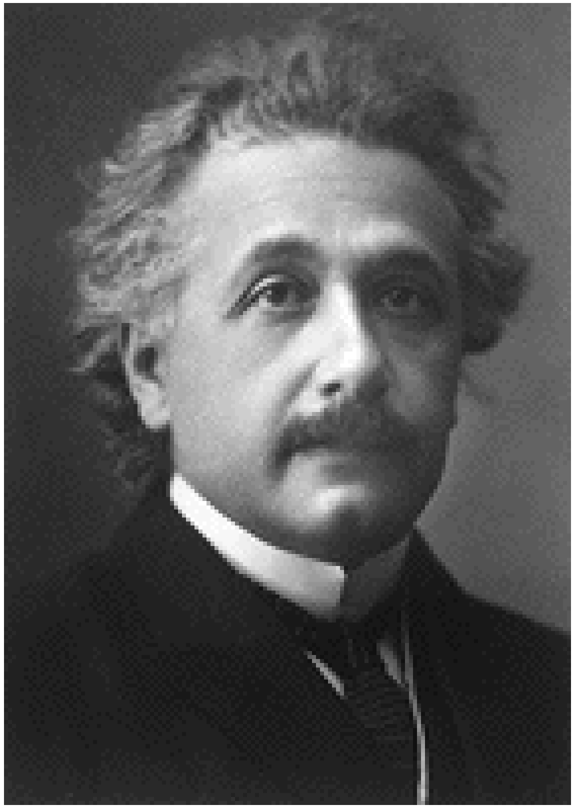
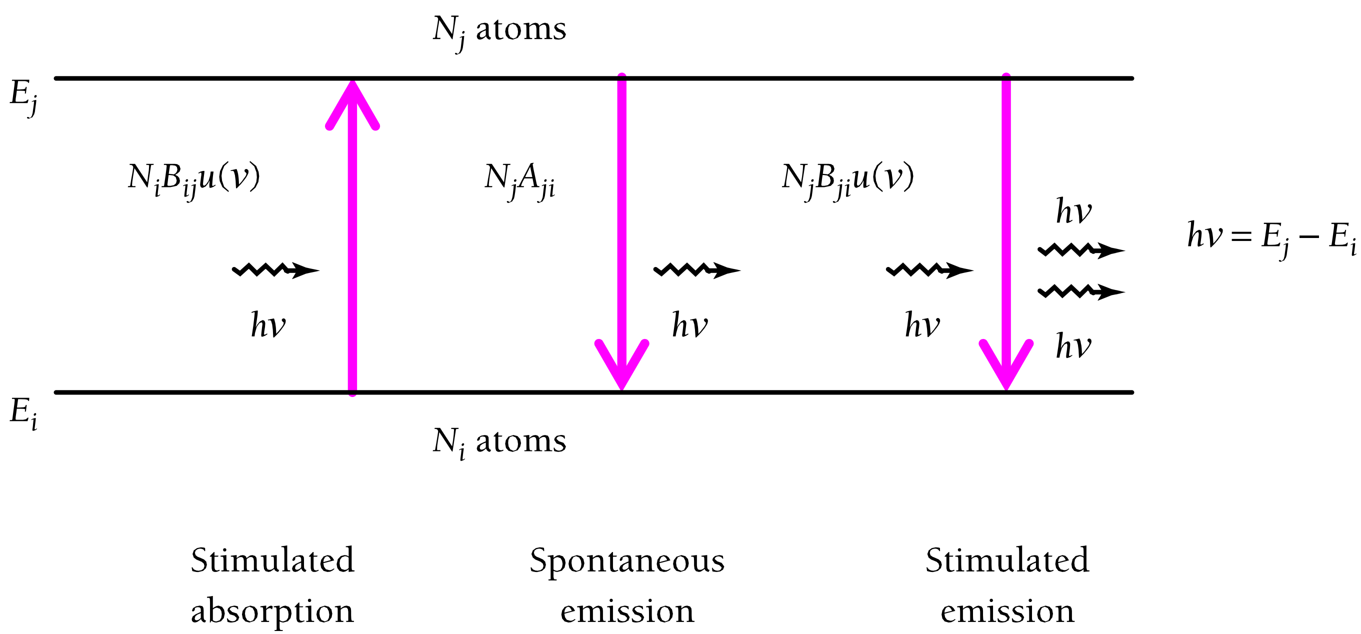
Einstein



Albert Einstein
(1879-1955)

"*Imagination is more important than knowledge.* For knowledge is limited to all we now know and understand, while imagination embraces the entire world, and all there ever will be to know and understand."

Stimulated Emission



At equilibrium

$$N_i B_{ij} u(\nu) = N_j \left[A_{ji} + B_{ji} u(\nu) \right]$$

Stimulated Emission

$$N_i B_{ij} u(\nu) = N_j \left[A_{ji} + B_{ji} u(\nu) \right]$$

$$u(\nu) = \frac{A_{ji} / B_{ji}}{\left(\frac{N_i}{N_j}\right)\left(\frac{B_{ij}}{B_{ji}}\right) - 1}$$

Boltzmann factors

$$\frac{N_i}{N_j} = e^{\left(E_j - E_i\right)/k_B T} = e^{h\nu / k_B T}$$

Planck's distribution

$$u(\nu) = \frac{8\pi h \nu^3 / c^3}{\left(\frac{B_{ij}}{B_{ji}}\right) e^{h\nu / k_B T} - 1}$$

