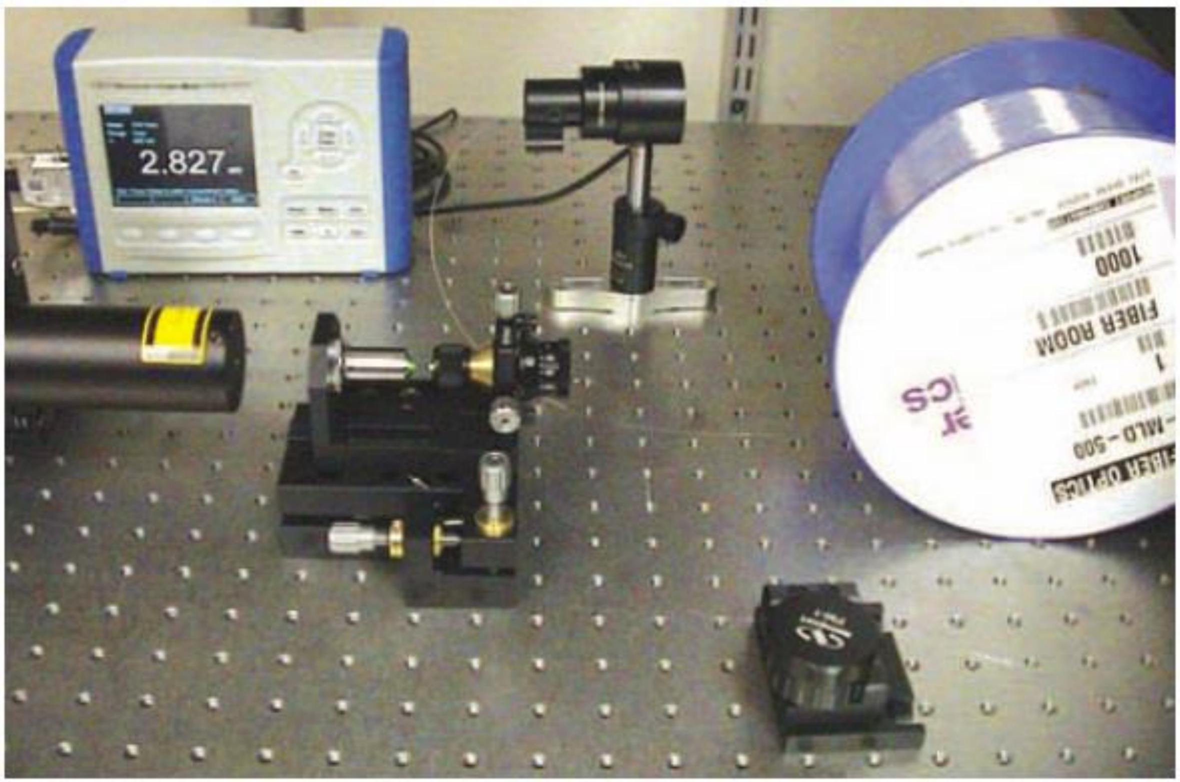
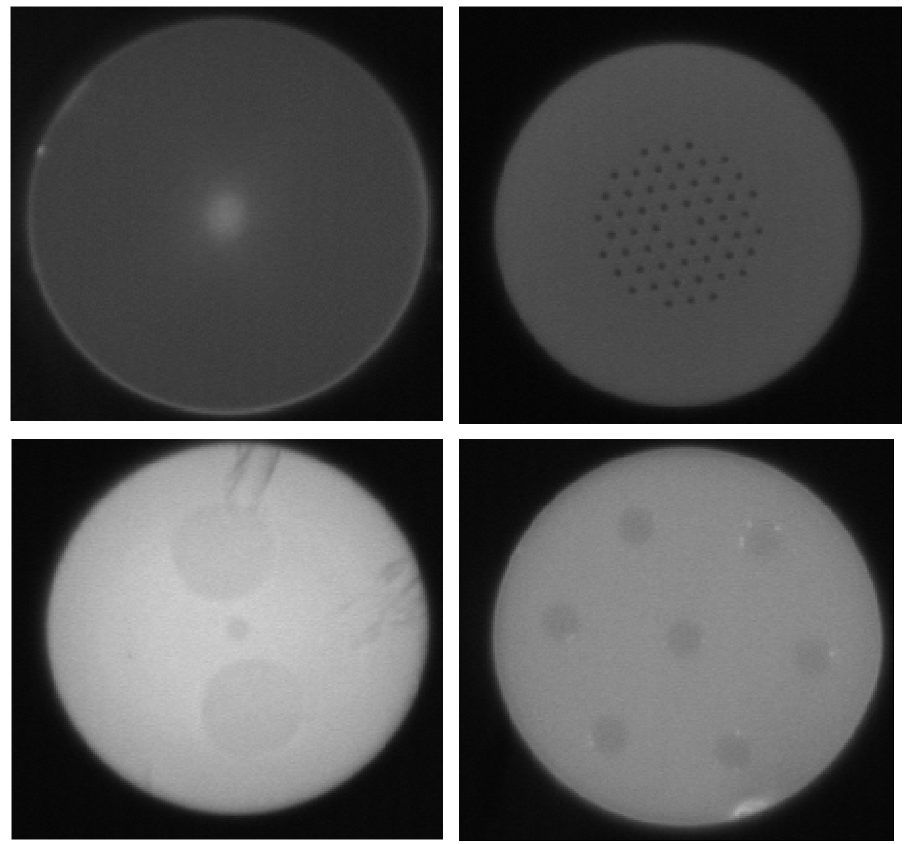
Propagation loss in optical fibers



Fiber optics: Basics

Types of fiber by construction:

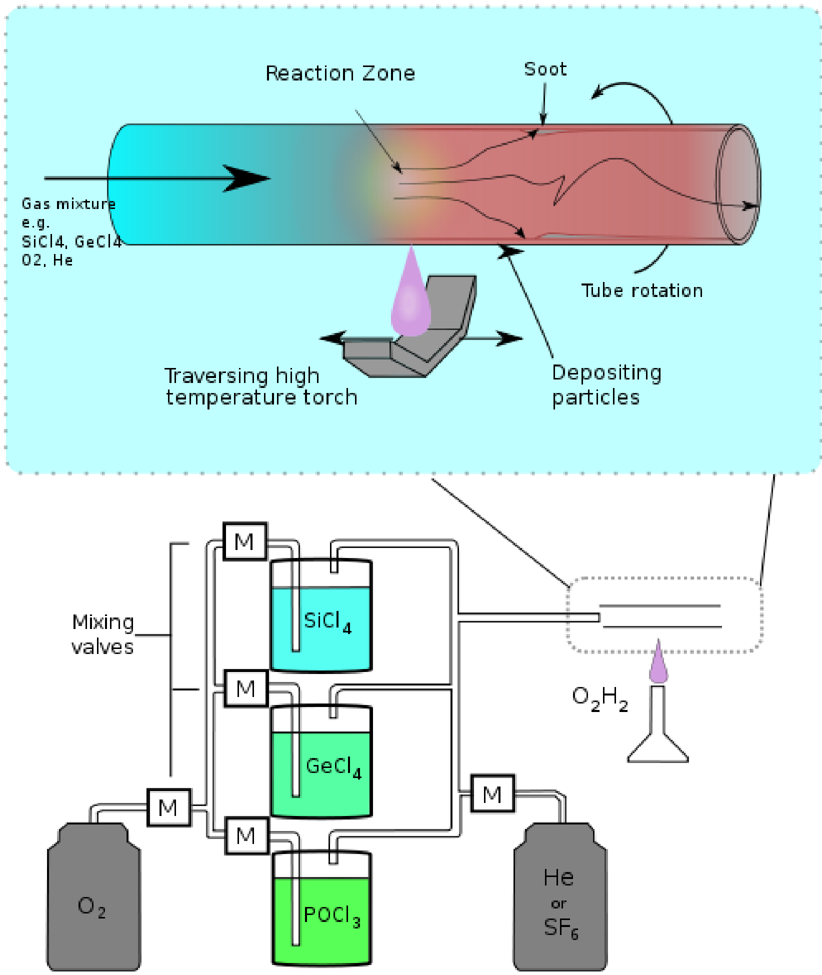
- step index
- graded index
- PM fiber
- photonic crystal fiber
- multi-core fiber



