

3小時學會拉曼光譜顯微鏡 的原理與實作

111年AI-MAT暑期實習課程

Prepared by :黎文鴻博士

What is Raman Spectroscopy?

- An analytical technique where scattered light is used to measure **vibrational energy modes** of molecules.
- Only detects vibrations where the **polarizability changes** during the movement (Raman-active)
- Complementary with fourier-transform infrared spectroscopy (FTIR)

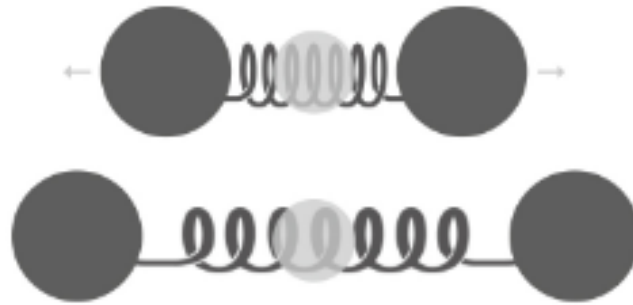
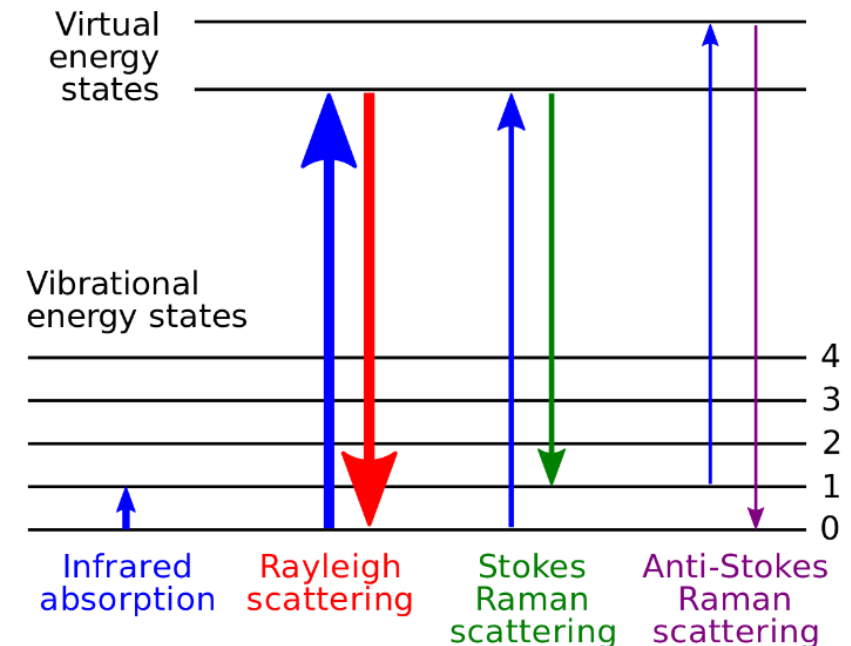
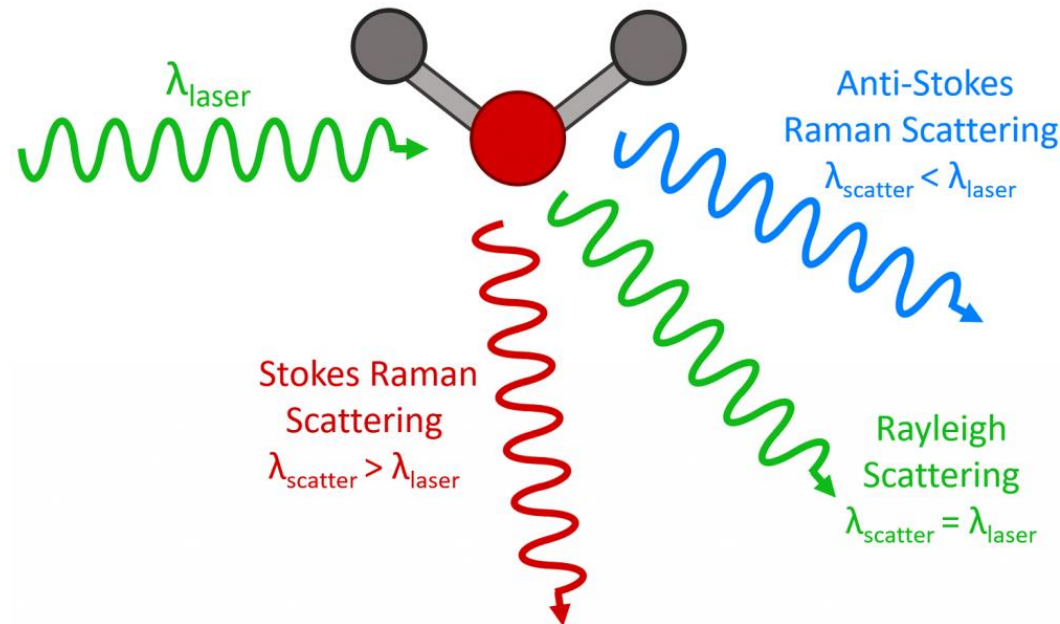


