초고전류에서 낮은 비용으로 시스템 구축이 가능
- 넓은 전류 감지 영역



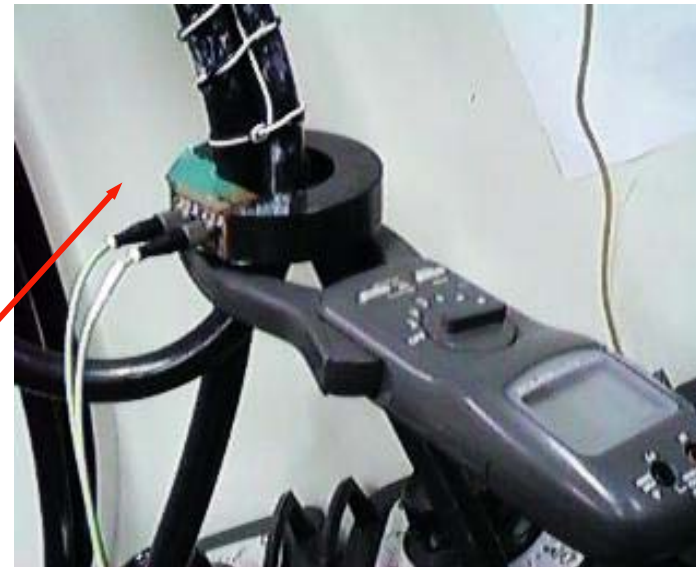
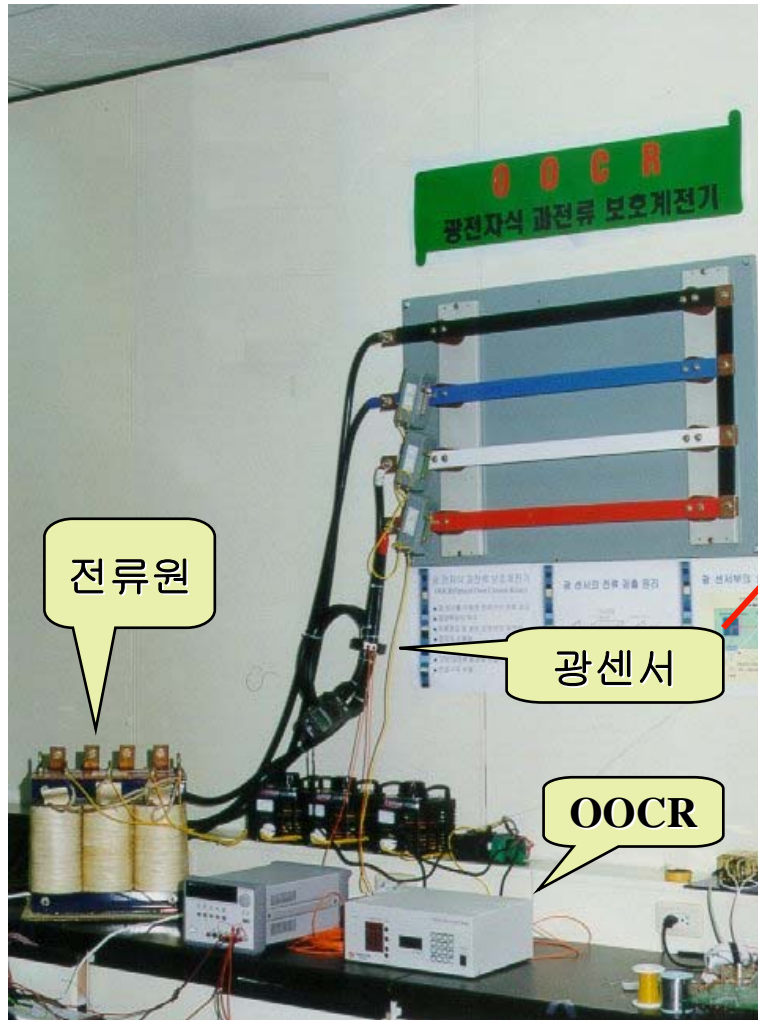
광 CT의 실험 Setup