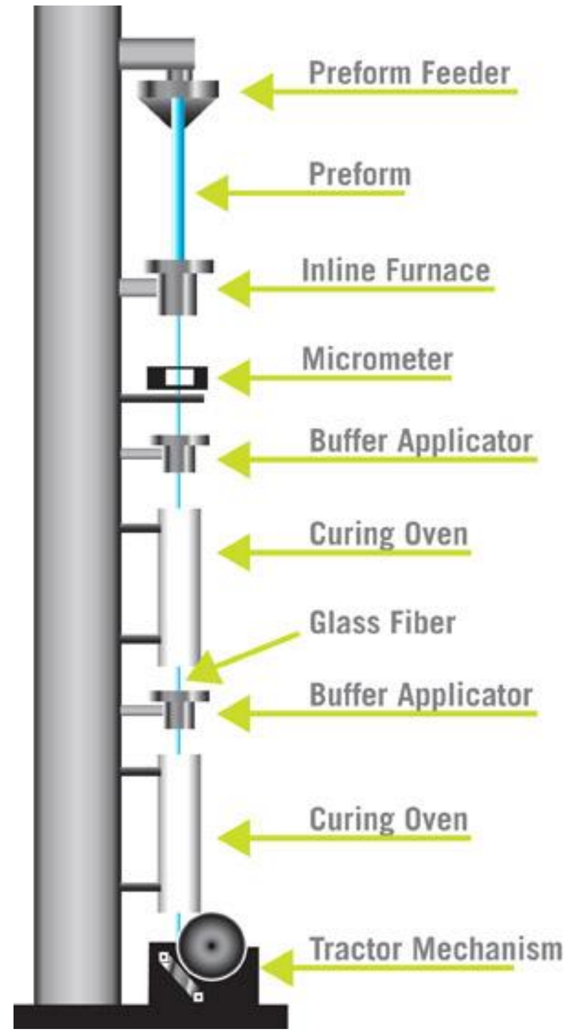
Types of fiber by functionality:

- passive fibers
- active fibers

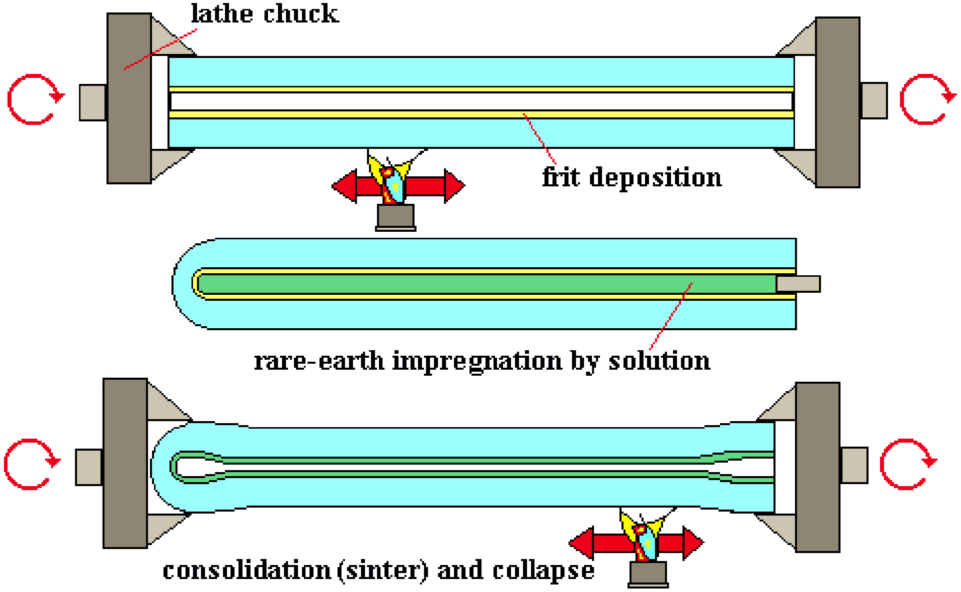
Fabrication methods



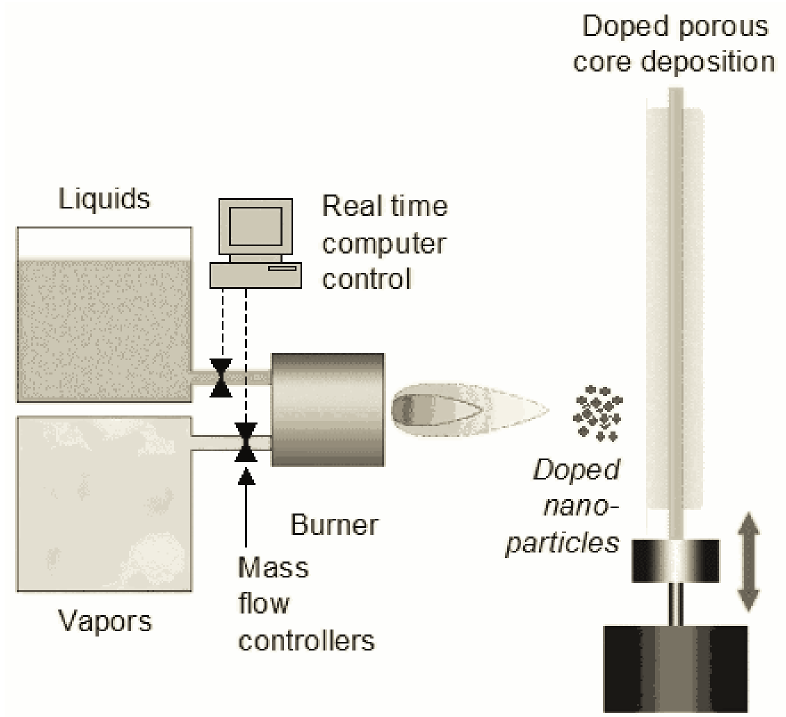
Modified chemical vapor deposition method



Fabrication methods: active fibers

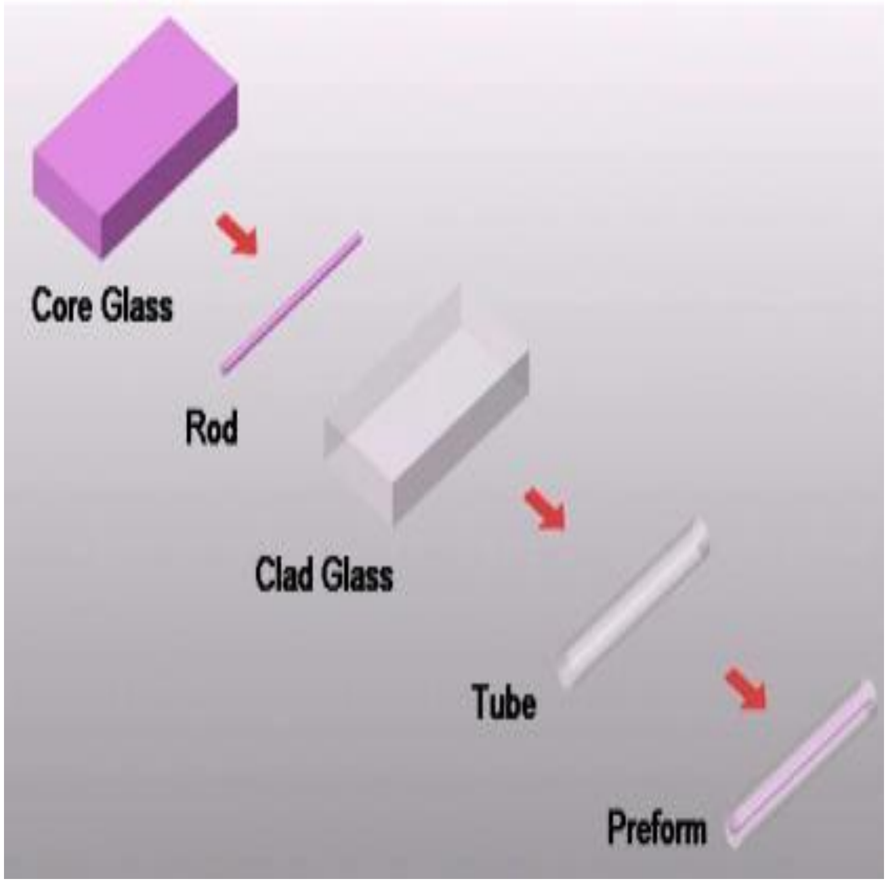


MCVD process



Nano-particle vapor deposition (Liekki)

