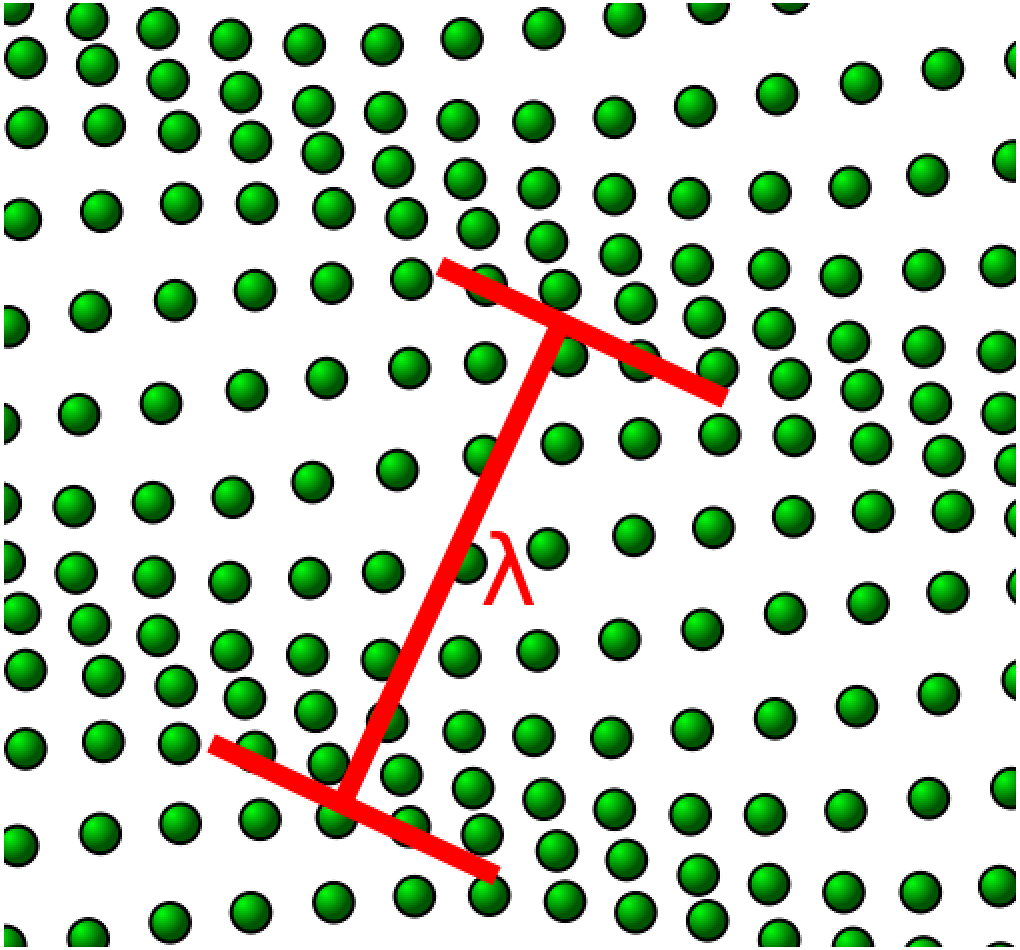
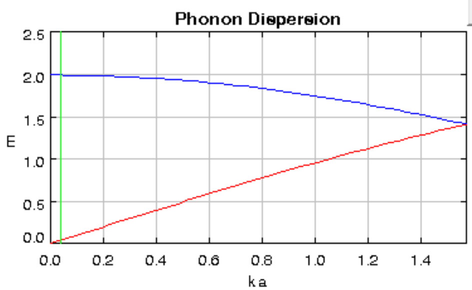
Phonons



Java Phonon Applet

Transverse Optical and Acoustic Phonon Dispersion

In the graph below, we have calculated the energy of the phonon traveling perpendicular to the lattice planes for a solid with a two-atom basis (like salt).
The vertical green line indicates the atom separation divided by phonon wavelength. Move the bottom slide bar at the right to change the wavelength. Move the top slide bar to vary the relative masses of the atoms.