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



광 CT를 이용한 과전류 보호계전기

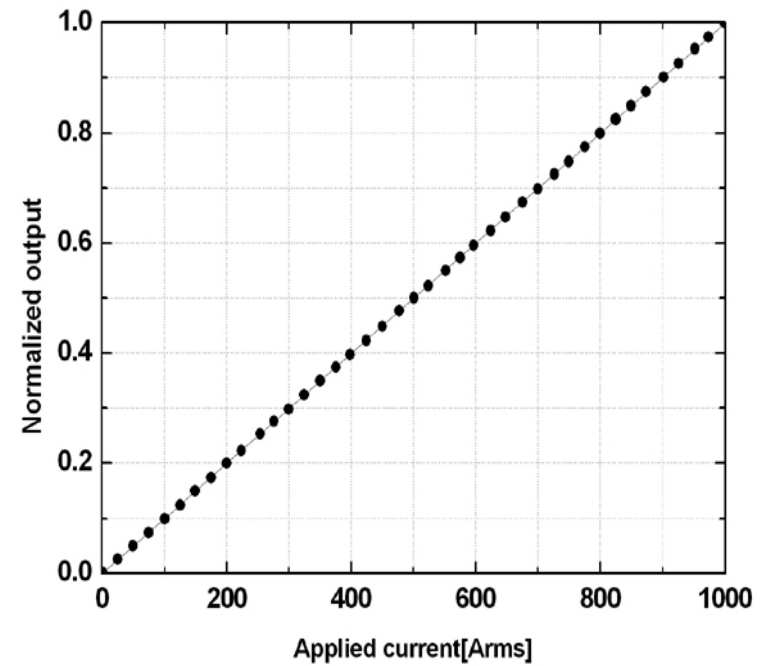
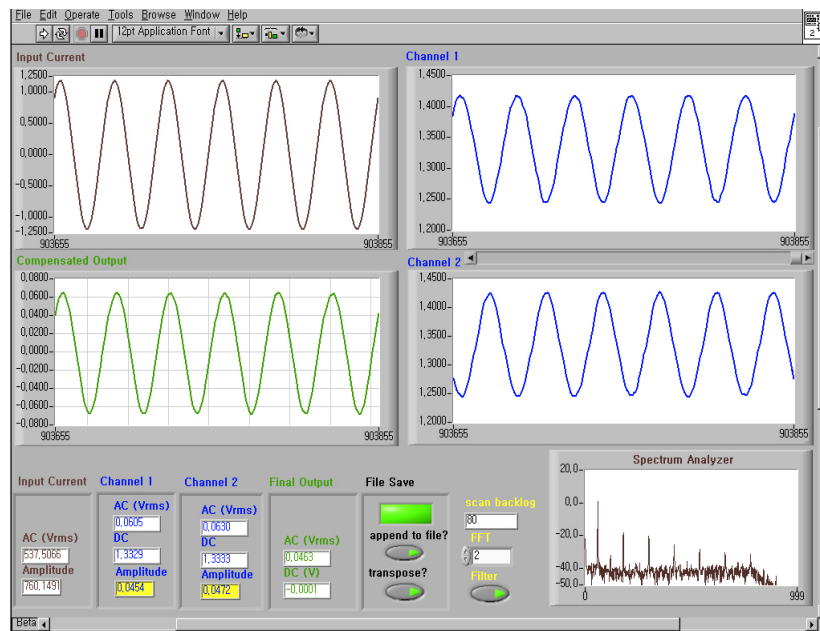
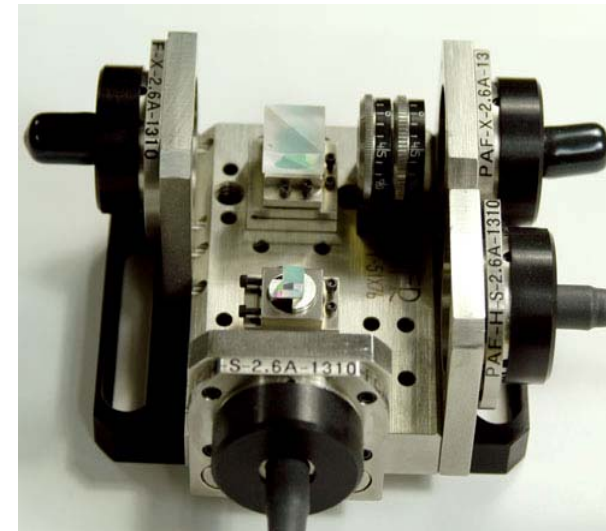