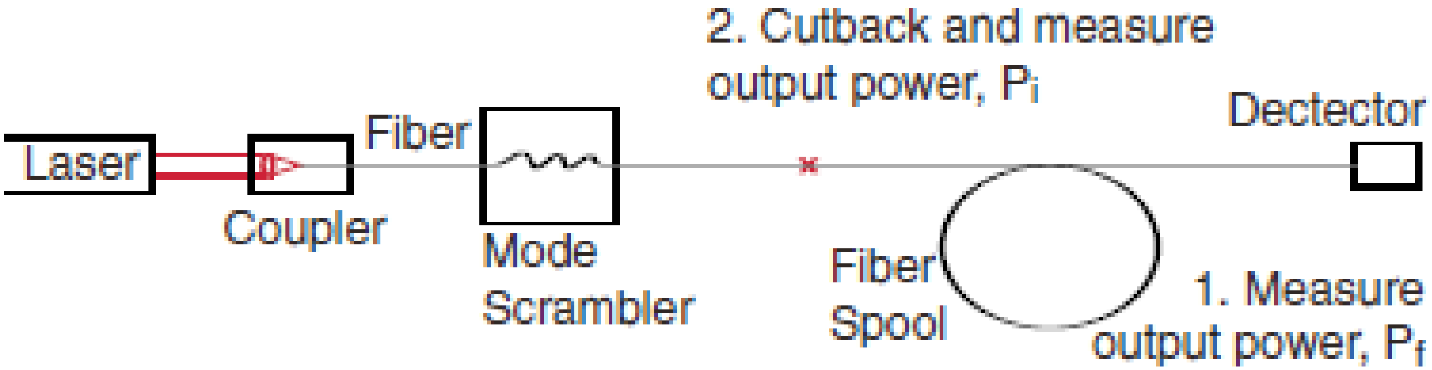
Fabrication methods: active fibers



Rod-in-tube method: UoA

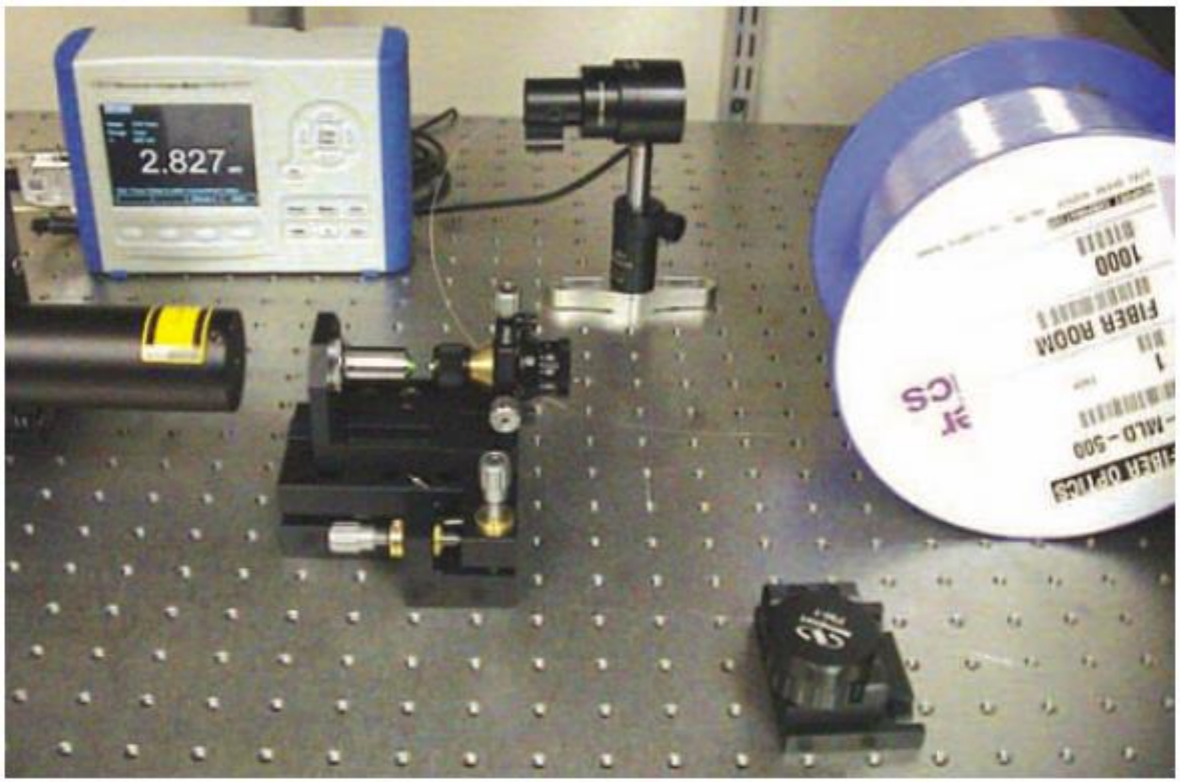
Project 2: Fiber loss measurement

Goal: Fiber attenuation measurement using cutback method



$$\propto = \frac{1}{L} 10 log_{10} \frac{P(0)}{P(L)}$$

Project 2: Fiber loss measurement

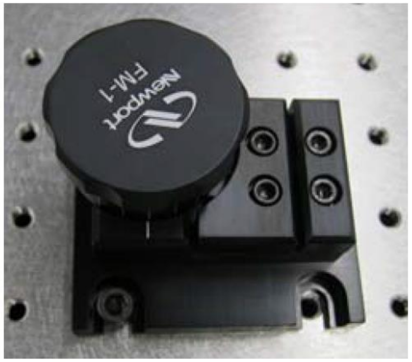


Project 2: Fiber loss measurement

Experimental equipment:

- Multimode fiber (to be used with the HeNe source), singlemode fiber (SMF28)
- Razor blade, Striper, Hand fiber cleaver, Fiber cleaver
- Temporary fiber connector
- Microscope
- He-Ne Laser source [1.5mW at 633nm]
- Semiconductor laser source with multiple out wavelengths (1310nm, 1480nm, 1550nm)
- Optical power meter (EXFO), Silicon detector to be used with the HeNe laser
- Mode scrambler
- **Arc fusion splicer** (FSM-40S), special fusion splicers (PM, filament)