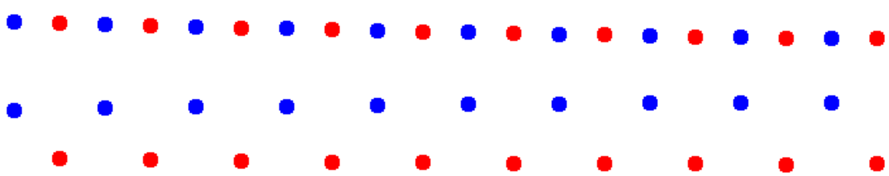
fill

Mass Ratio = 1.01

k a = 0.04

Stop | Start

Acoustic Mode

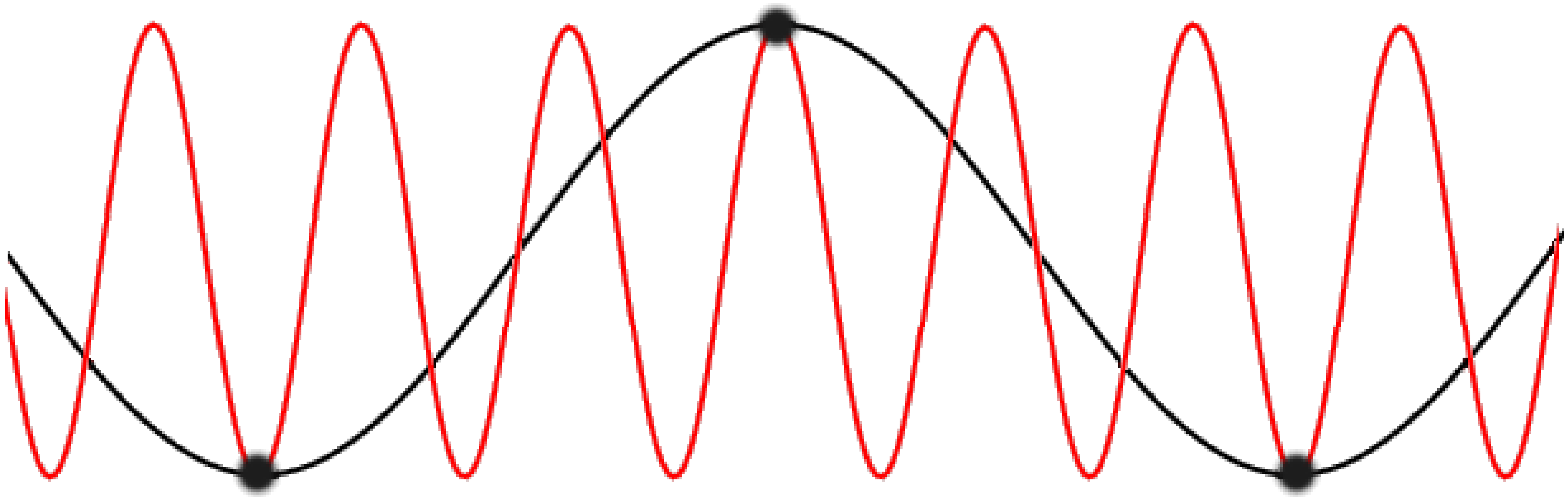


Optical Mode

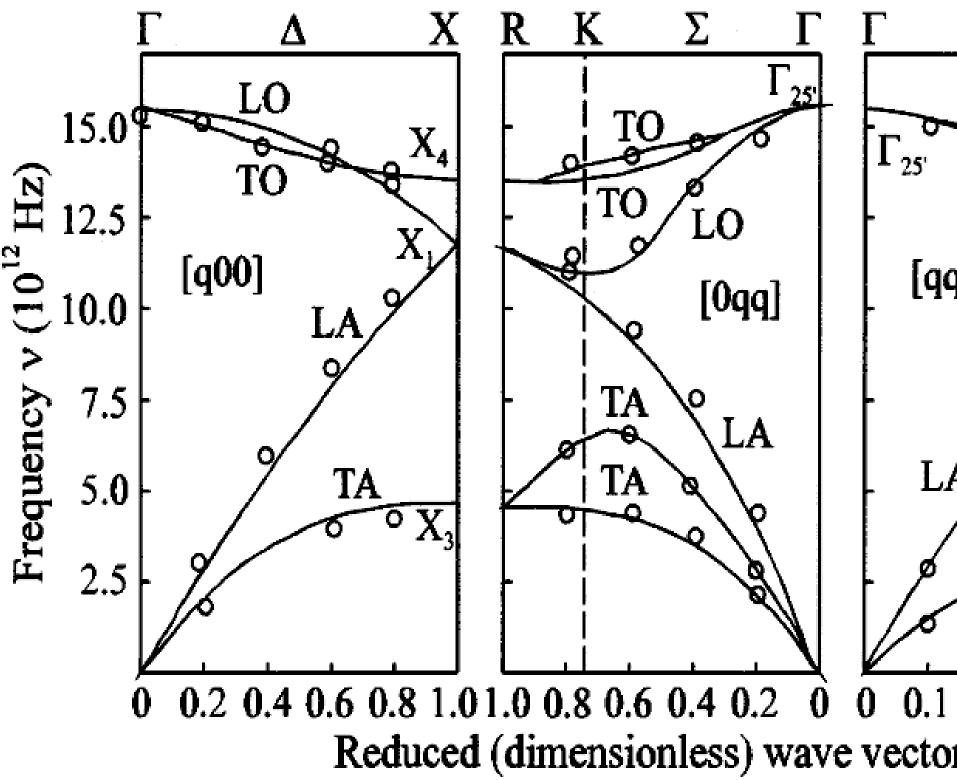
This Applet developed by Michael A. Lee and Kevin E. Schmidt.

Last modified April 13, 2000.

Wavevectors of phonons outside 1BZ are meaningless



Phonon dispersion of Si (fcc)



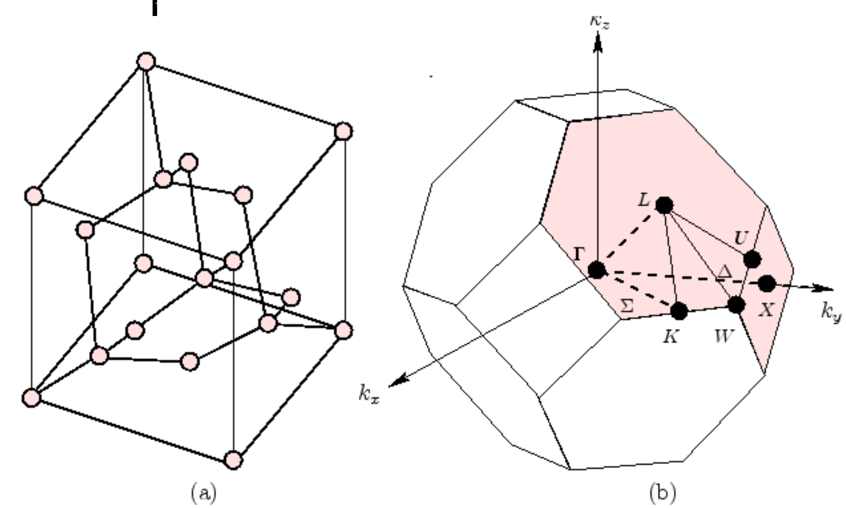


Figure 3.4: (a) Structure of the fcc Si crystal lattice.(b) Brillouin zone of a fcc lattice with the notation for special symmetry direction and points.

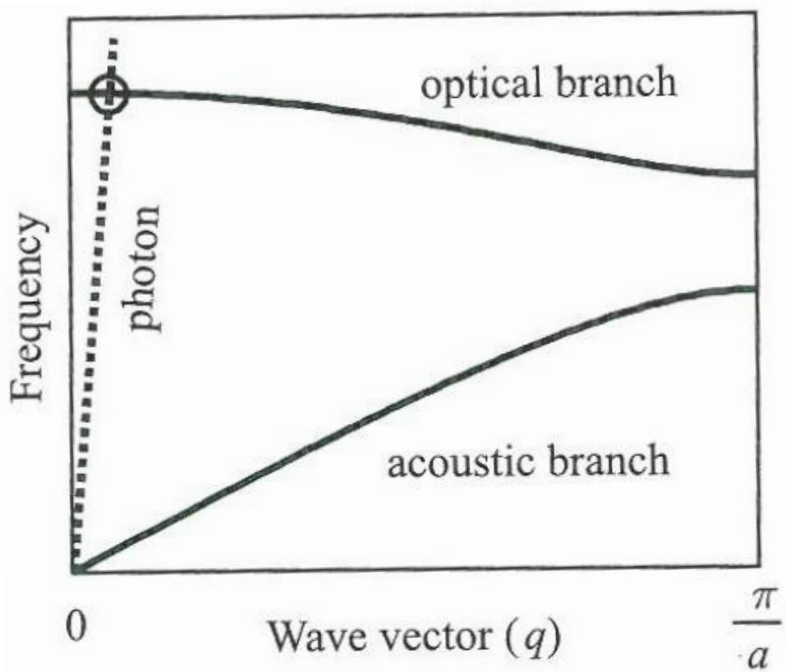
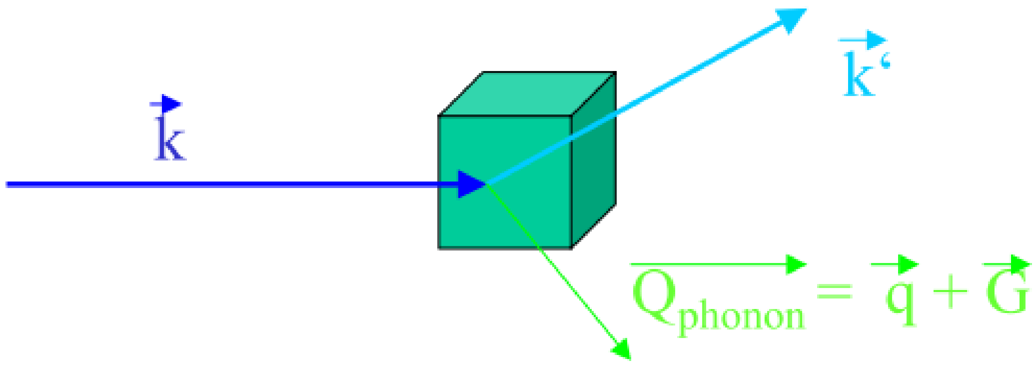
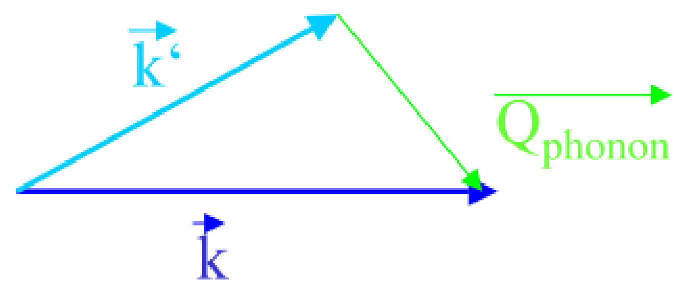


Fig. 10.2 Dispersion curves for the acoustic and optical phonon branches in a typical crystal with a lattice constant of a. The dispersion of the photon modes in the crystal is shown by the dotted line.

Wechselwirkung und Streugesetze



Streudreieck:



$$\text{Impuls:}\quad \vec{Q} = \vec{k} - \vec{k}'$$

$$E = \frac{\hbar^2 \cdot k^2}{2 \cdot m}$$

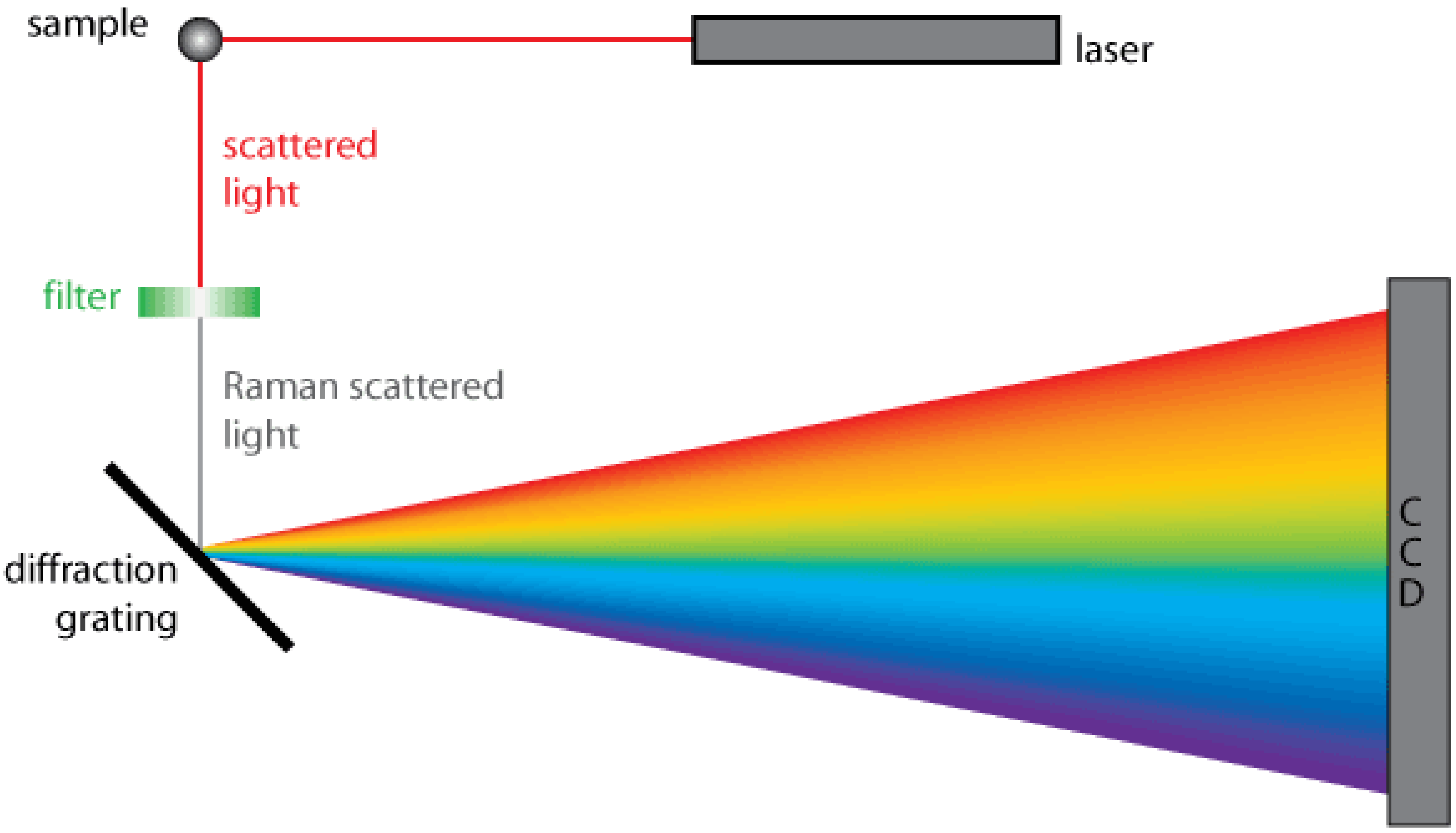
$$\text{Energie:}\ E = E' + E_{\text{Phonon}}$$

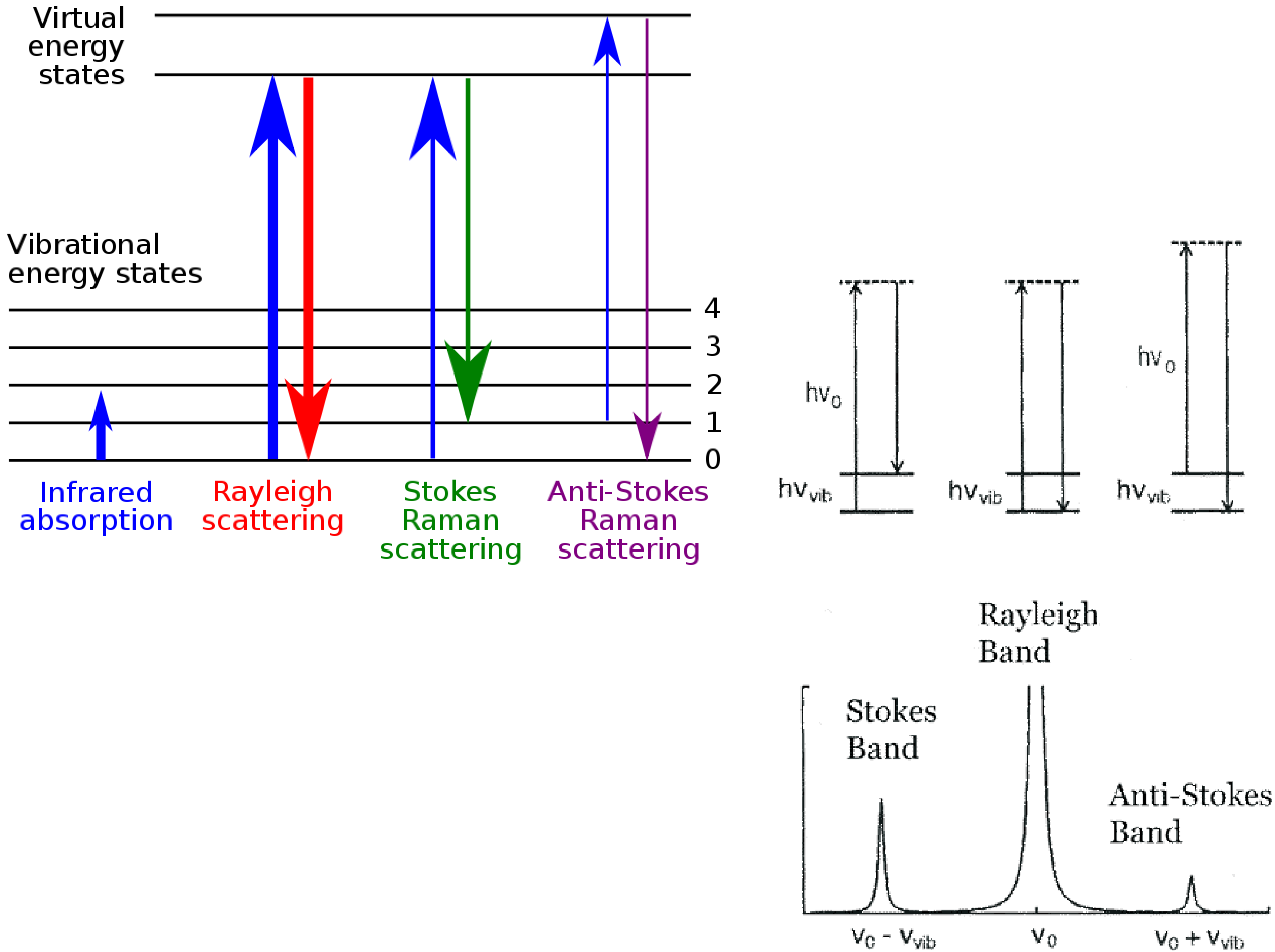
$$E_{\text{Phonon}} = \hbar \cdot \omega = \frac{\hbar^2}{2 \cdot m} \cdot (k^2 - k'^2)$$

Spin : Gesamt - Spin vorher und nachher

Nobel price in physics 1930 " for his work on the scattering of light and for the discovery of the effect named after him"

Raman spectrometer





Virtual energy states
Vibrational energy states
4
3
2
1
0
Infrared absorption
Rayleigh scattering
Stokes Raman scattering
Anti-Stokes Raman scattering
hν0
hνvib
hν0
hνvib
hν0
hνvib
Rayleigh Band
Stokes Band
Anti-Stokes Band
ν0 - νvib
ν0
ν0 + νvib