한국전력 전력연구원



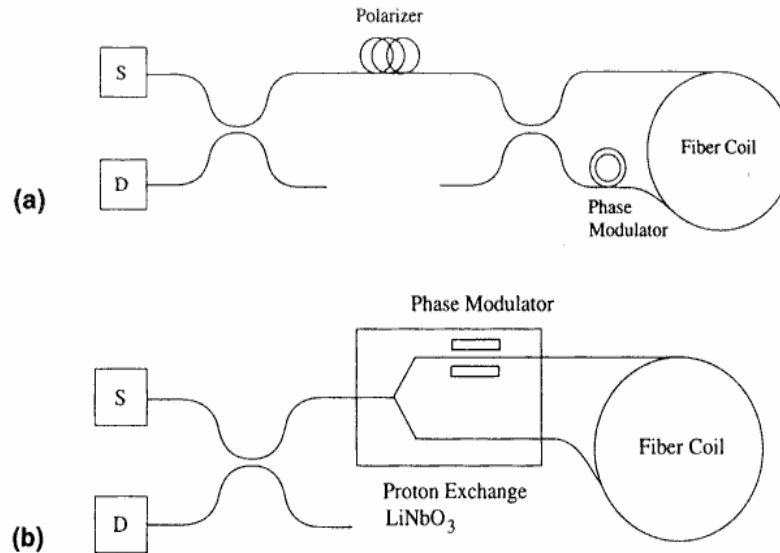
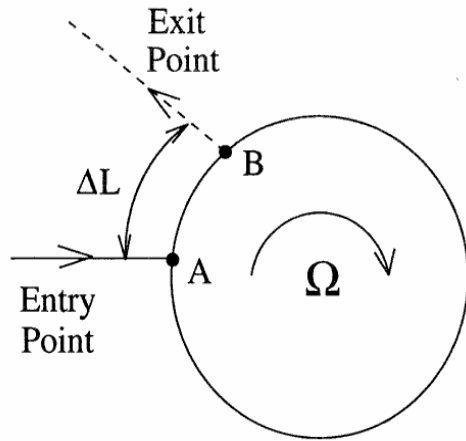
Seoul National University

NRL HoloTech





광을 이용한 자이로스코프 (Gyroscope)