Emission's *A*, *B* Coefficients

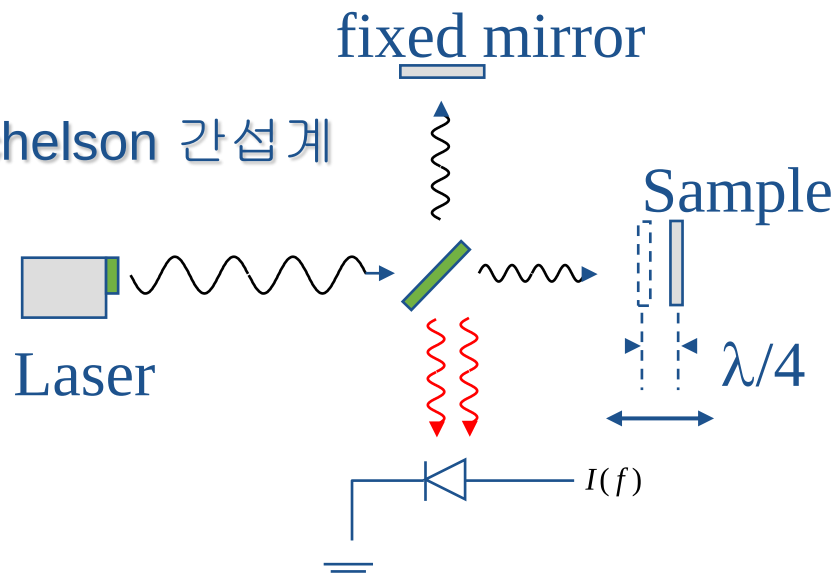
$$B_{ij} = B_{ji} \equiv B$$

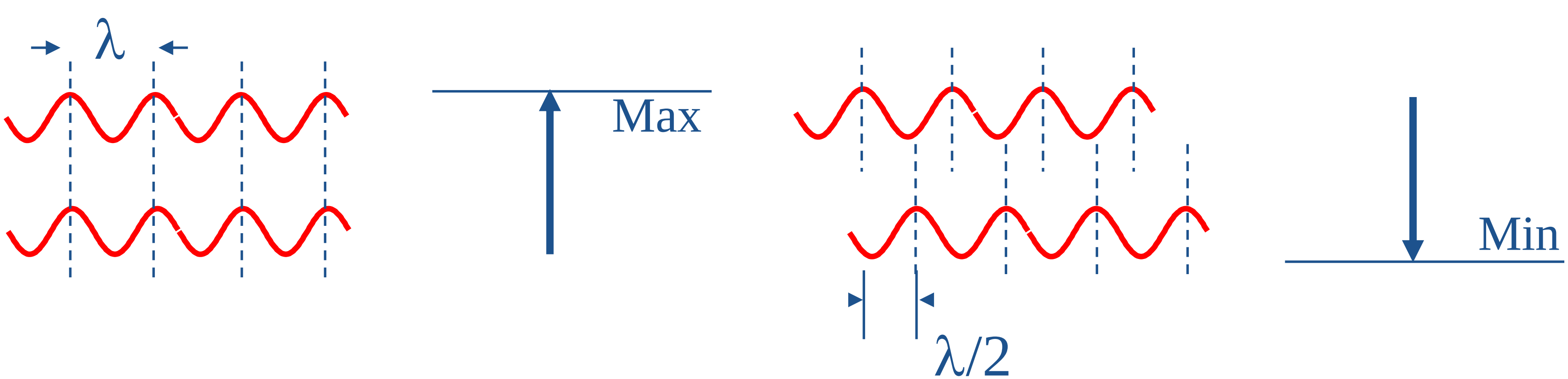
$$A \equiv A_{ji} = \frac{8\pi h\nu^3}{c^3} B_{ji}$$

Stimulated emission should exist!