Stokes / Anti-Stokes

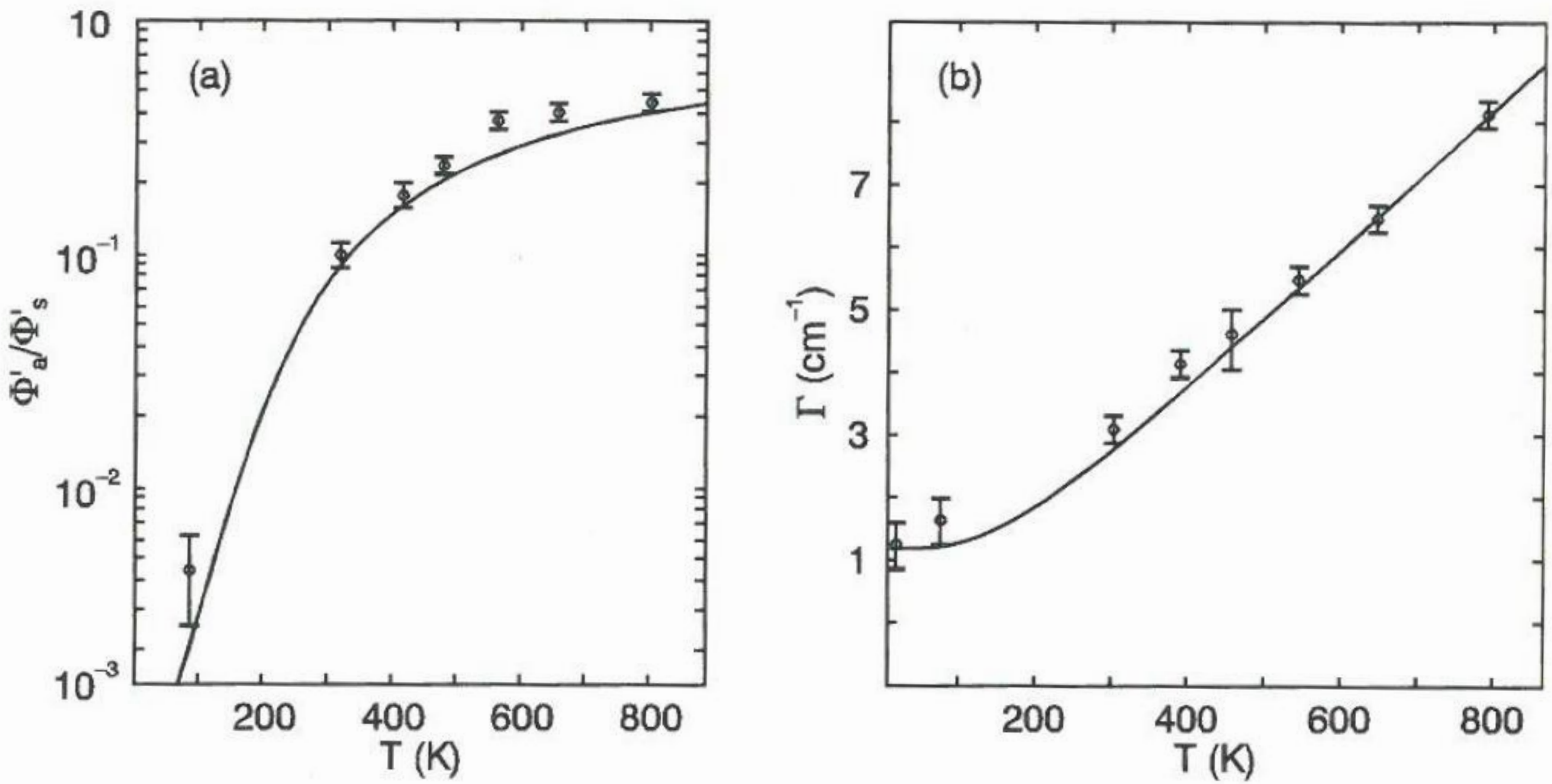


Fig. 9.12. Ratio of antiStokes to Stokes Raman intensities for Si versus temperature; (•): experiment, (—): calculated from (9.34) (**a**), and width of the Raman line in Si versus temperature; (•): experiment, (—): calculated (**b**); after [9.5].

Raman spectrum of GaAs

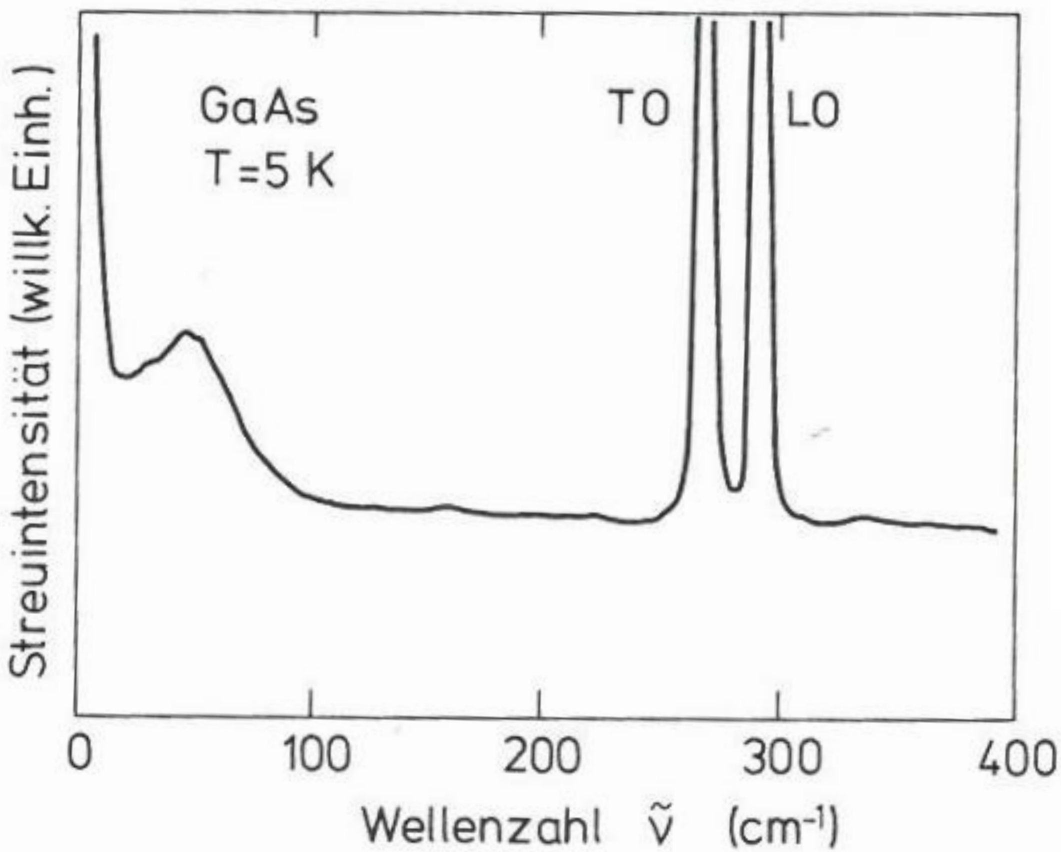
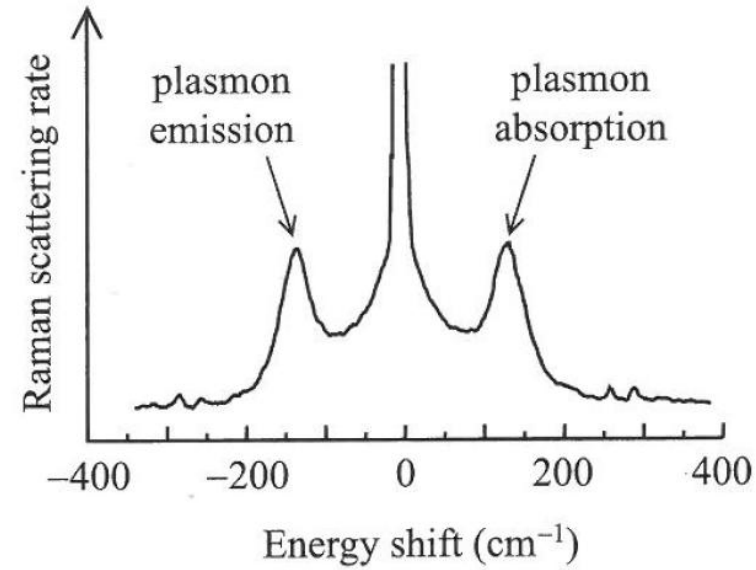
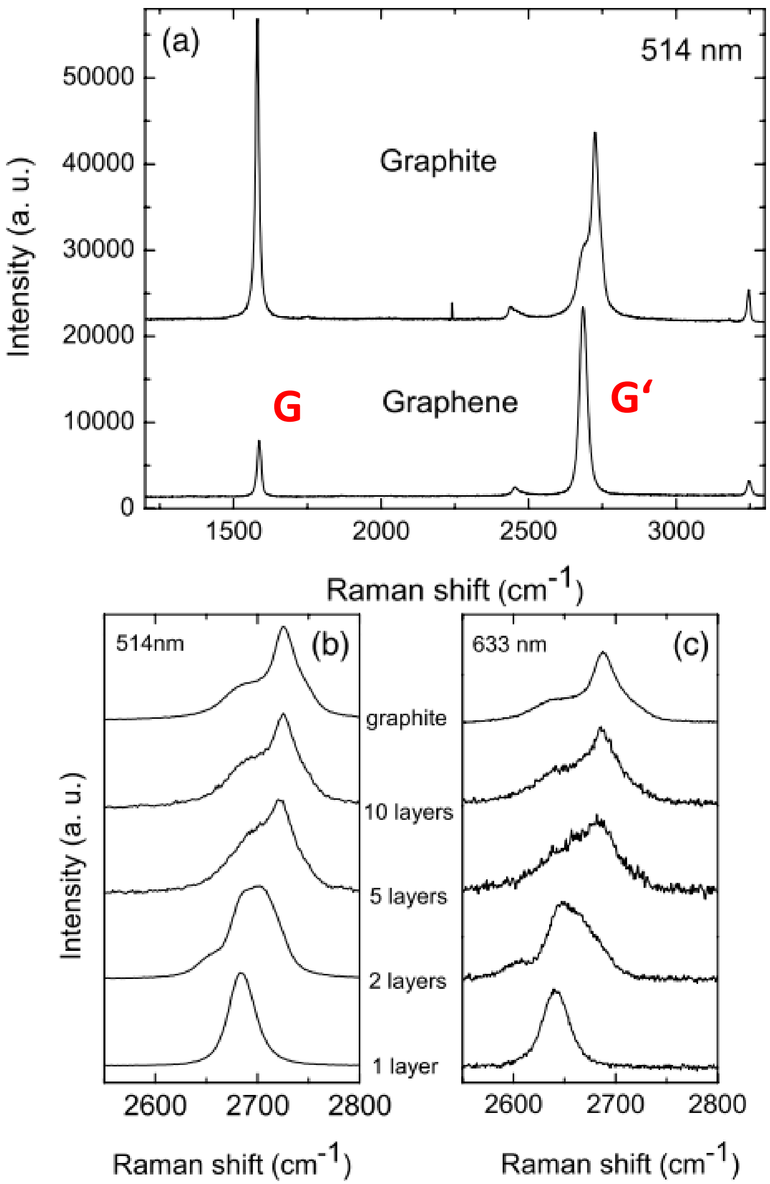