Project 2: Fiber loss measurement



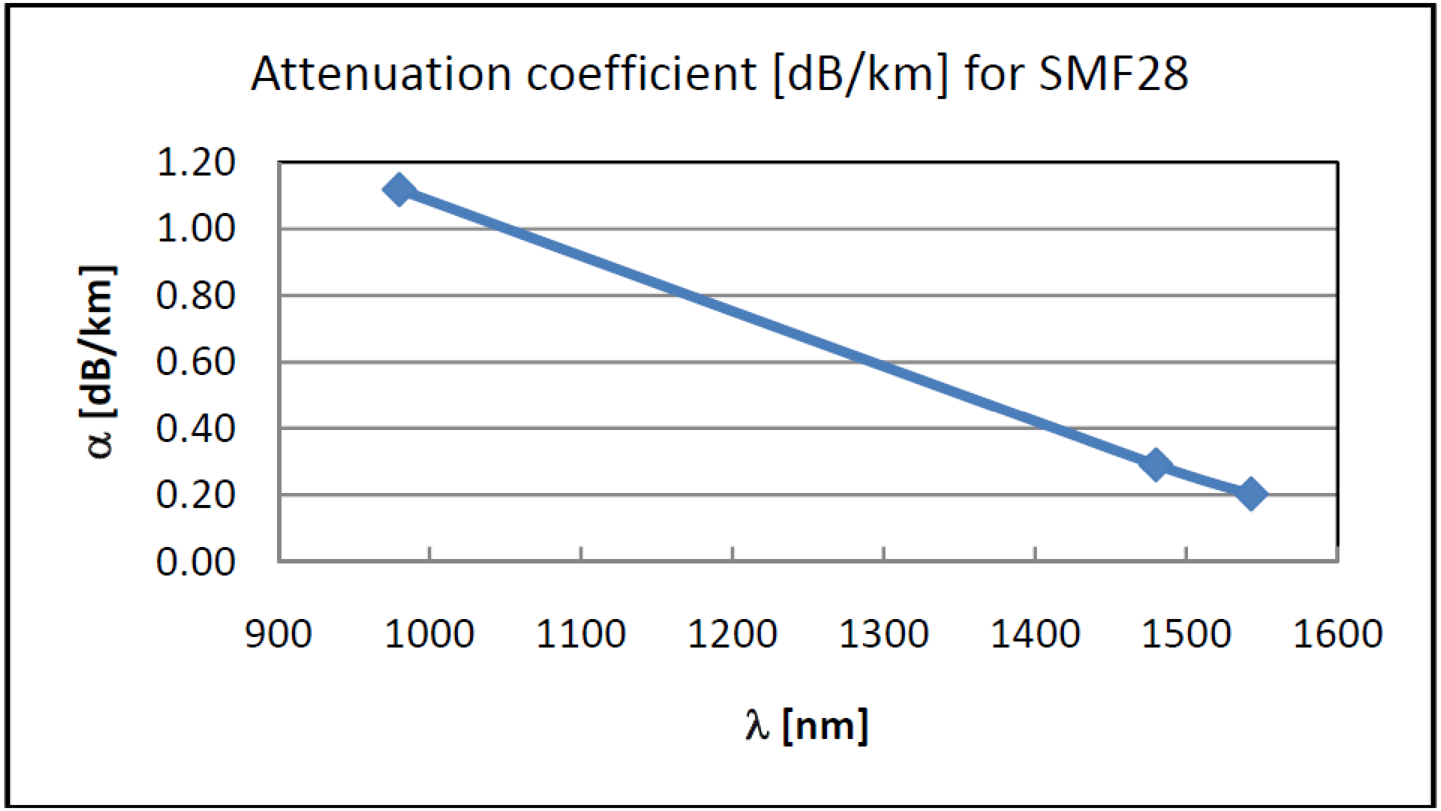
From top left to bottom right: He-Ne laser source, power meter, mode scrambler, multi wavelength laser source, fusion splicer

Project 2: Fiber loss measurement

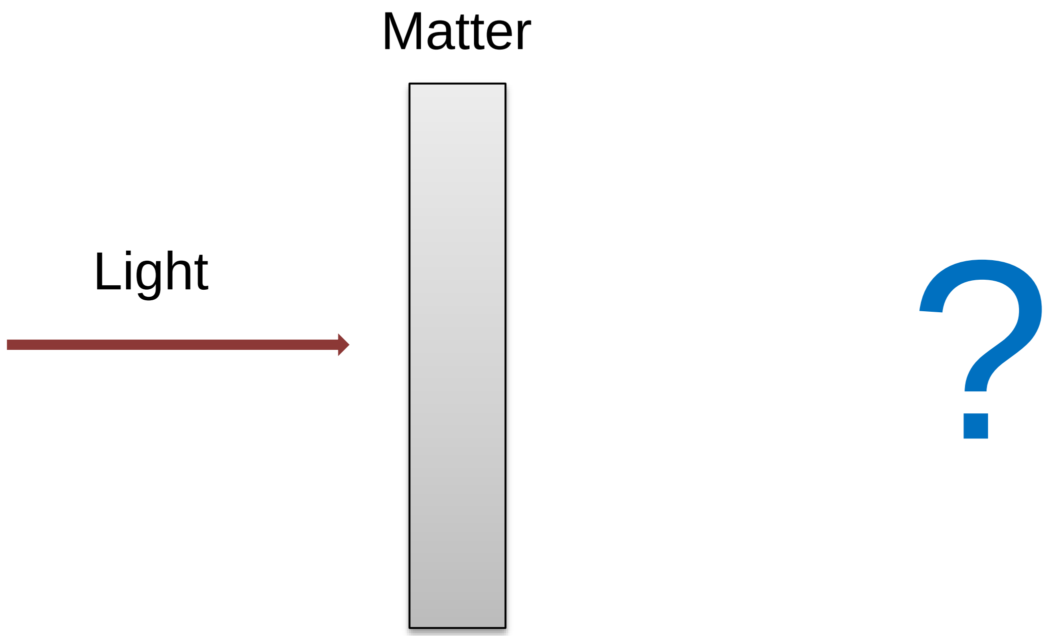
Skills learned:

- Fiber stripping and cleaning
- Fiber end preparation for power measurement (cleaving)
- Coupling light into multimode fiber
- Fiber splicing (with arc fusion splicer)
- Semiconductor laser and fiber connector
- Use of laser power meter
- Cutback method for waveguide loss measurement

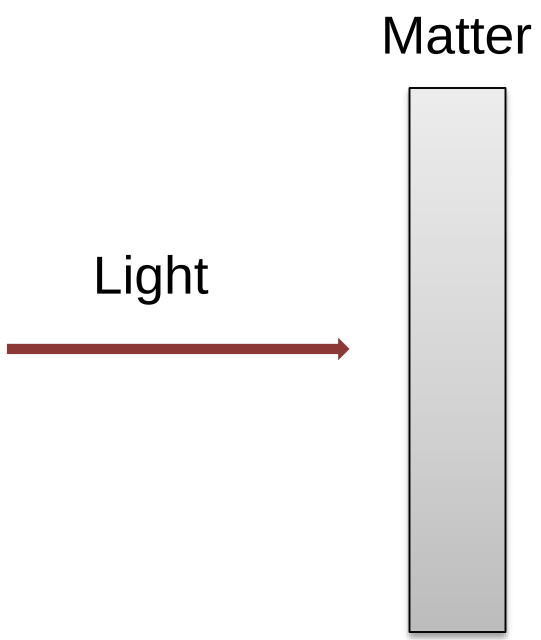
Project 2: Fiber loss measurement



Light-matter interactions



Light-matter interactions



- Refraction, reflection
- Absorption
- Scattering: Rayleigh, Brillouin, Raman
- Amplification
- Frequency generation: SHG, FWM, SPM…
- …….

Absorption

Absorption of electromagnetic radiation is the way by which the energy of a photon is taken up by matter

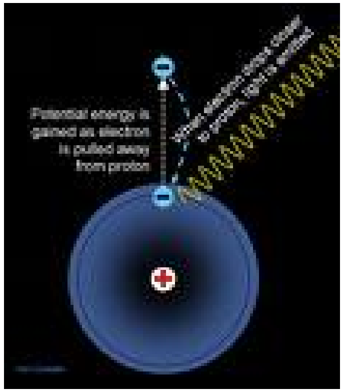
What can absorb light?

