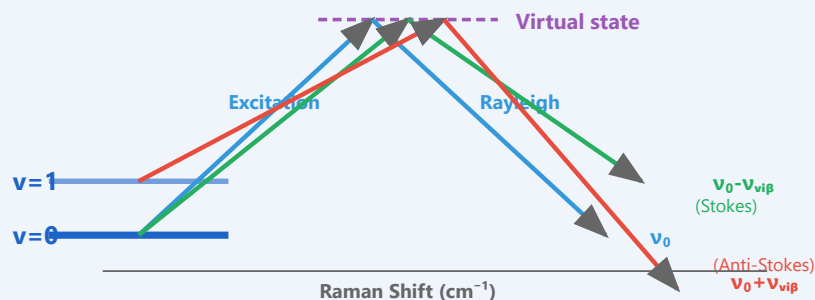


# Raman Spectroscopy

Raman Scattering Energy Diagram



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

**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