Figure 7: The symmetric stretching vibration of carbon dioxide (CO₂) increases the size of the electron cloud. It is therefore Raman-active.

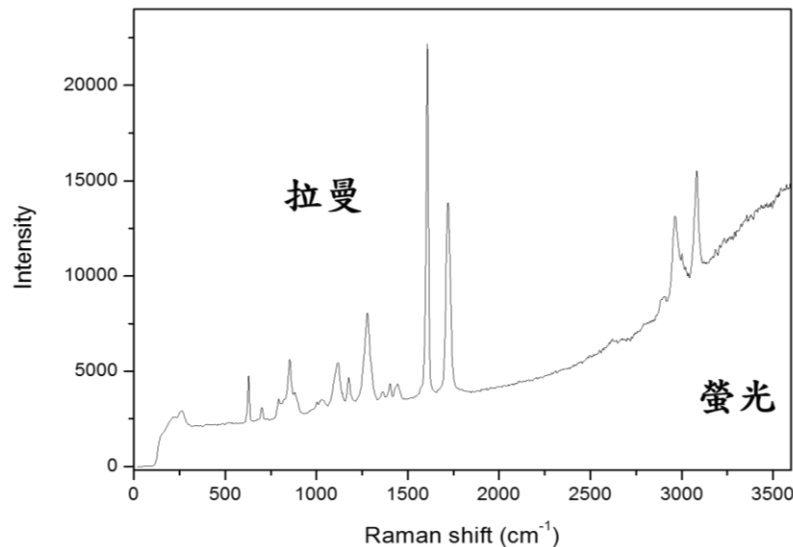
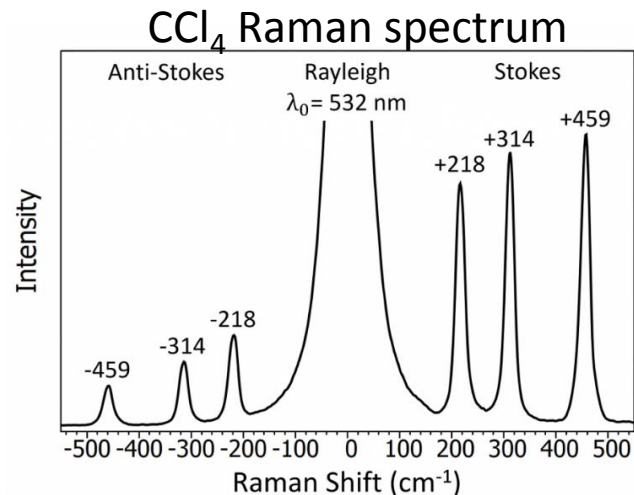
Raman Scattering

- **Inelastic** photon-phonon interactions in the sample
- formation of a very short-lived complex between the photon and molecule, commonly called the **virtual state** of the molecule.
- The oscillating electromagnetic field of a photon induces a polarization of the molecular electron cloud which changes the energy state of the molecule.



Raman Spectrum

- Provide both chemical and structural information, as well as the identification of substances through their characteristic Raman 'fingerprint'.
- The vibrations of certain distinct subunits of a molecule, called its functional groups, will appear in a Raman spectrum at **characteristic Raman shifts**.

