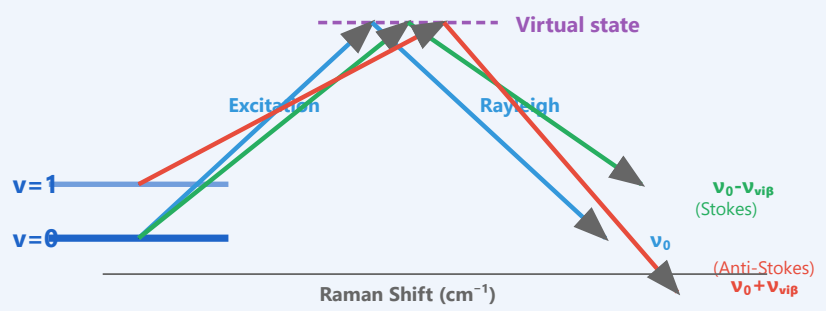
Raman Spectroscopy

Raman Scattering Energy Diagram



$\Delta\nu = \nu_0 - \nu_{scattered}$

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