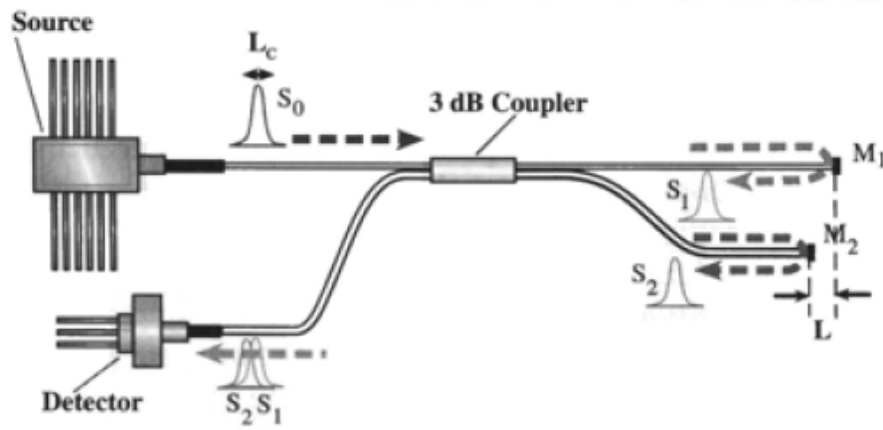
회전에 의한 위상차 발생 → 위상차의 측정

- 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

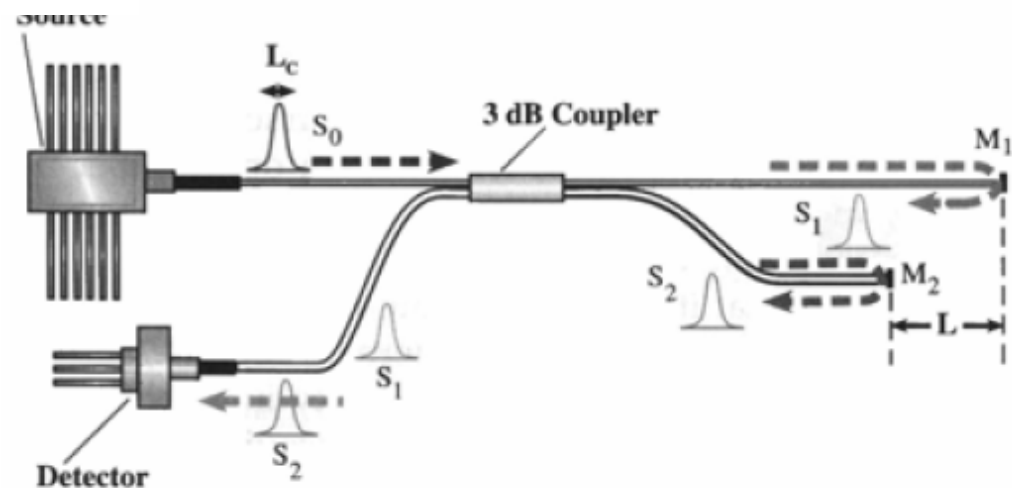


Low-Coherence Interferometer

Interference Arises when Twice Separation of Fiber End Mirrors, $2L$, $<$ Source Coherence Length, L_c

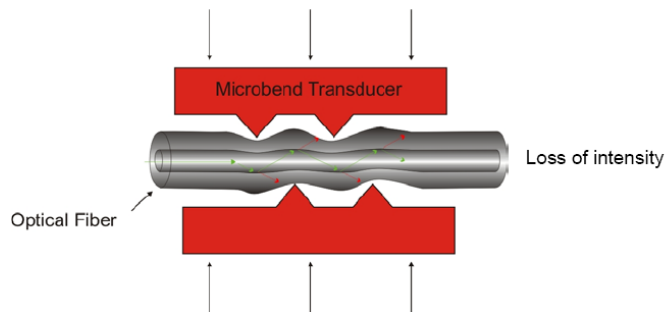


No Interference when Twice Separation of Fiber End Mirrors, $2L$, $>$ Source Coherence Length, L_c



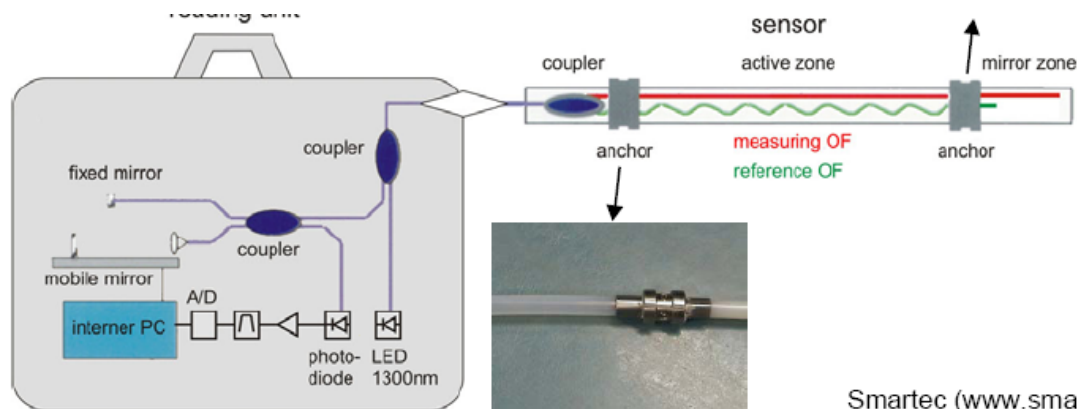
Low-Coherence Interferometer Applications