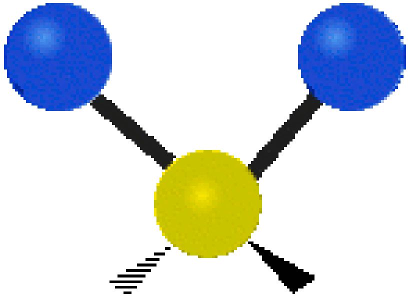
Absorption

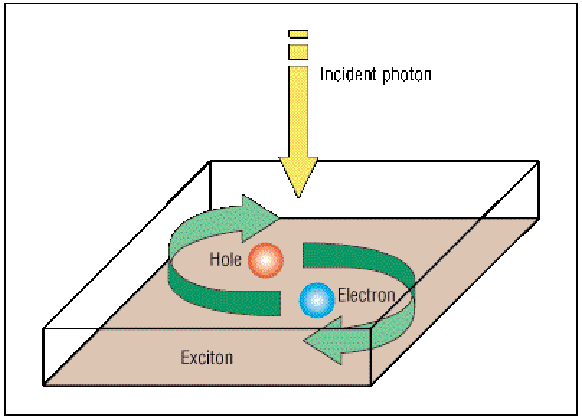
Absorption of electromagnetic radiation is the way by which the energy of a photon is taken up by matter

What can absorb light?

Electrons, molecules (through vibration and rotation), excitons…



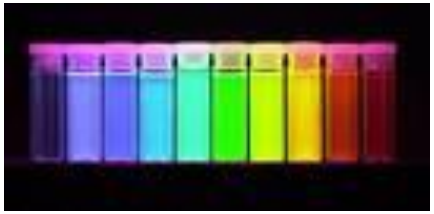




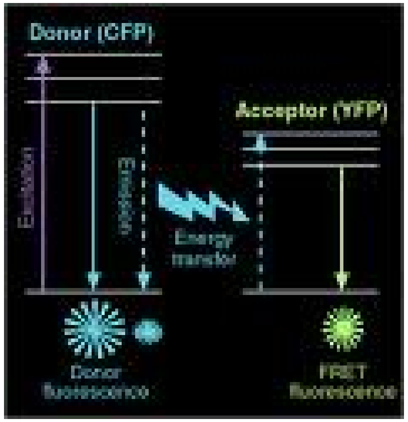
What happens when a photon is absorbed?

Heat generation

Fluorescence

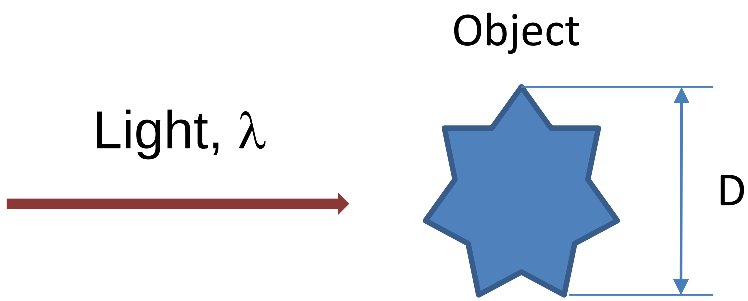


Transfer energy to nearby atoms, molecules (FRET)



Ionization (spie.org)

Light scattering



D << λ: Rayleigh scattering

D ~ λ: Mie scattering

D >> λ: Geometrical scattering

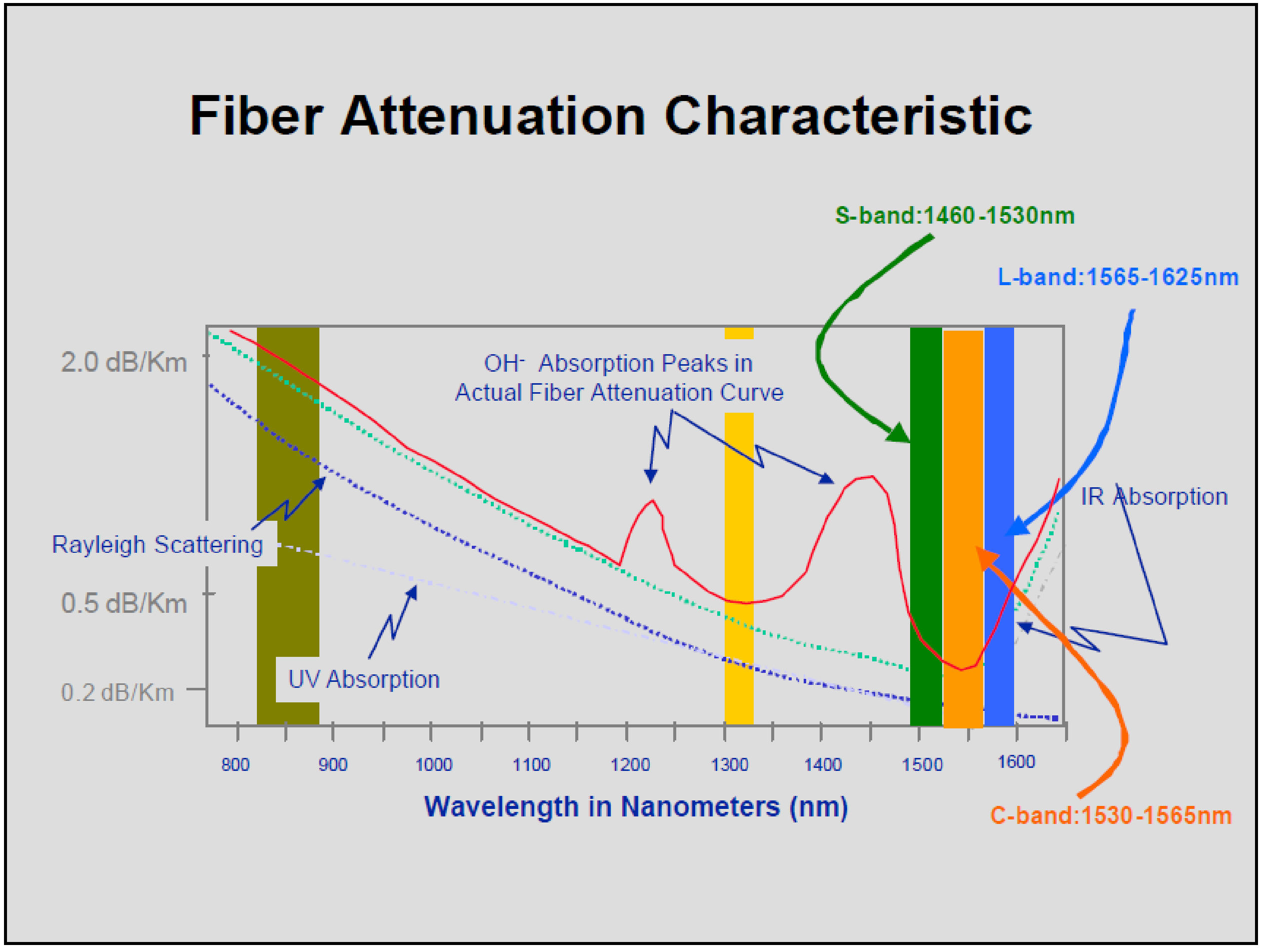
Rayleigh scattering is one of the dominant sources of loss in optical fibers

Rayleigh scattering

$$I(\theta) \sim D^6(1 + \cos^2(\theta))/\lambda^4$$

(source: Wikipedia)