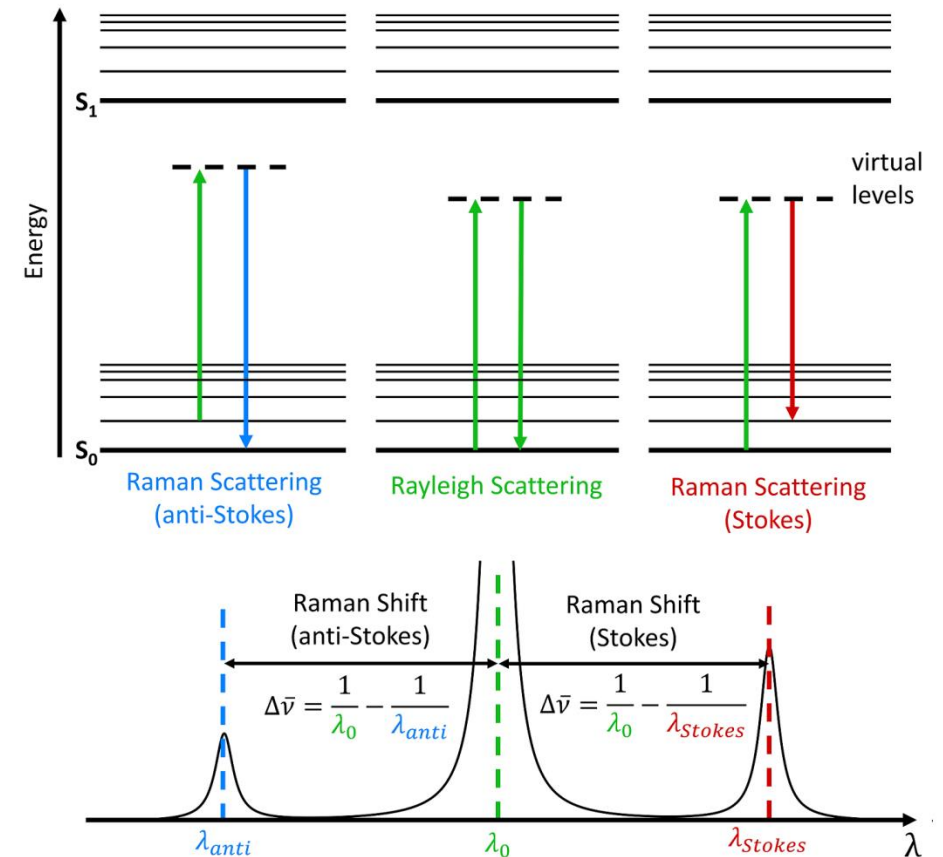


Raman Shift

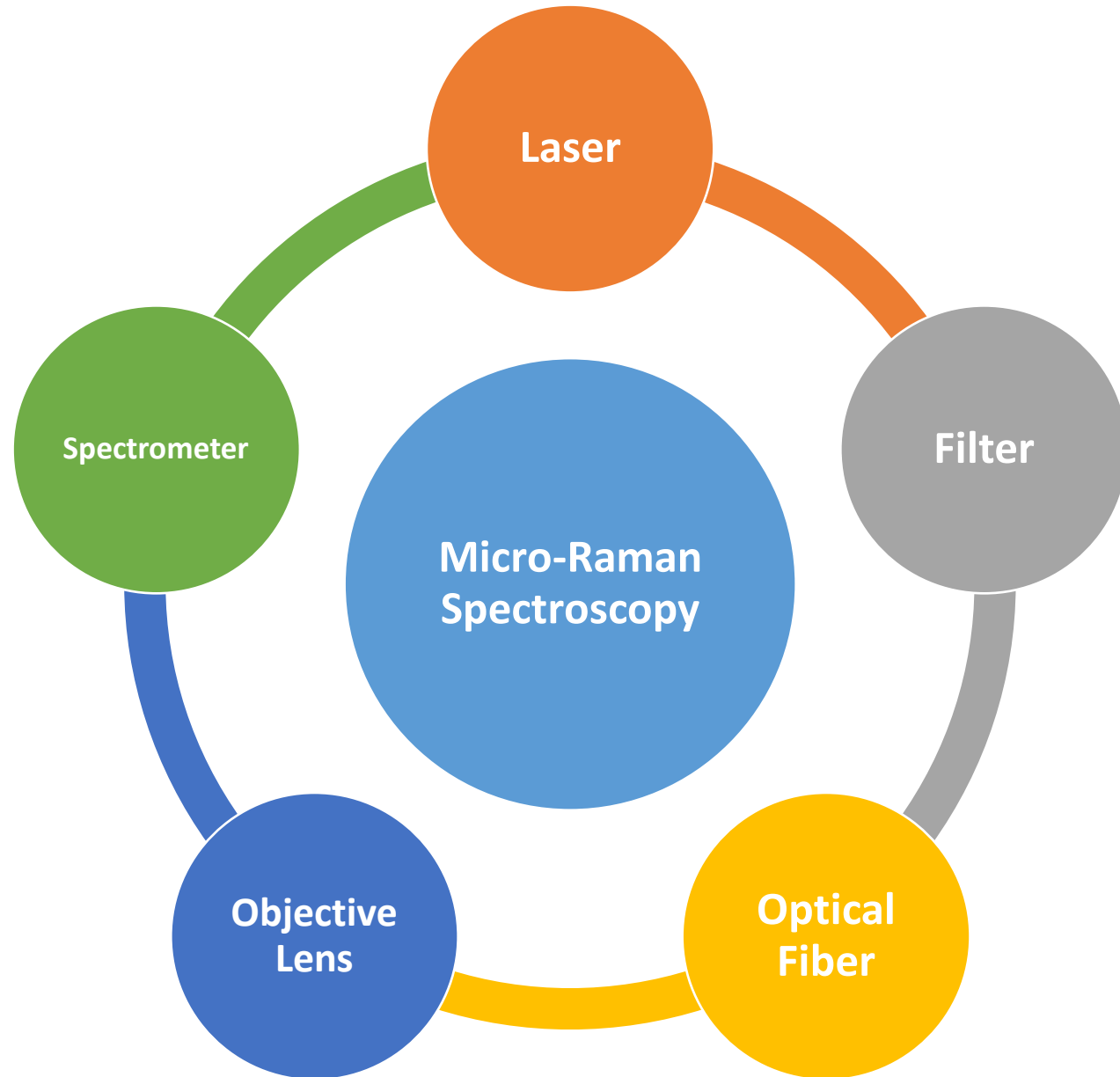
- Energy difference between the incident light and the scattered light, usually expressed in wavenumbers. .

$$\text{Raman shift (cm}^{-1}\text{)} = \left(\frac{1}{\lambda_{\text{laser}}(\text{nm})} - \frac{1}{\lambda_{\text{Raman}}(\text{nm})} \right) \times 10^7$$