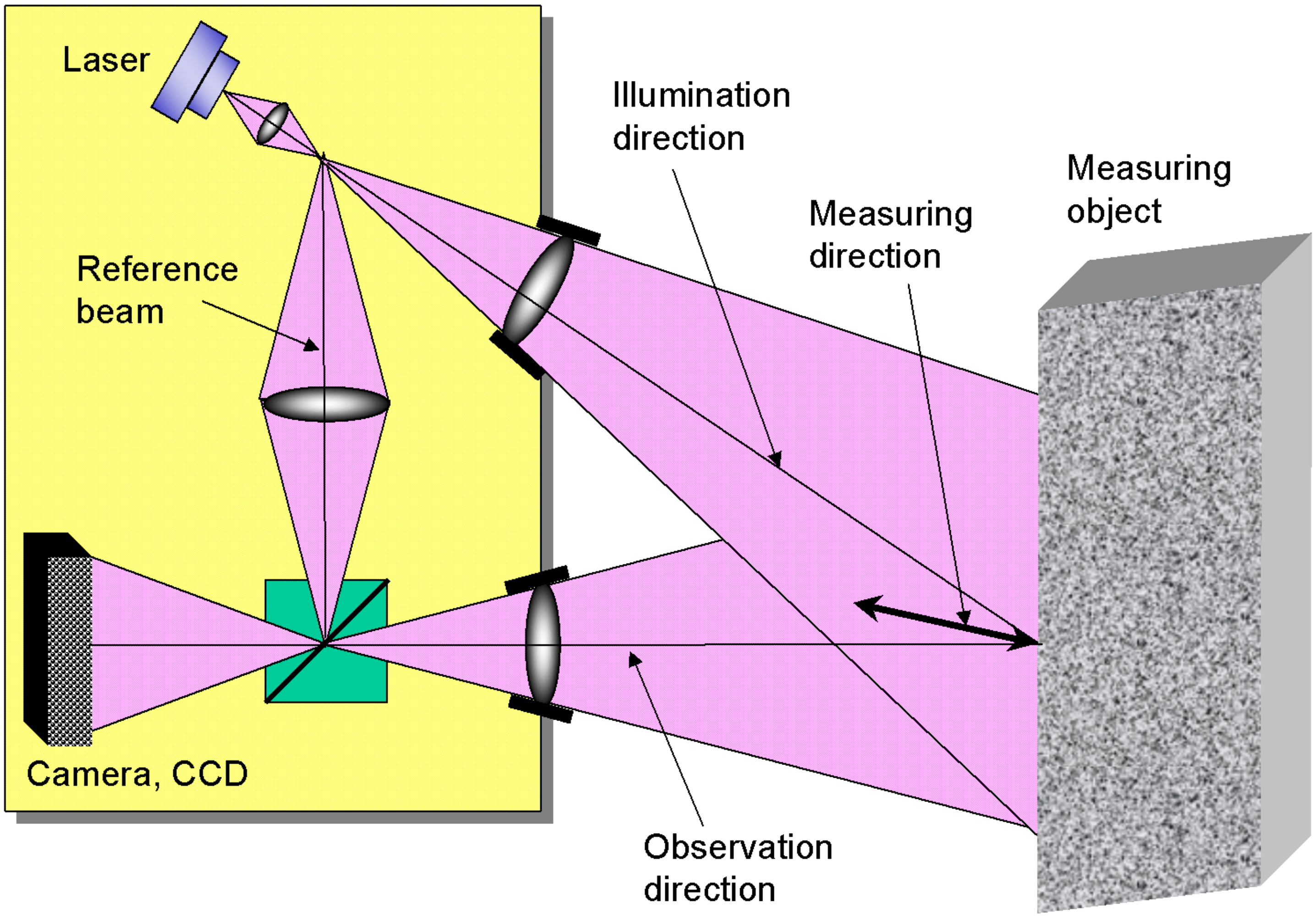
간섭계를 이용한 진동 해석

Michelson 간섭계

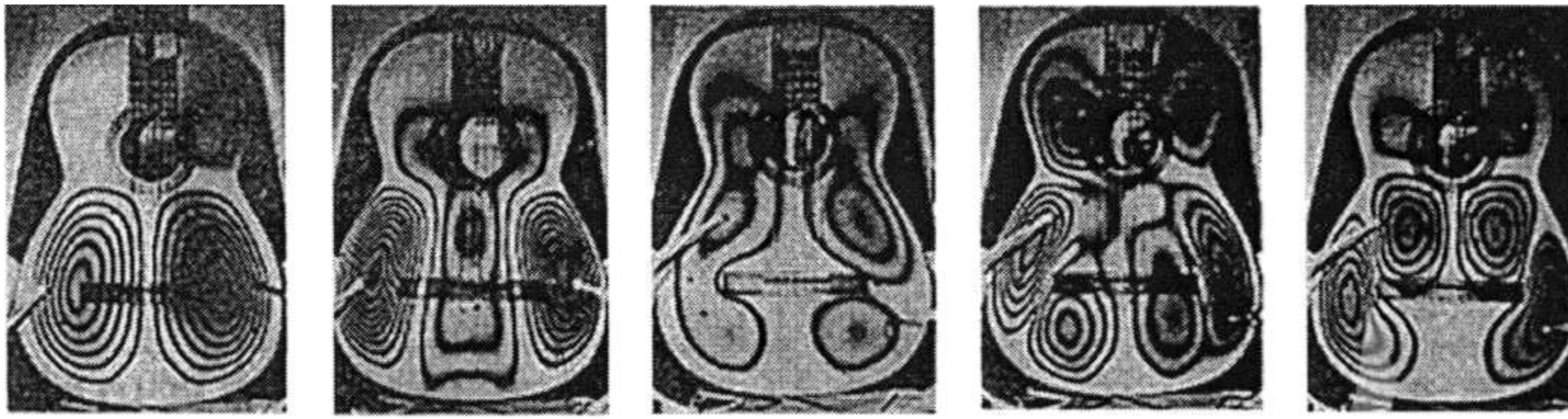




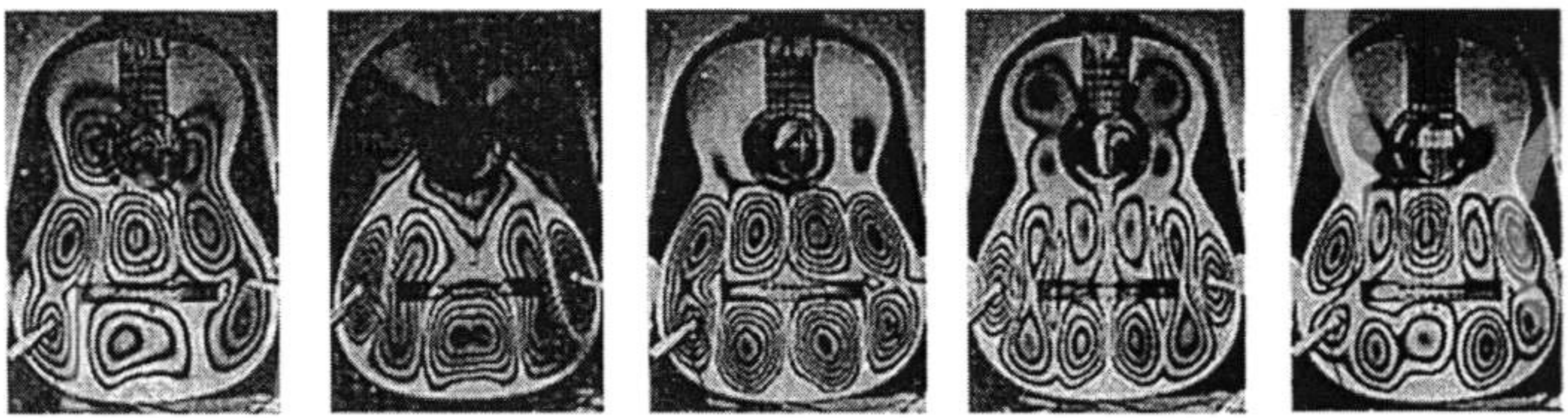
Electronic Speckle Pattern Interferometry