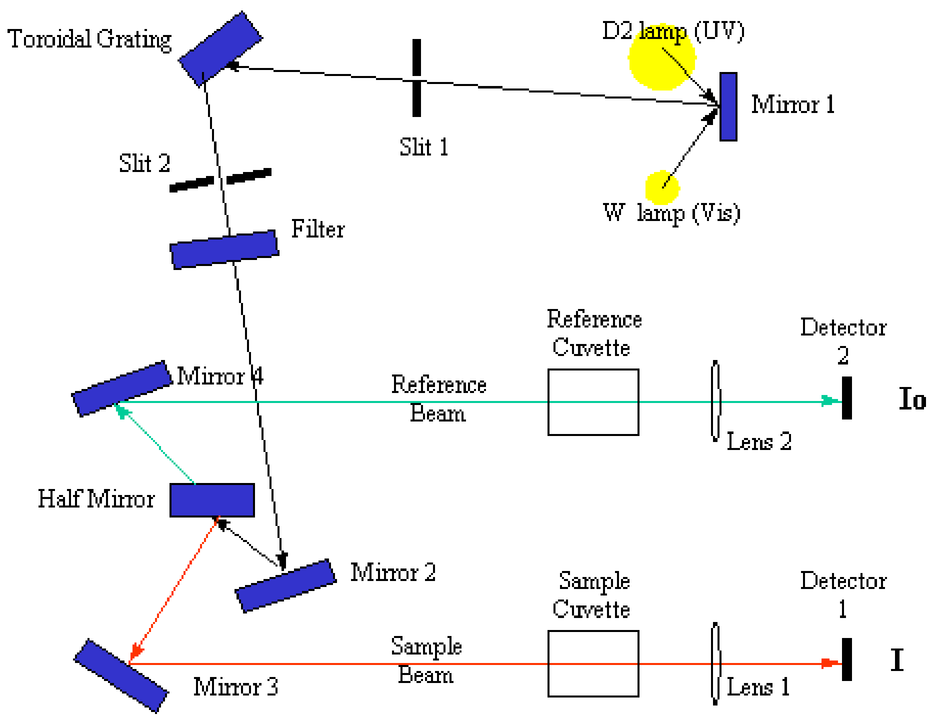
Propagation loss in optical fibers

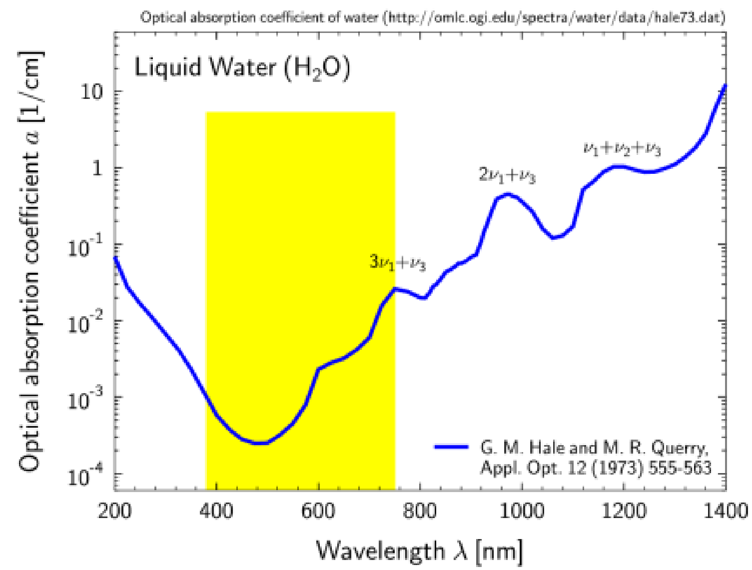


Methods of measuring absorption spectrum

- Spectrophotometers
- Optical Spectrum Analyzers, Monochromators
- Absorption spectrum measurement with tunable lasers
- Fourier Transform Spectrometers
- Frequency –to-Time Conversion Technique

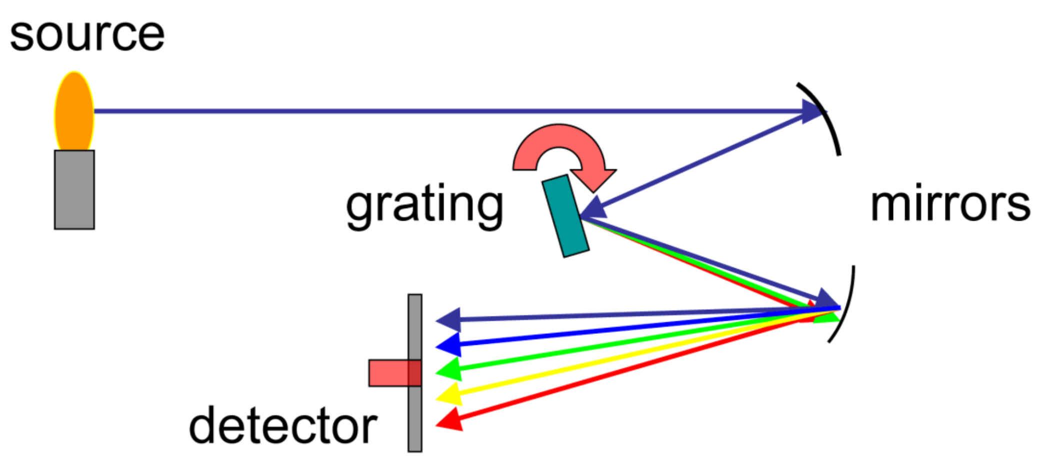
Spectrophotometers





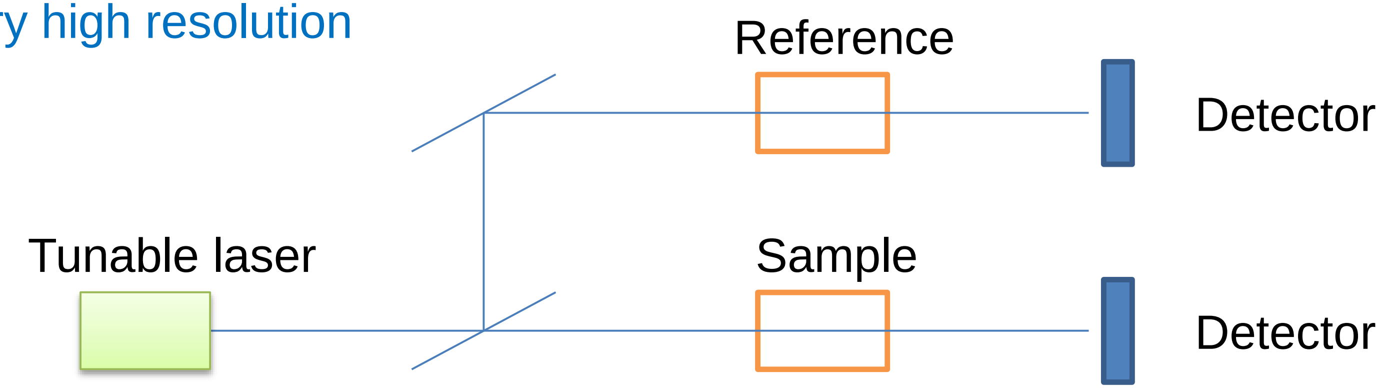
Schematic diagram of the U-2001 UV/Visible Spectrophotometer