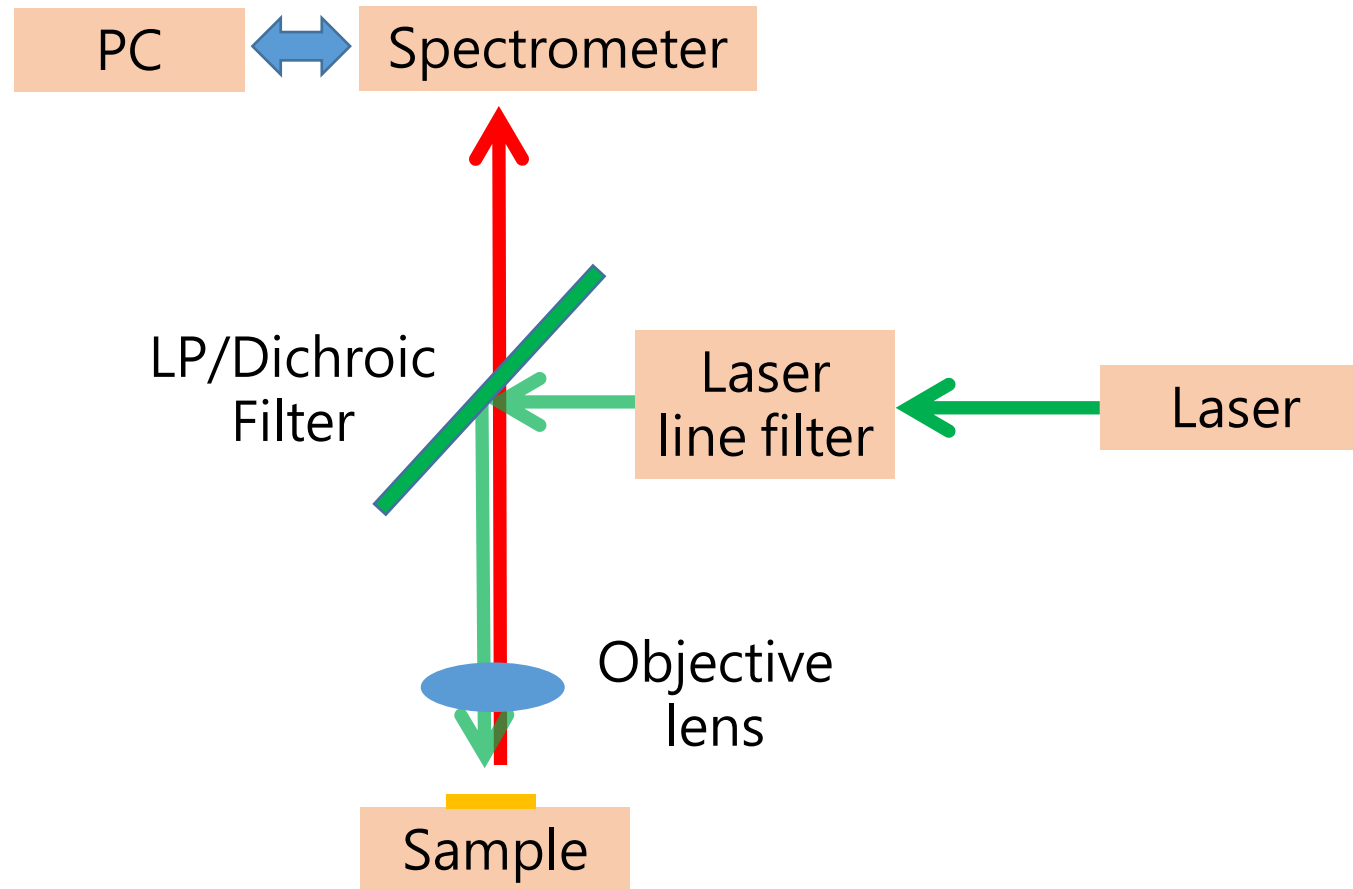
- Stokes & Anti-Stokes



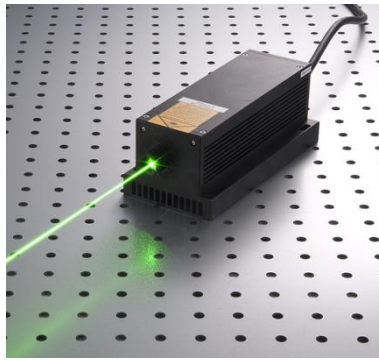
Components in Micro-Raman Spectroscopy



Simple Raman Setup



Laser



Wavelength

- Excitation below bandgap can avoid photoluminescence
- Raman scattering efficiency is proportional to λ^{-4}
- Affects spatial resolution
- Resonance wavelength

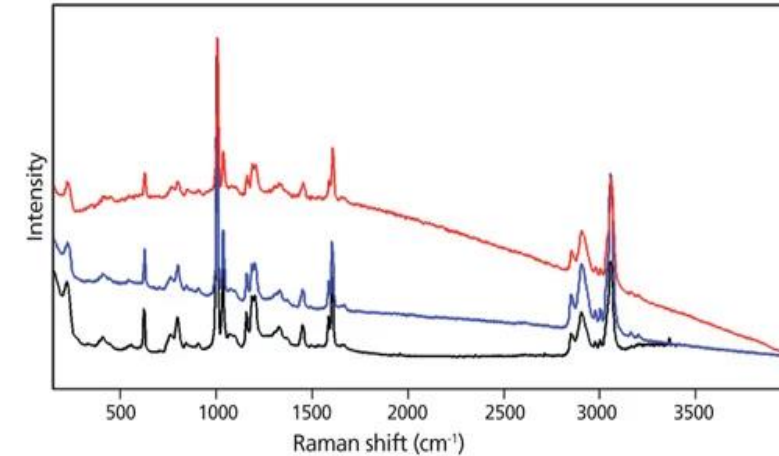
Bandwidth

- Affects spectral resolution
- Crucial for low frequency Raman mode detection.