진동 모드 측정의 예

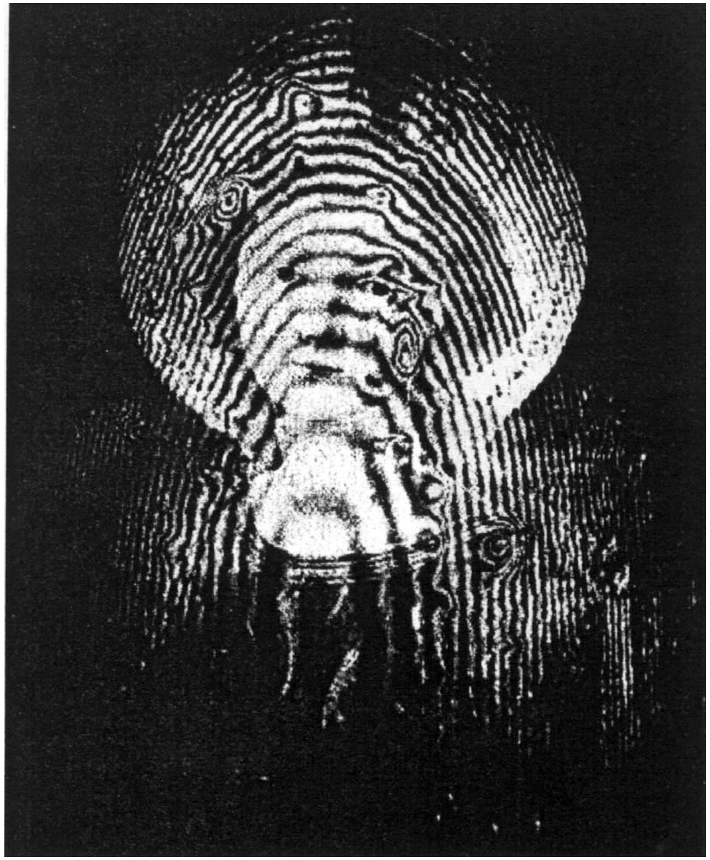


268 Hz (Q=52) | 553 Hz (Q=66) | 628 Hz (Q=83) | 672 Hz (Q=61) | 731 Hz (Q=72)

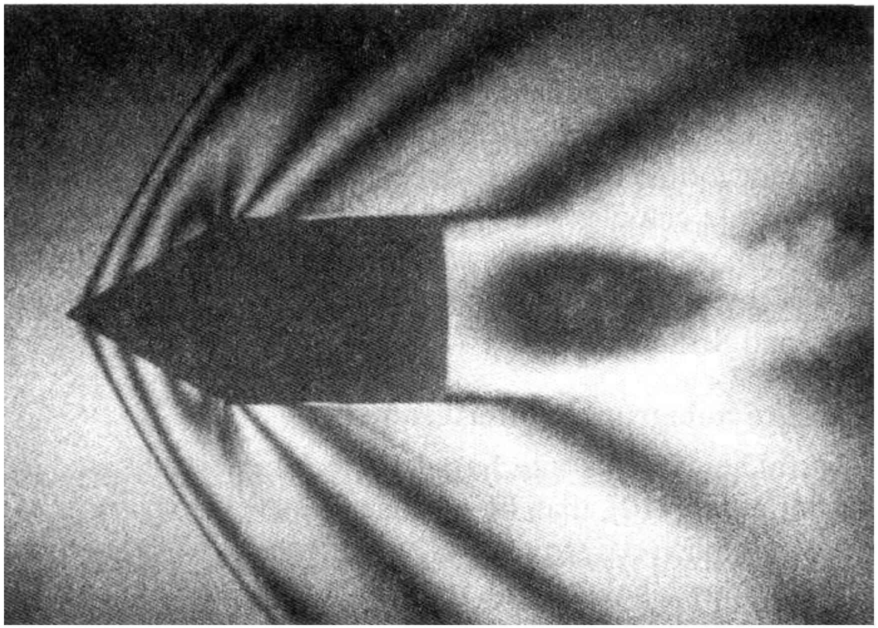


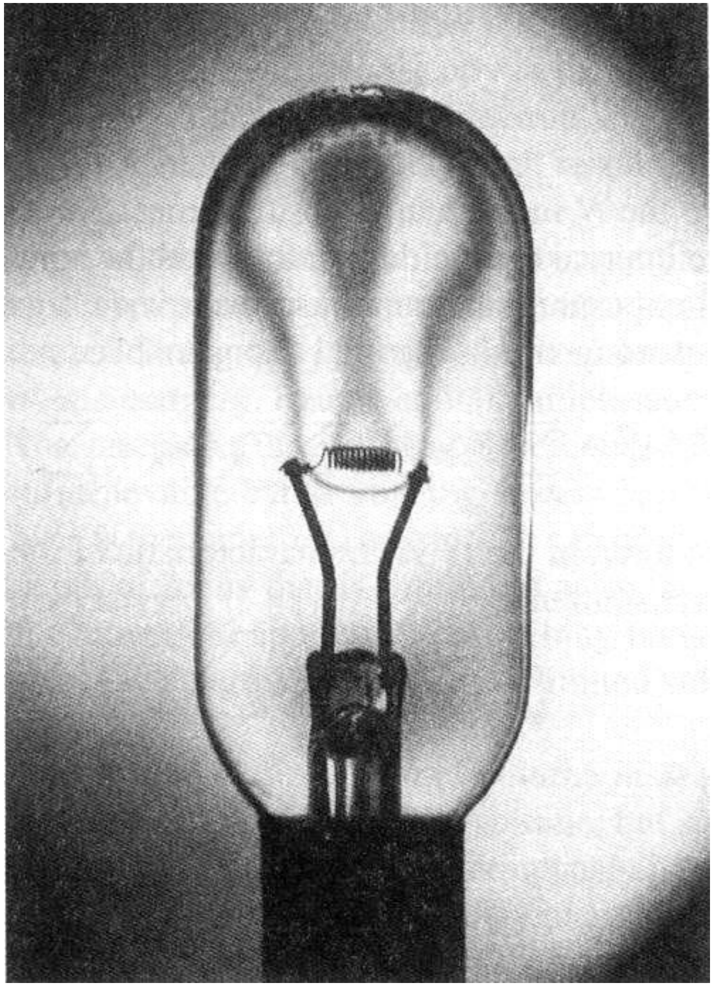
873 Hz (Q=75) | 980 Hz (Q=48) | 1010 Hz (Q=80) | 1174 Hz (Q=58) | 1194 Hz (Q=39)

Interferometry



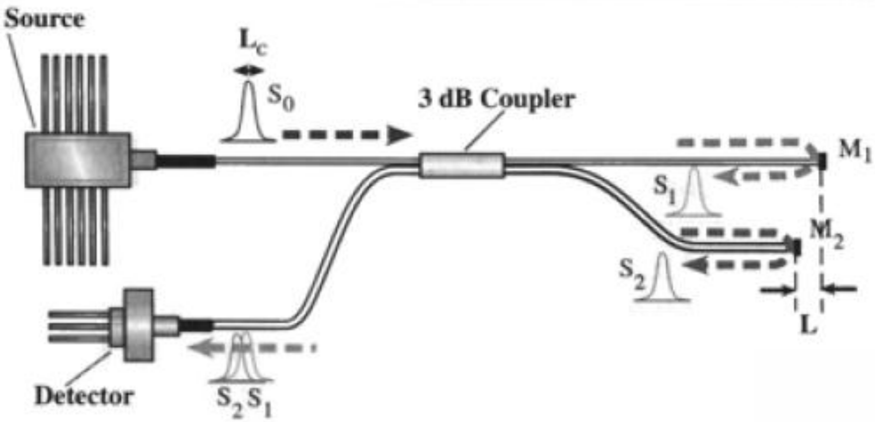
Double-Exposure Holographic Interferometry