✓ Optical sensor for pressure and deformation



✓ Optical sensor for strain

– Resolution 2micron & Fiber length: 0.2 ~ 20m



Smartec (www.smartec.ch)

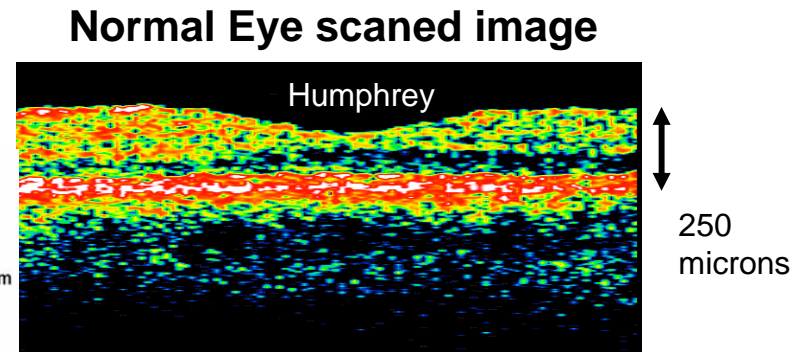
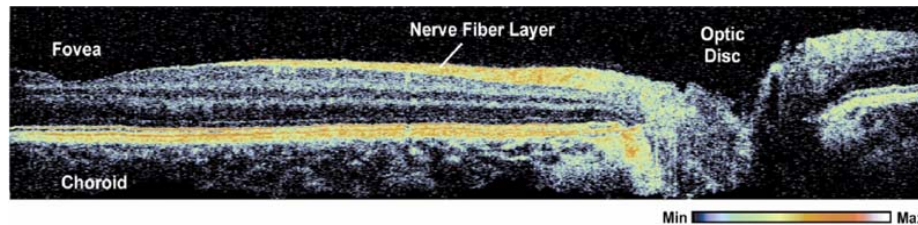
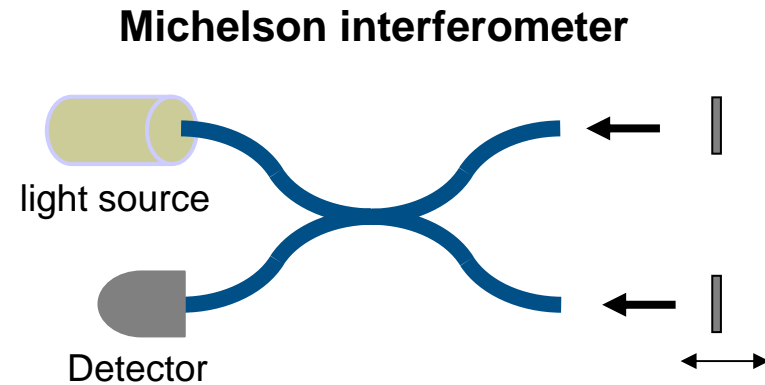
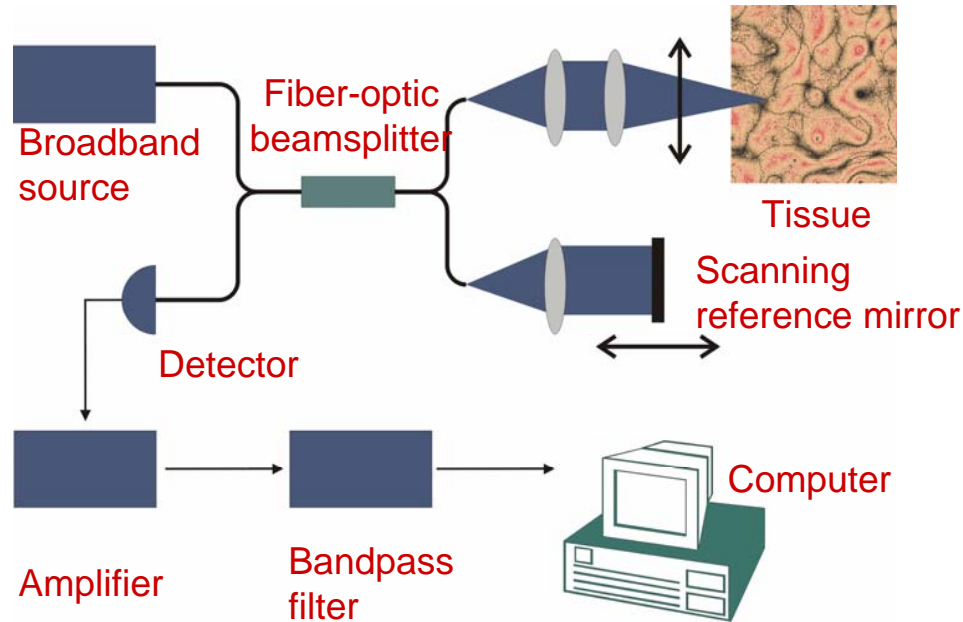