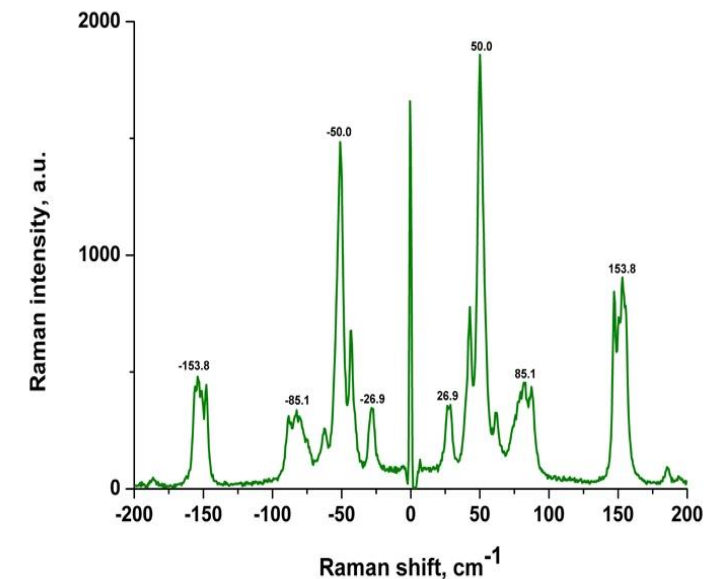
Power

- Below damage threshold can avoid sample degradation

Raman spectrum of polystyrene



Raman spectrum of sulfur



Filter



Laser line filter

- Reduces the laser bandwidth

Long-pass filter

- Transmitting light above its cut-off wavelength

Dichroic mirror

- Selectively reflect and transmit light depends on its wavelength range

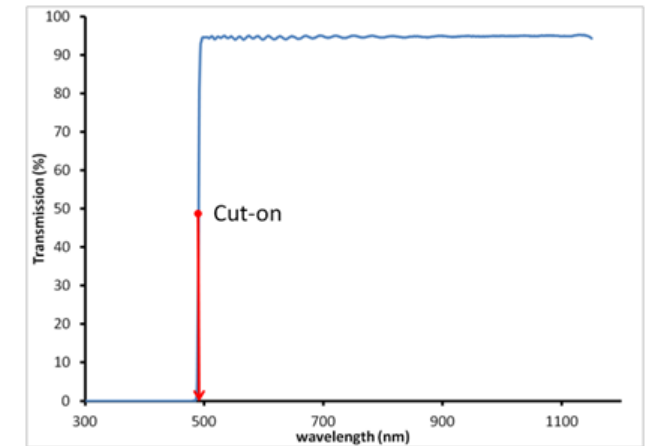
Notch filter

- Eliminates the laser wavelength from the total signal