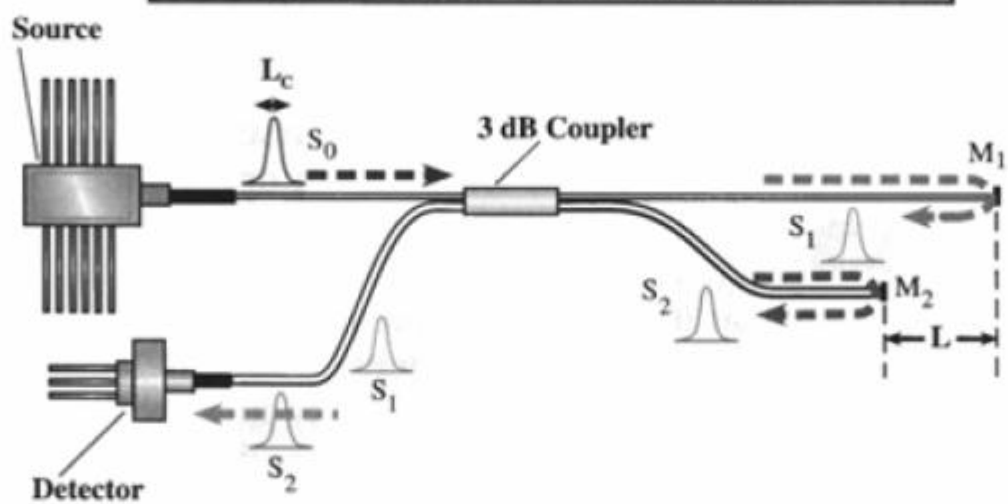


Low-Coherence Interferometer

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

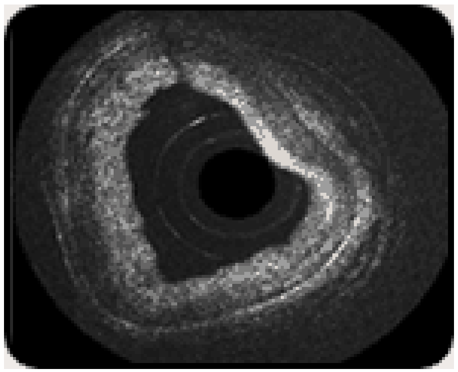


No Interference when Twice Separation of Fiber End Mirrors, 2L, > Source Coherence Length, L_c