Optical Spectrum Analyzers

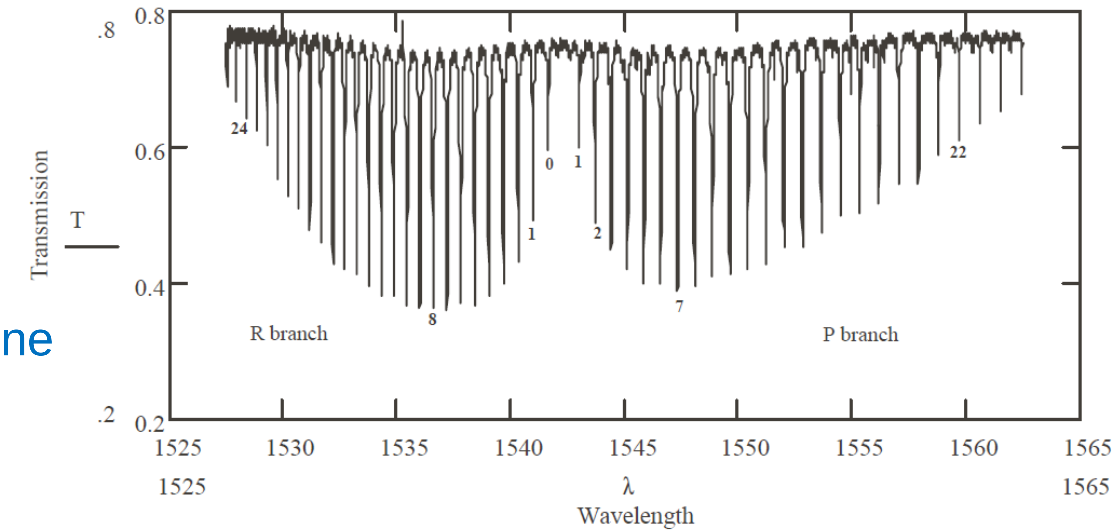


Measure absorption spectrum with a tunable laser

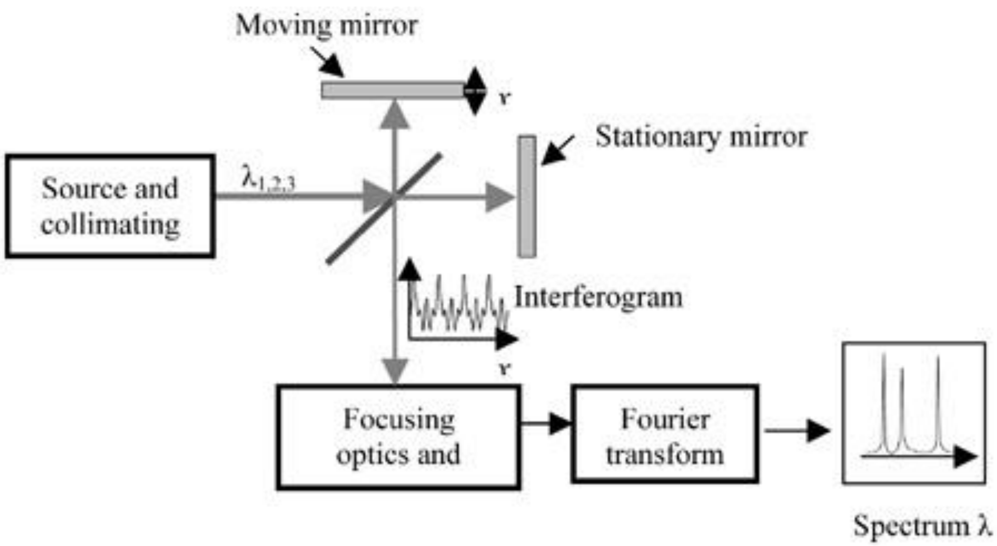
Very high resolution



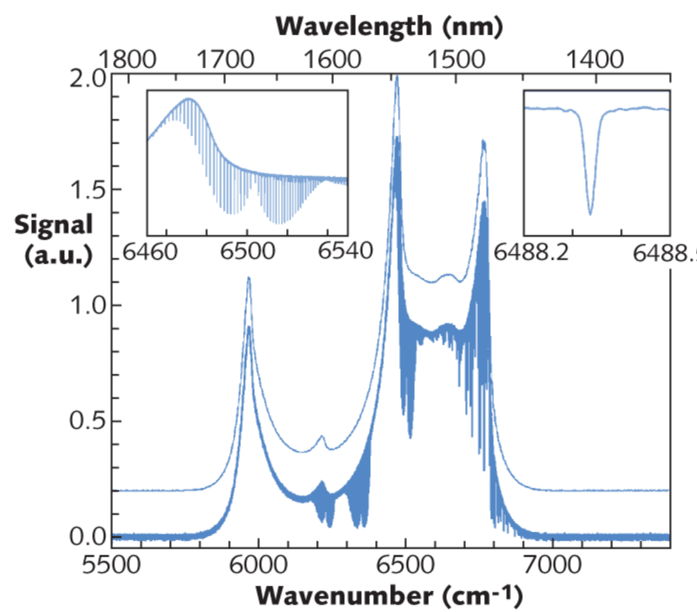
Absorption spectrum and Cyanine (H13C14N)



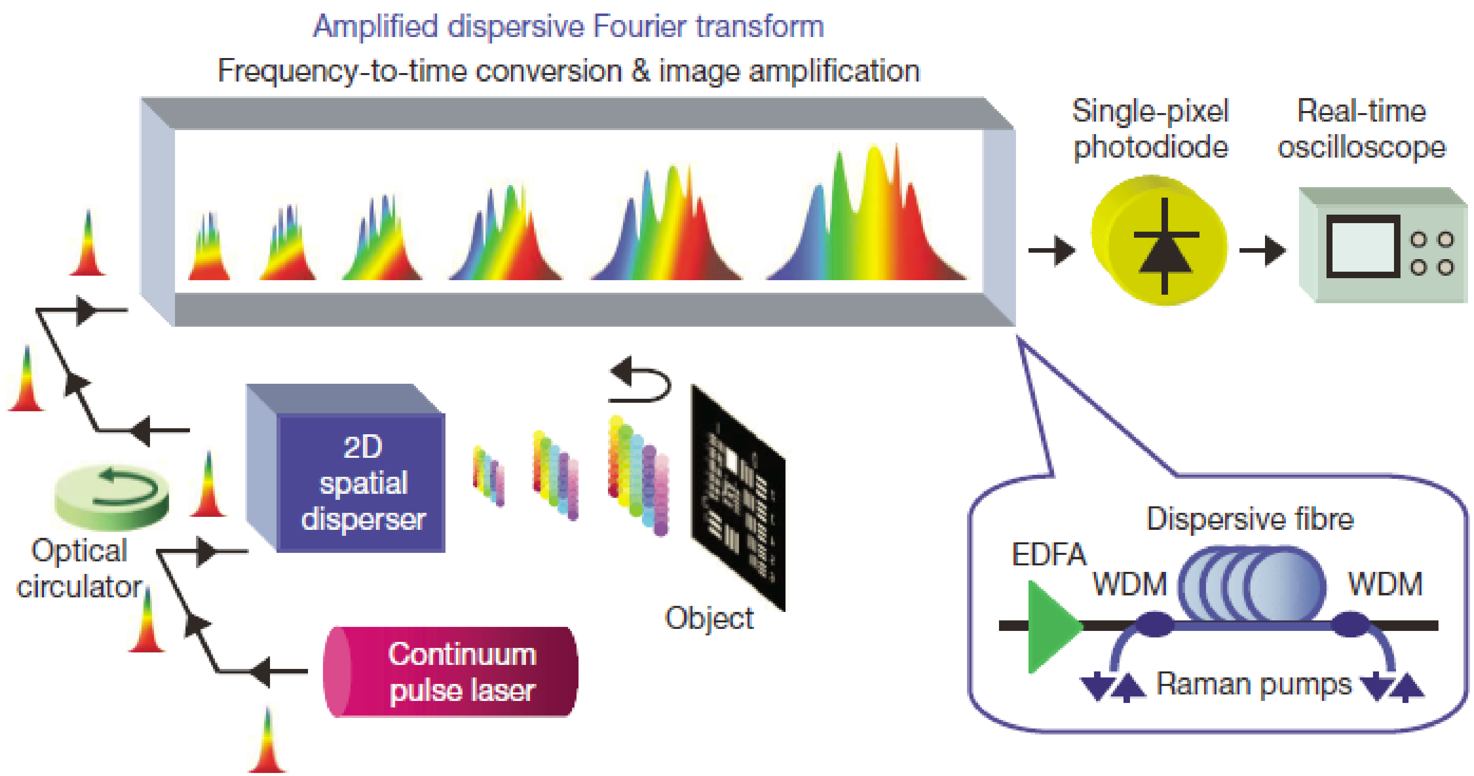
Fourier Transform Spectrometers



A high-resolution spectrum of CO_2 in the near-IR was obtained using a Fourier-transform spectrometer (laserfocusworld.org)



Frequency –to-Time Conversion Technique



K. Goda, K. K. Tsia, and B. Jalali, *Nature* 458, 1145 (2009)

Applications of absorption

Is absorption good or bad?

Applications of absorption

Linear absorption:

- Photodetectors
- Sensing
- Laser frequency stabilization
- ....

Nonlinear absorption:

- Saturable absorbers
- Optical limiting
- Multi-photon absorption
- ....