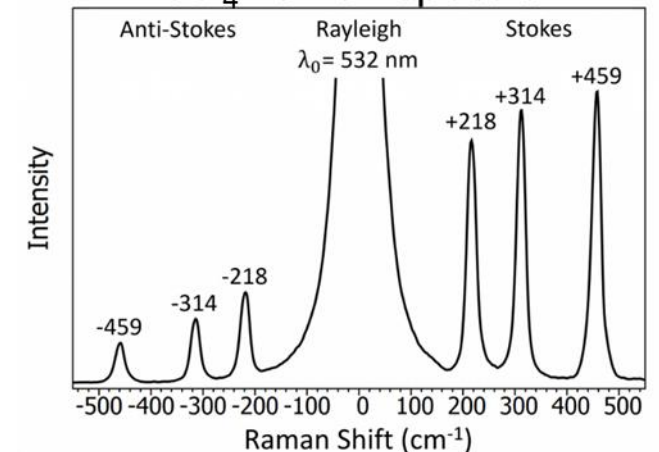
ND filter

- Attenuates the laser intensity

Typical long-pass filter transmission



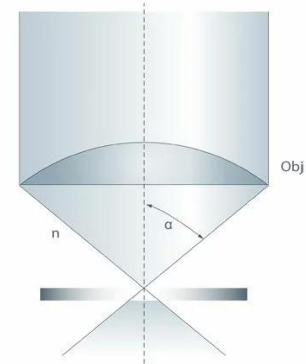
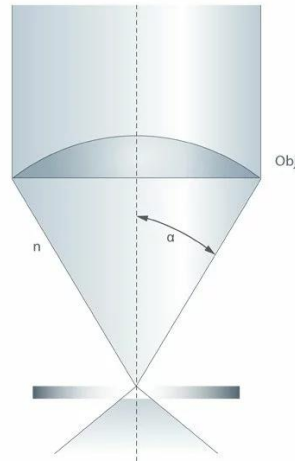
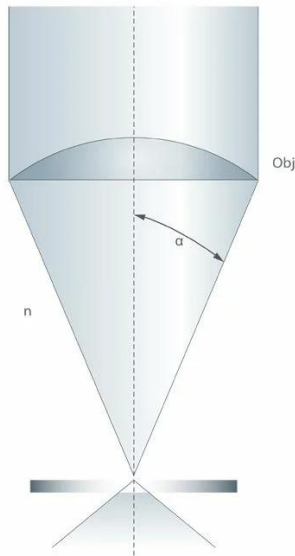
CCl_4 Raman spectrum



Objective lens



- On sample laser intensity
- Spatial resolution



Spectrometer



Slit width

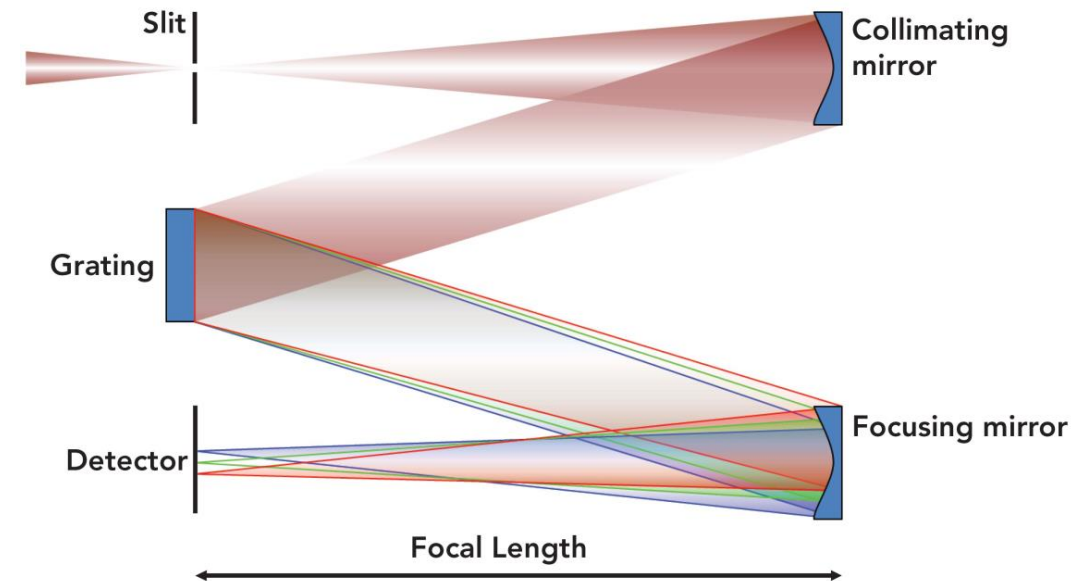
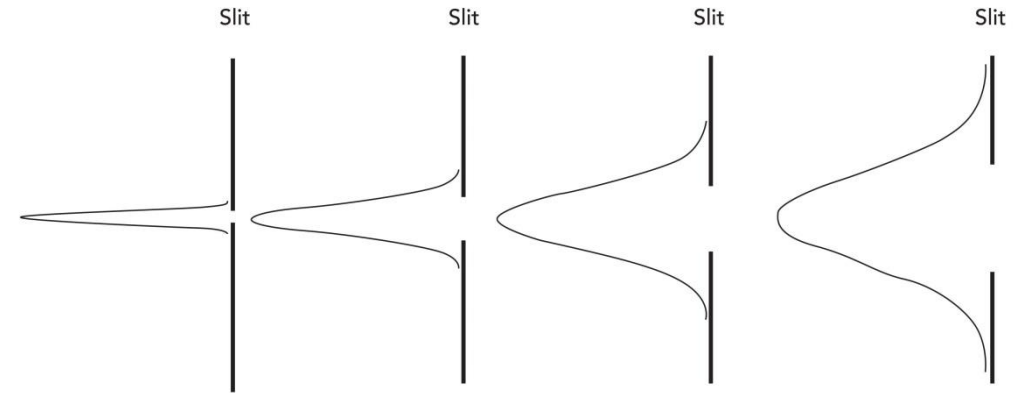
- Spectral, spatial resolution