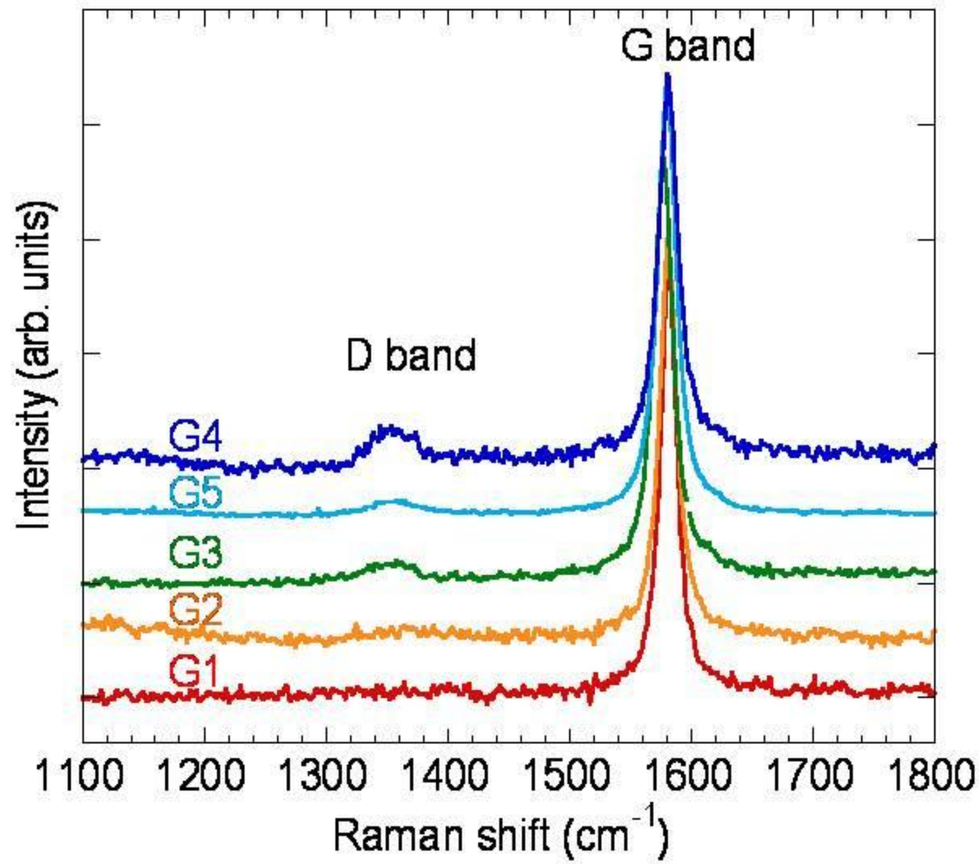
Abb. III.3. Raman-Spektrum, aufgenommen an *n*-dotiertem GaAs bei 5 K Probentemperatur (Konzentration freier Elektronen $n \approx 10^{16}\,\mathrm{cm}^{-3}$); TO und LO bezeichnen transversal bzw. longitudinal optische Phononen. Die Bande bei $40\,\mathrm{cm}^{-1}$ rührt im wesentlichen von Plasmon-Anregungen her. (Nach Mooradian [III.3])



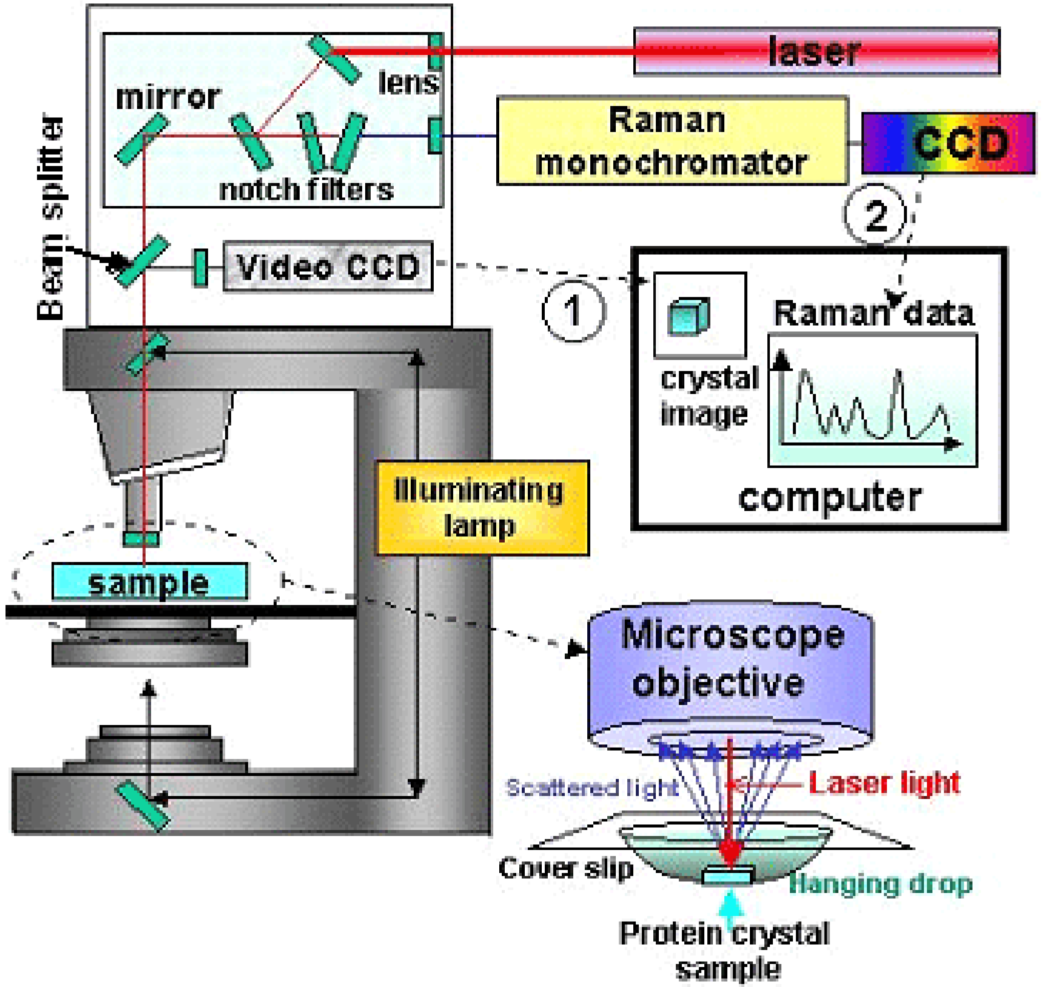
Different plasmon frequency due to different charge carrier concentration (doping)