Propagation loss in optical fibers

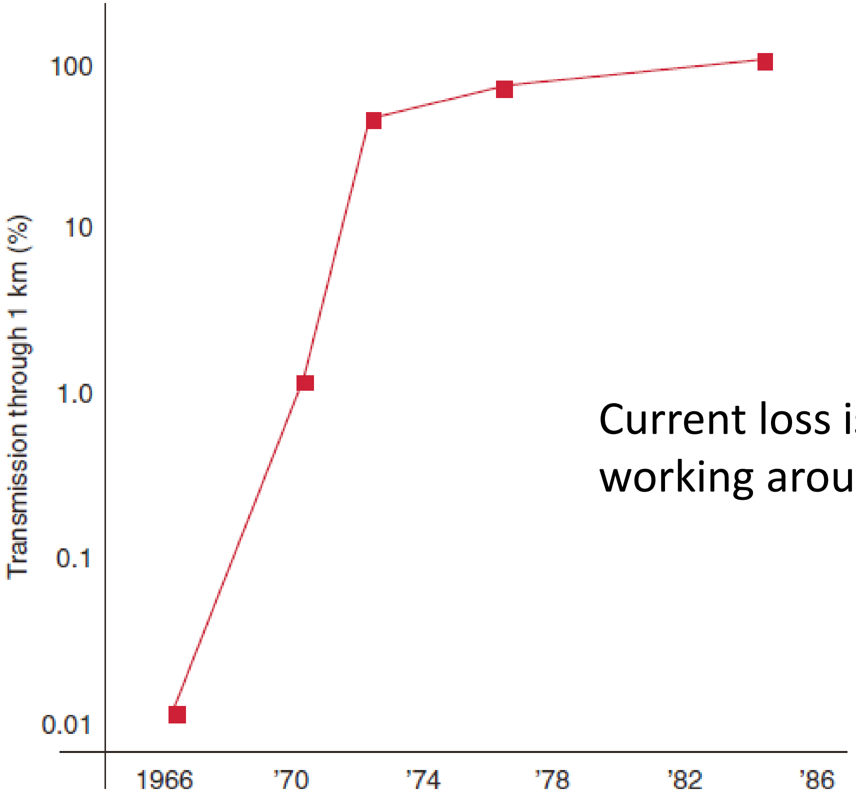


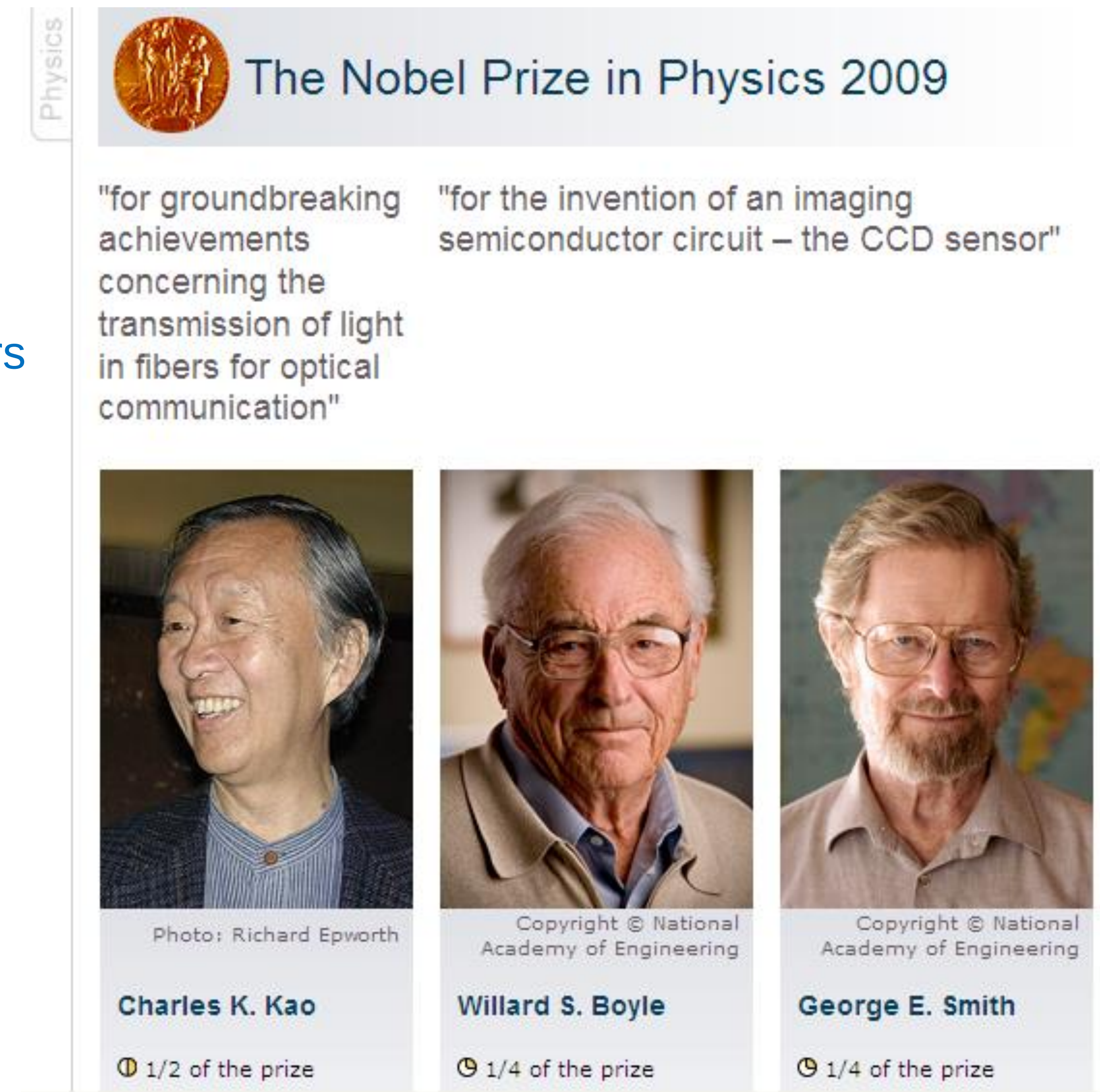
Figure 0.3. Progress in optical fiber transmission. The last two data points represent results near the theoretical limits at 0.85 and 1.55 µm.

Current loss is < 0.2dB/km for singlemode fiber working around 1550nm

Fiber optics telecommunication

1. Low loss optical fiber based on fused silica

2. Compact, low-cost diode lasers



Fiber optics telecommunication

Dielectric-fibre surface waveguides for optical frequencies

K. C. Kao, B.Sc.(Eng.), Ph.D., A.M.I.E.E., and G. A. Hockham, B.Sc.(Eng.), Graduate I.E.E.

Synopsis

A dielectric fibre with a refractive index higher than its surrounding region is a form of dielectric waveguide which represents a possible medium for the guided transmission of energy at optical frequencies. The particular type of dielectric-fibre waveguide discussed is one with a circular cross-section. The choice of the mode of propagation for a fibre waveguide used for communication purposes is governed by consideration of loss characteristics and information capacity. Dielectric loss, bending loss and radiation loss are discussed, and mode stability, dispersion and power handling are examined with respect to information capacity. Physical-realisation aspects are also discussed. Experimental investigations at both optical and microwave wavelengths are included.

Predict the loss in optical fiber could be < 20dB/km

Loss was ~1000dB/km at that time

Questions for thoughts

- What are the techniques to mitigate propagation loss in optical fibers?
- In principle, can we create an optical fiber with zero loss?
- What does a scientist need to do to win the Nobel prize?
- Since optical fiber has such a low propagation loss, could it be a good platform to transfer energy (like the electrical grid) to home?
- Fiber optics communication to other planets (Calculate the propagation loss of an optical signal traveling through an optical fiber connecting the earth and the moon)?
- Can we use an optical fiber to transmit sunlight from one side of the earth to the other?