Seoul National University

NRL HoloTech

Optical Coherence Tomography

Experimental Set-up of OCT and Results



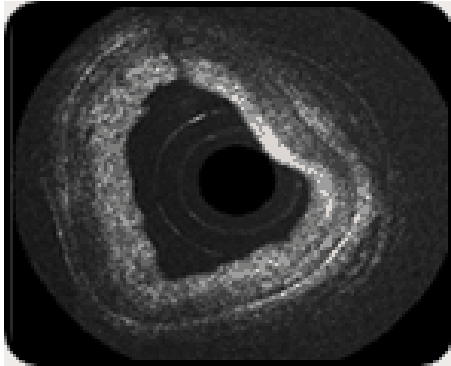
W. Drexler *et al.*, "Ultra-high-resolution ophthalmic optical coherence tomography", *Nature Medicine* **7**, 502-507 (2001)



OCT

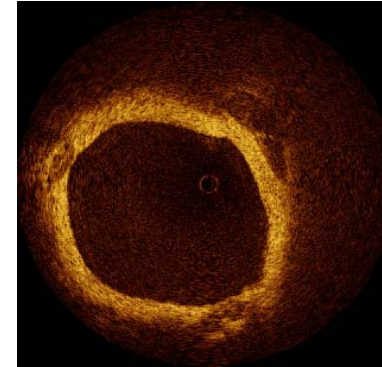
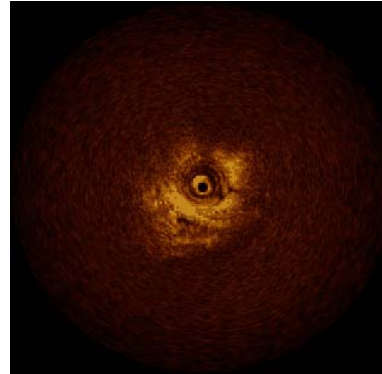
□ Some Examples of OCT

✓ Imaging inside Veins

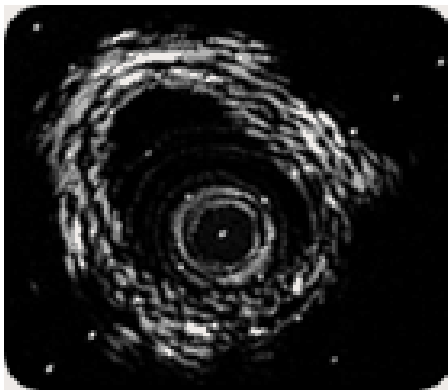


OCT

Real-time cardiology



In-vivo human anterior eye segments



Ultrasound