Raman spectra of graphene



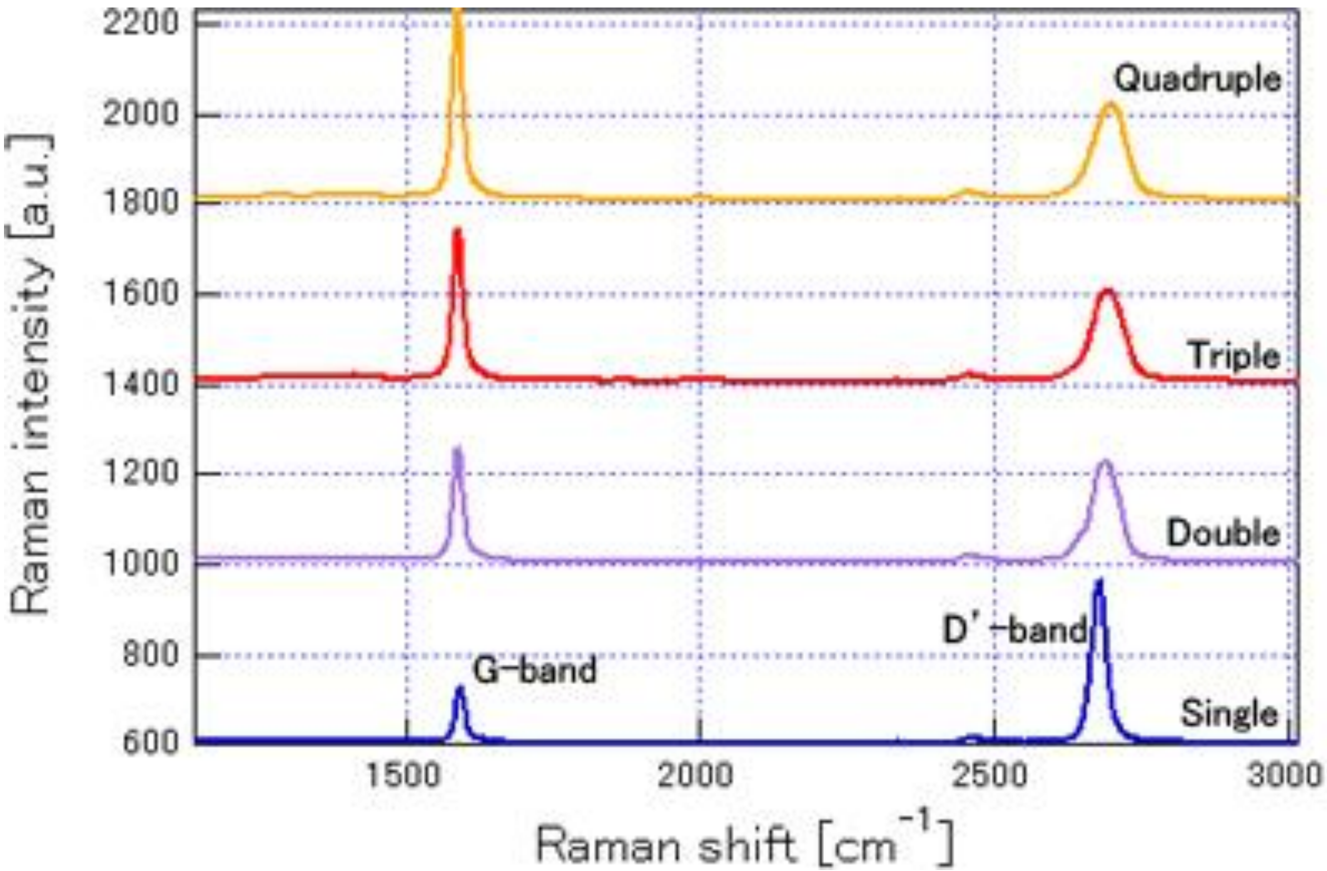


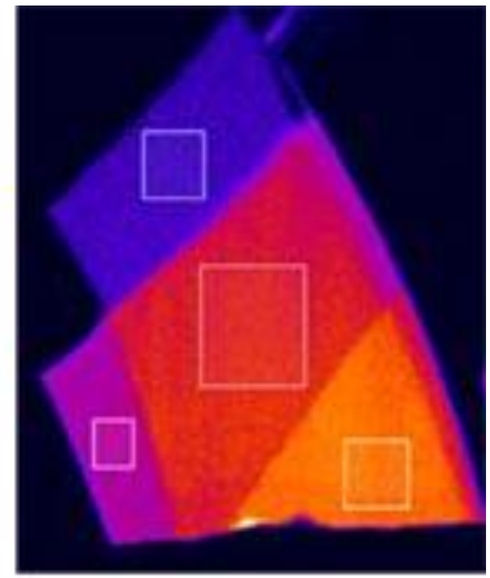
Raman microscope



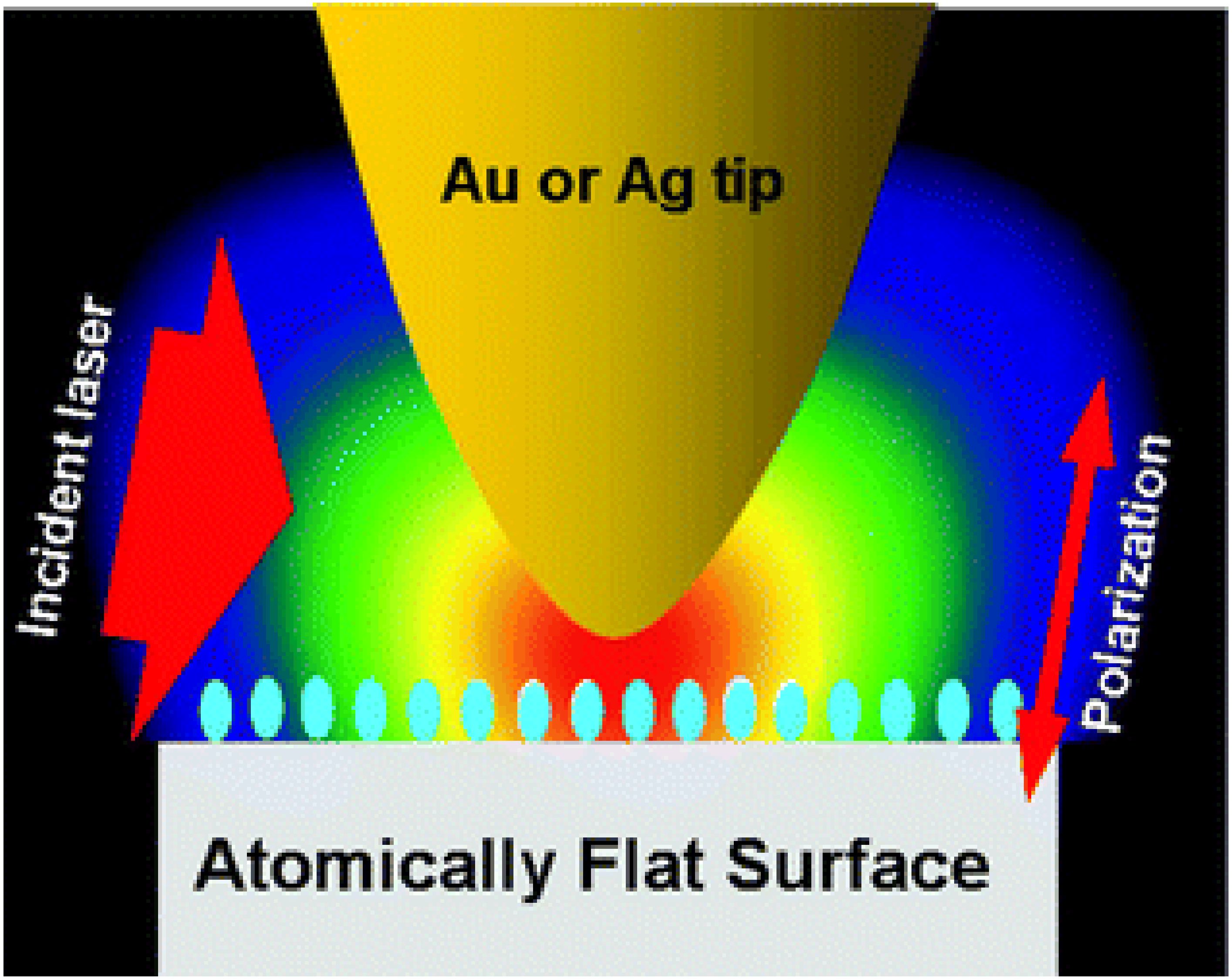
Schematic drawing of a Raman microscope (not to scale) and Raman microscopy of a single protein crystal.