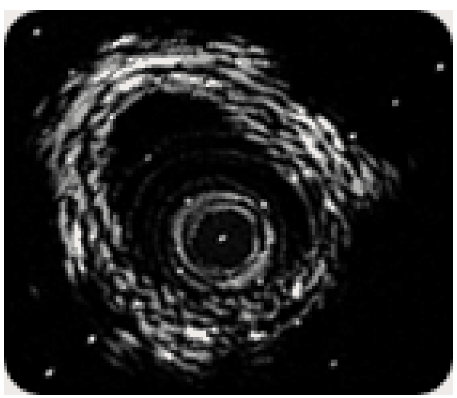


Optical Coherence Tomography

Imaging inside Veins

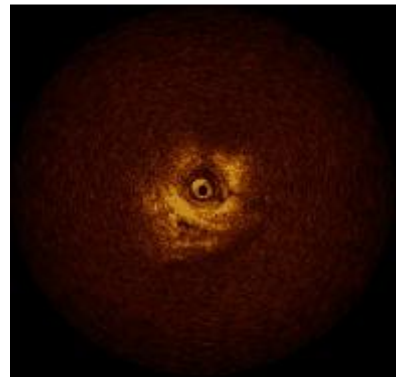


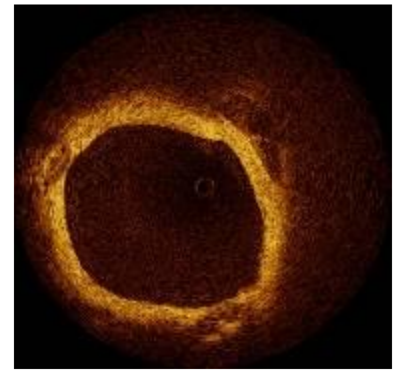
⑩OCT



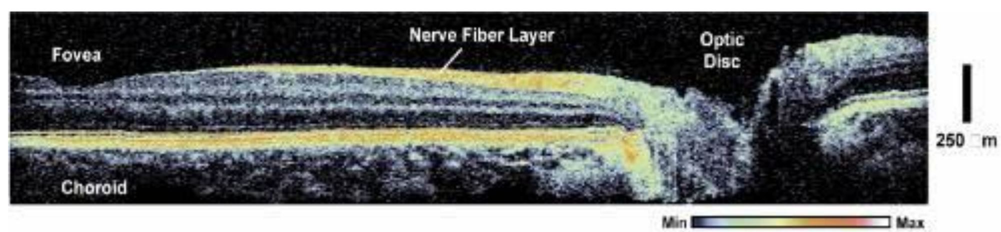
⑩Ultrasound

Real-time cardiology





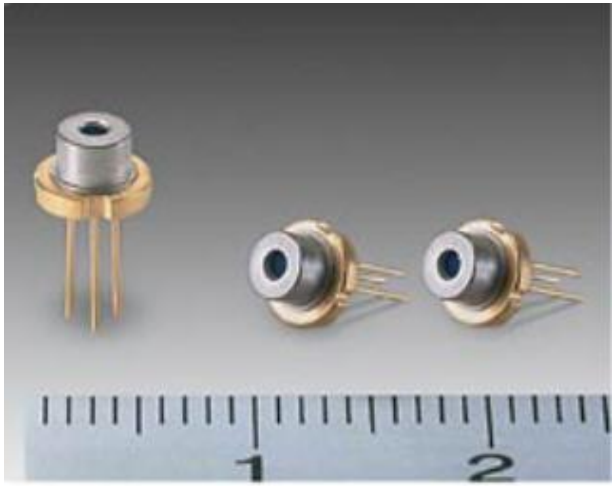
Human eye



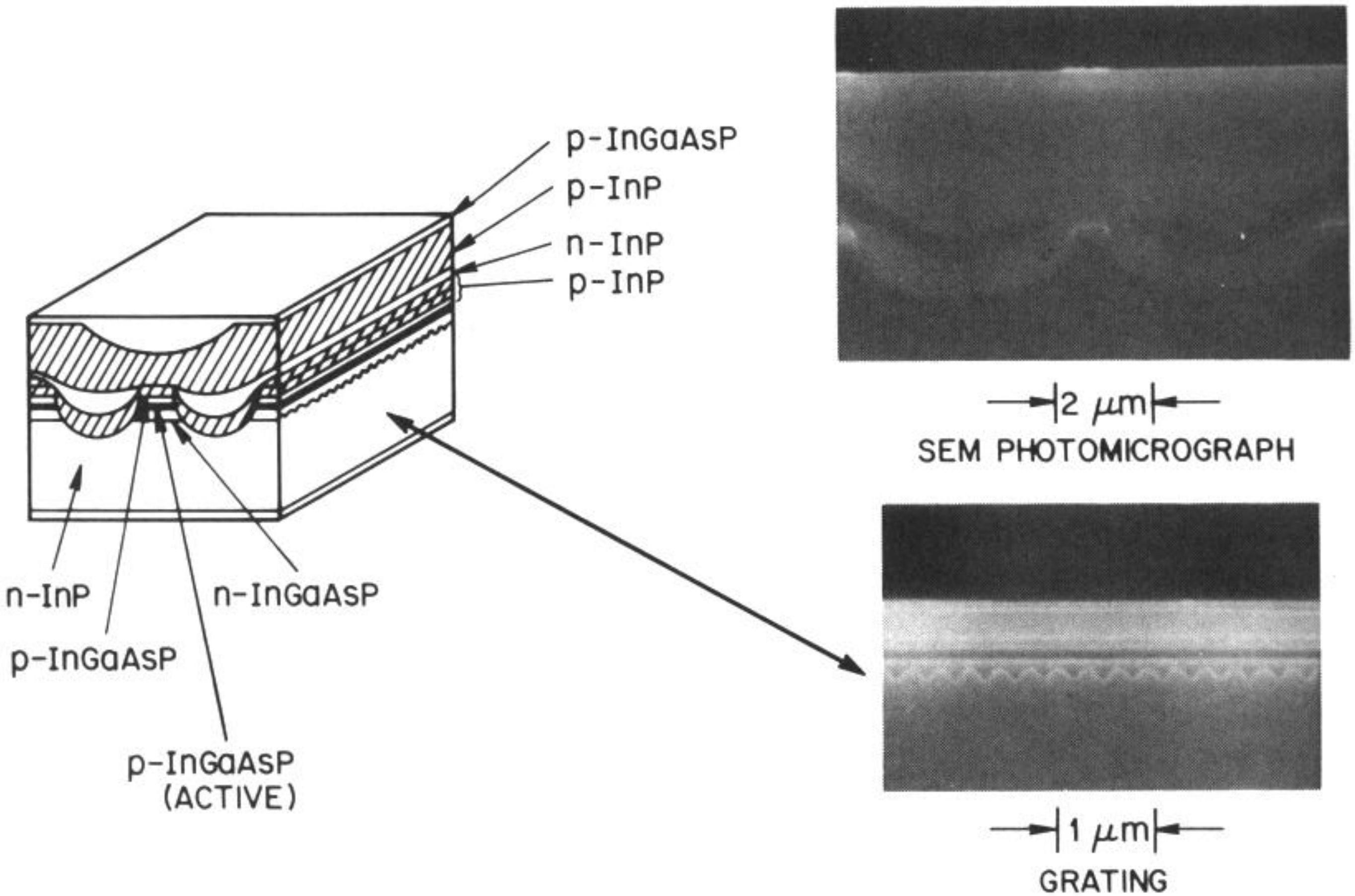
W. Drexler *et al*., “Ultrahigh-resolution ophthalmic optical coherence tomography”, Nature Medicine **7**, 502-507 (2001)

반도체 레이저의 응용

- CD, DVD, 광통신, 의료용
- 현재 가장 수요가 많은 반도체 레이저는 780nm 파장대의 것으로 CD 구동장치의 광원으로 가장 많이 이용되고 있고, 800nm 대의 것은 Nd:YAG 레이저의 여기광원과 의료용으로, 1.3㎛와 1.5㎛의 레이저는 주로 광통신용으로 이용되고 있으며 최근 상품화가 된 670nm 대의 것은 헬륨-네온 레이저를 대신하는 용도로 사용