Grating

- Spectral resolution, measurement wavelength range

CCD

- Effective wavelength range, spectral resolution

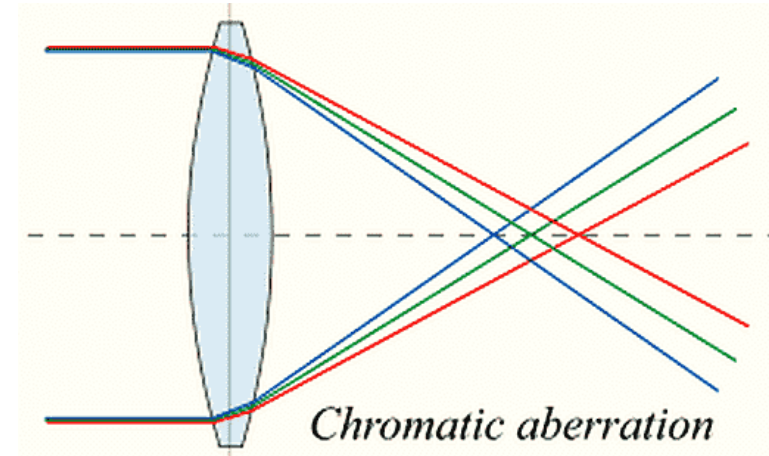
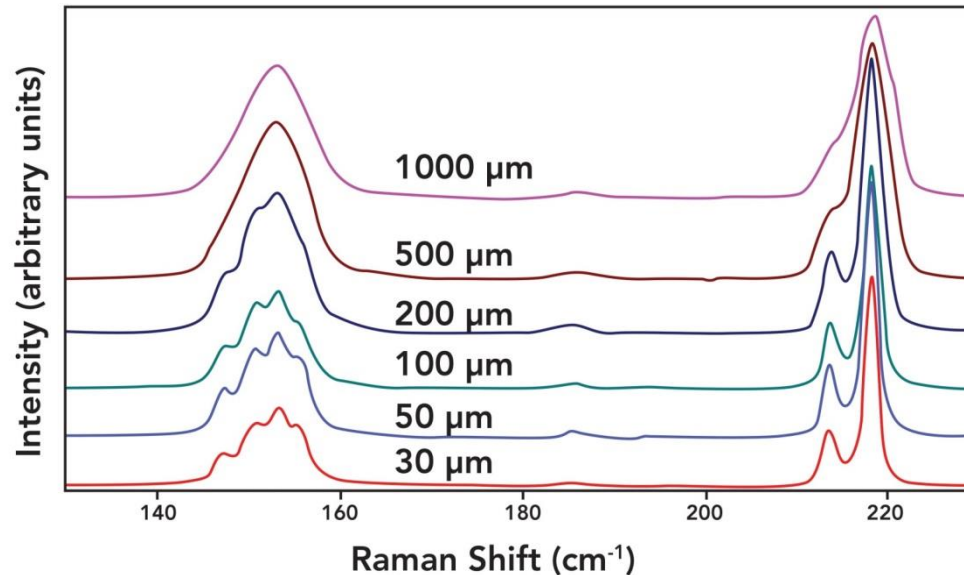


Optical Fiber



Fiber core size

- Signal intensity
- Spectral & spatial resolution



The End

Thank you