Raman microscopy of graphene





Tip enhanced raman spectroscopy (TERS)



TERS - example

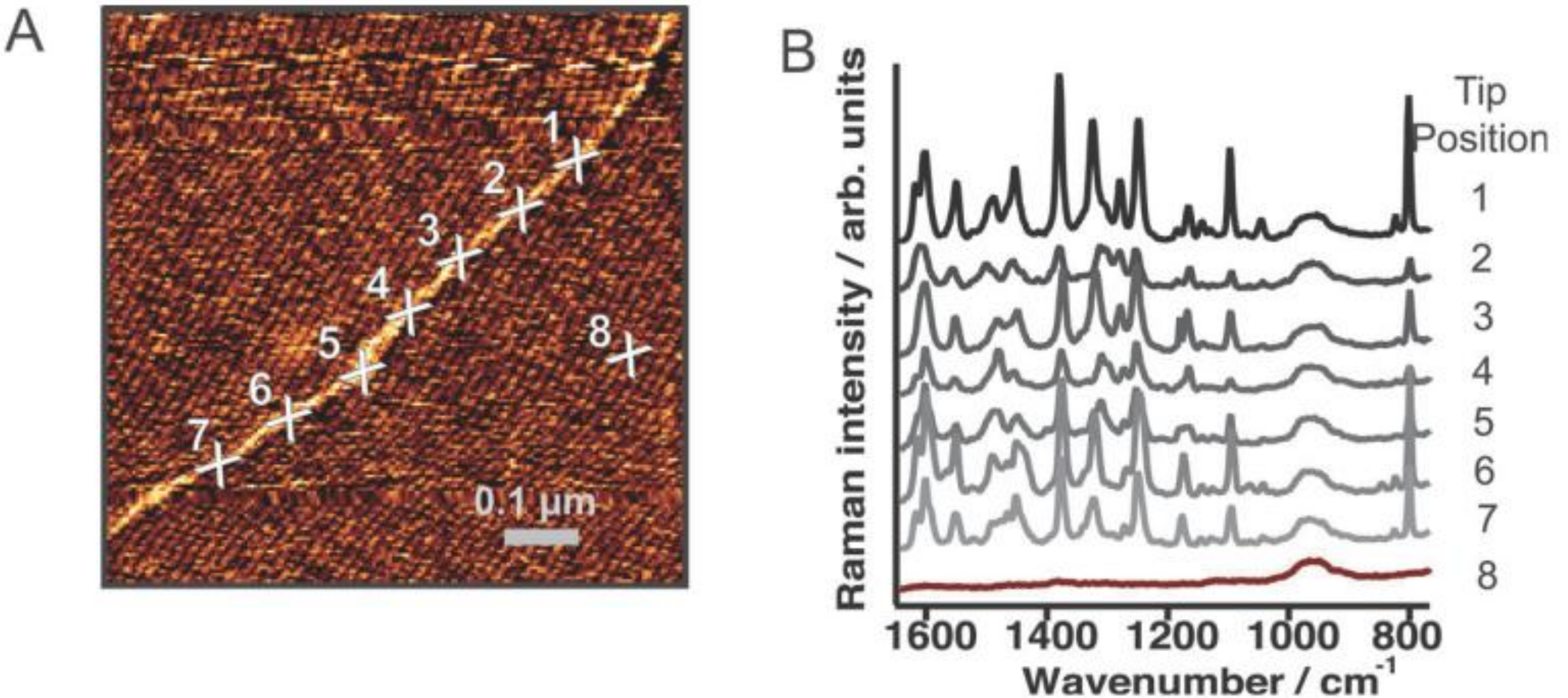


Fig. 14 TERS experiment along a RNA strand. (A) Topographic image (same as Fig. 13A). (B) TERS spectra at the seven adjacent (1–7) spots correspondingly marked in (A), position 8 marks a reference measurement. Adapted from ref. 34.