장거리 광통신용 반도체 레이저(DFB LD) 구조도



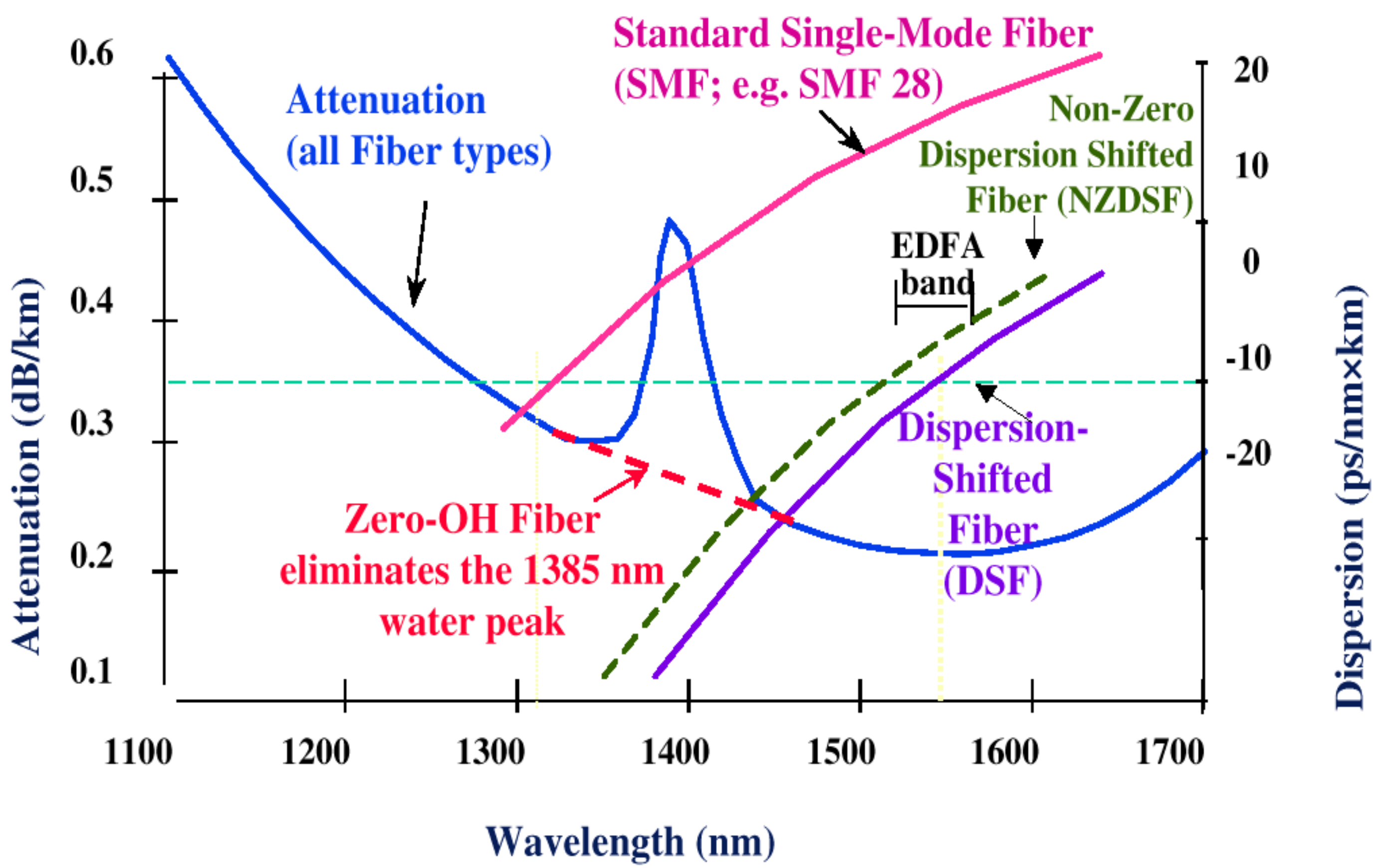
광통신의 역사 I

- 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)

단일 모드 광섬유의 종류

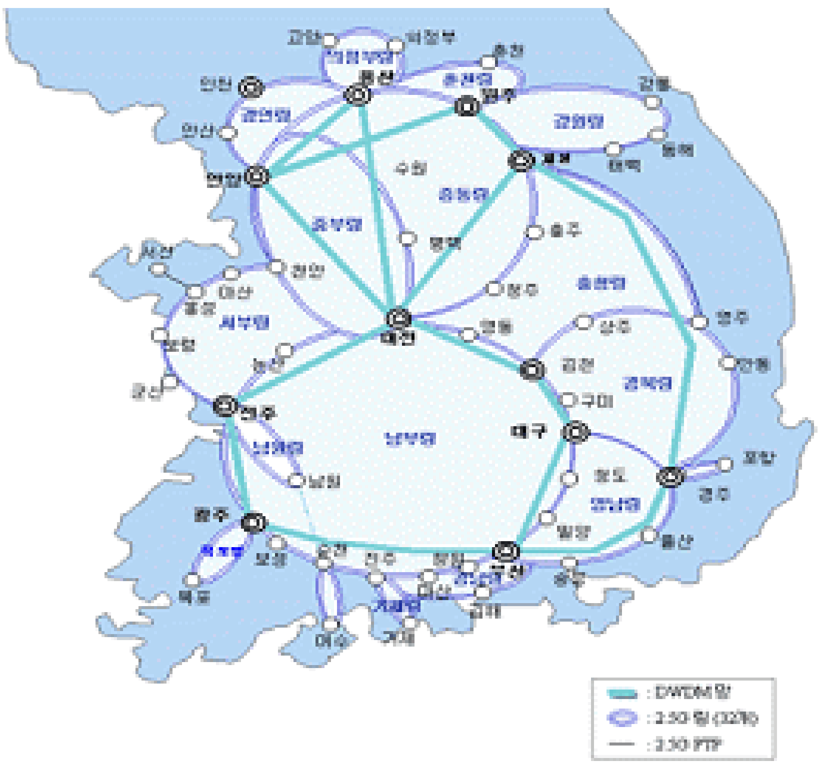


Standard Single-Mode Fiber
(SMF; e.g. SMF 28)
Attenuation
(all Fiber types)
Non-Zero
Dispersion Shifted
Fiber (NZDSF)
EDFA
band
Dispersion-
Shifted
Fiber
(DSF)
Zero-OH Fiber
eliminates the 1385 nm
water peak
0.6
0.5
0.4
0.3
0.2
0.1
20
10
0
-10
-20
1100
1200
1300
1400
1500
1600
1700
Attenuation (dB/km)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

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 …

우리나라의 기간망


인천
안산
춘천
원주
강릉
동해
태백
수원
충주
서산
대전
영동
상주
김천
구미
대구
안동
영주
포항
경주
청도
밀양
울산
전주
남원
광주
보성
목포
여수
진주
거제
김해
: DWDM 망
: 2.5G 링 (32개)
: 2.5G PTP

해저 광케이블