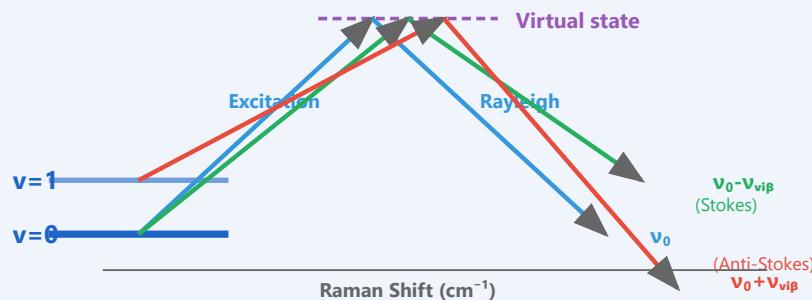


Raman Spectroscopy

Raman Scattering Energy Diagram



$$\Delta\nu = \nu_0 - \nu_s \text{scattered}$$

Raman Shift: Chemical fingerprint without labels

Stokes: Energy loss
(molecule gains vibrational energy)

Anti-Stokes: Energy gain
(less intense, temperature dependent)

Provides molecular vibrational information

Biological Applications

- Cell imaging:** Label-free analysis
- Drug distribution:** Tissue mapping
- Cancer diagnostics:** Tissue characterization
- Protein structure:** Secondary structure analysis

SERS (Surface-Enhanced)

- Enhancement:** 10^6 - 10^{14} fold
- Metal nanoparticles (Au, Ag)
- Single molecule detection possible
- Biosensing applications

Raman Imaging

- Spatial mapping of molecular composition
- Confocal Raman microscopy
- Chemical maps of cells/tissues
- Sub-micron resolution

Label-free Analysis

- No fluorophores needed
- Native state biomolecules
- Non-destructive measurement
- Real-time monitoring possible

 **SERS Enhancement: 10^6 to 10^{14} Signal Amplification**

Enables ultra-sensitive detection for biosensing and single-molecule studies