Polariton in GaP

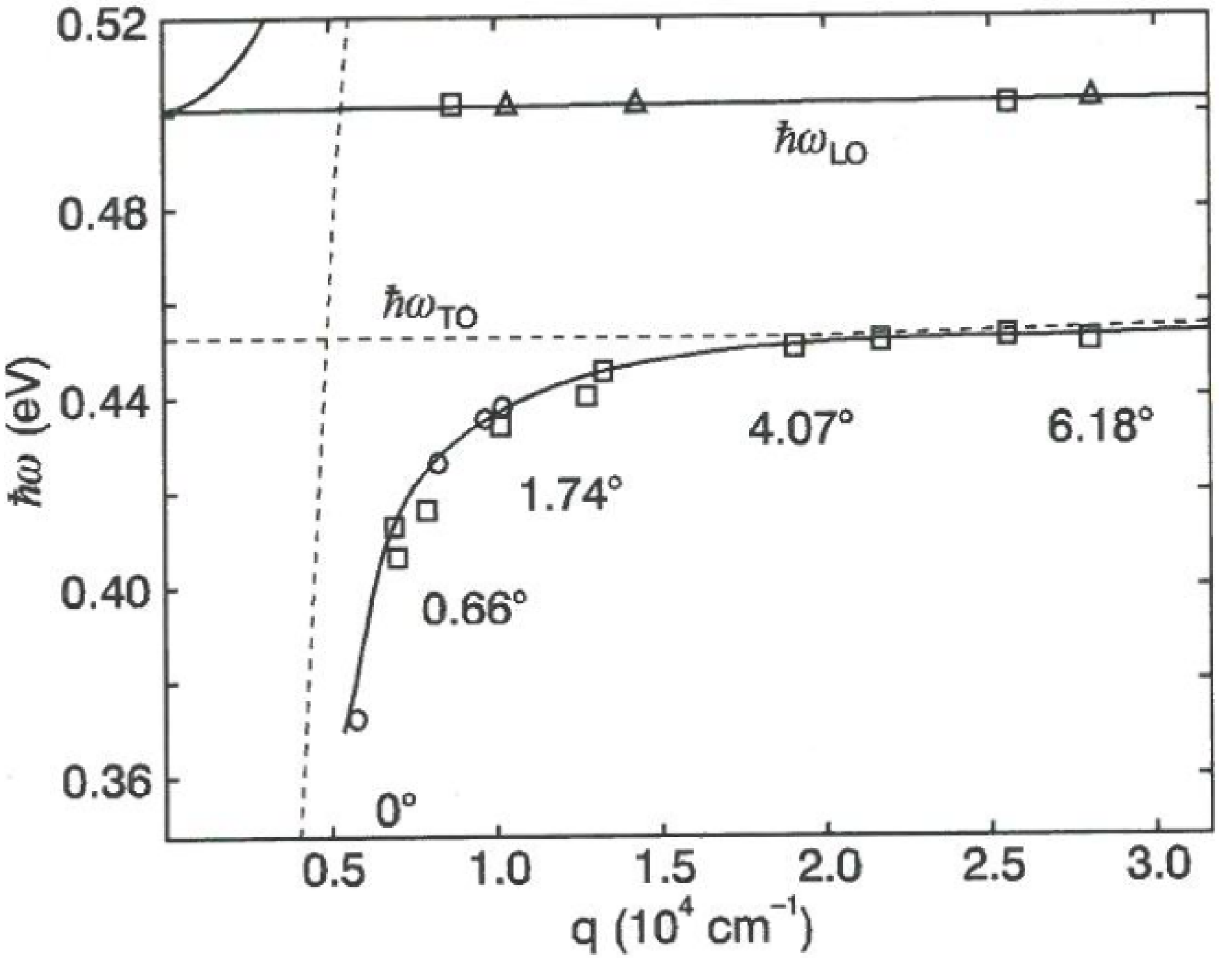
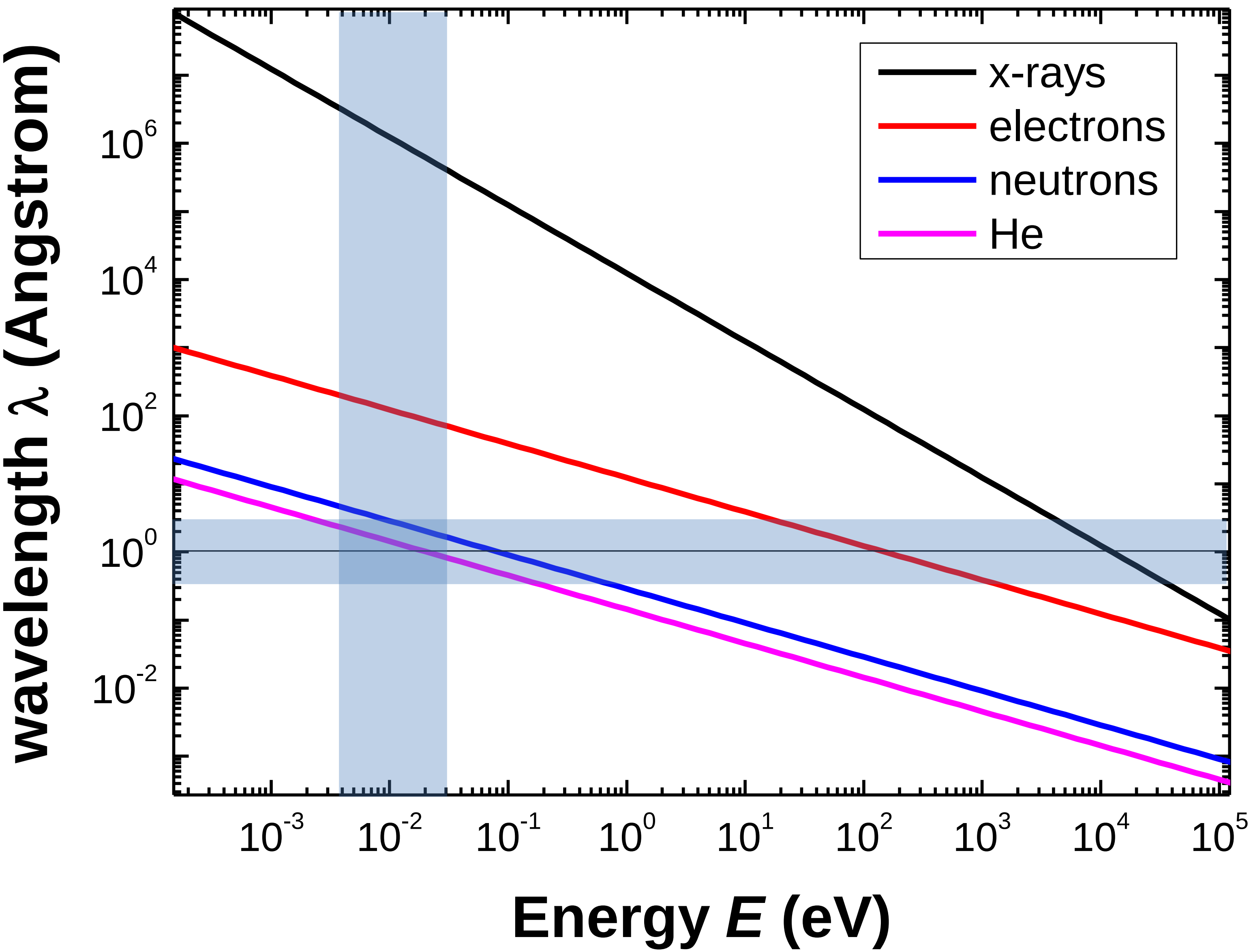
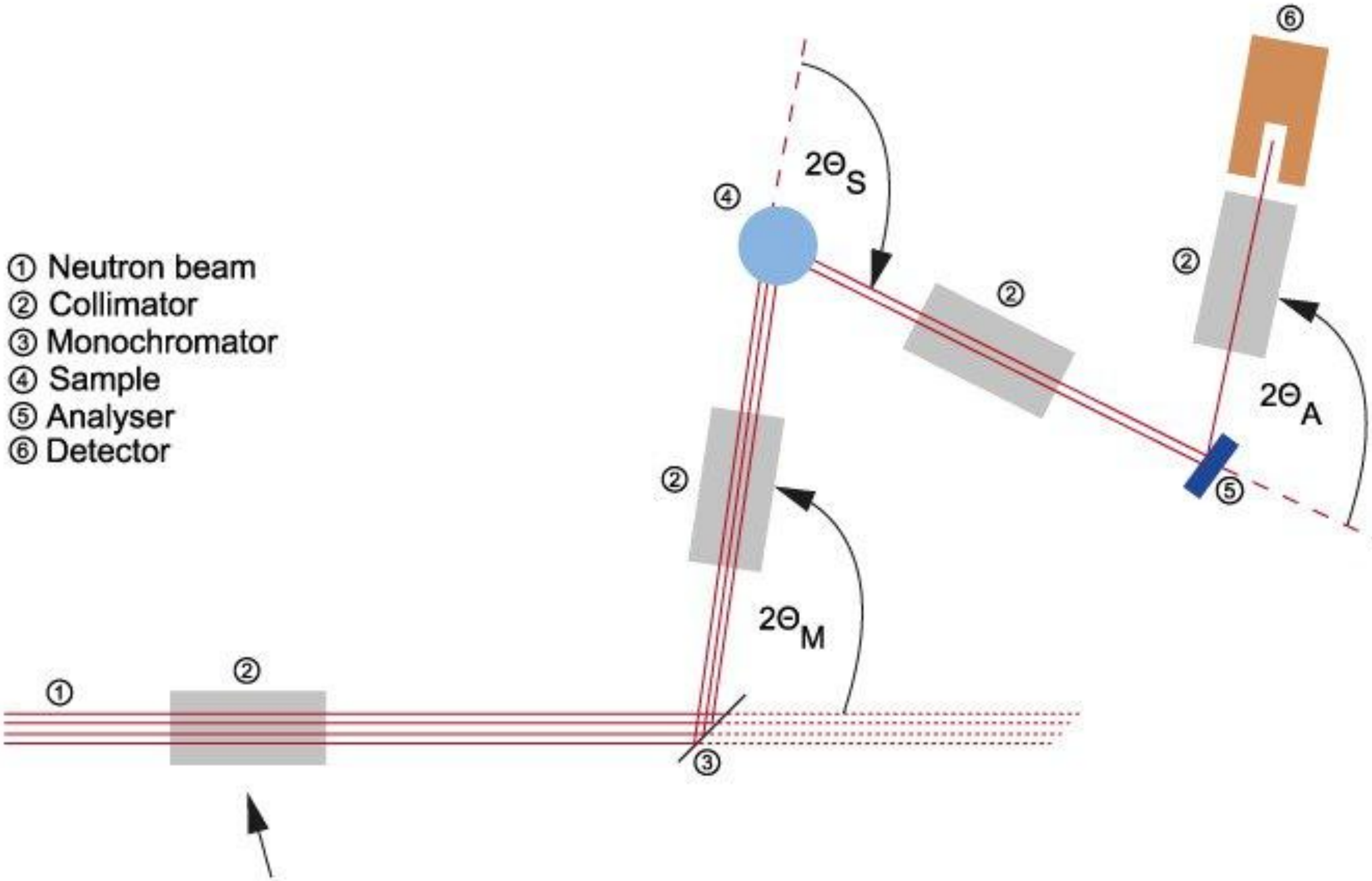


Fig. 9.10. Polariton dispersion of GaP as measured by Raman scattering in the forward direction. The dashed lines give the dispersion for the uncoupled photons and phonons. The angles indicated refer to the scattering geometry; after [9.4].

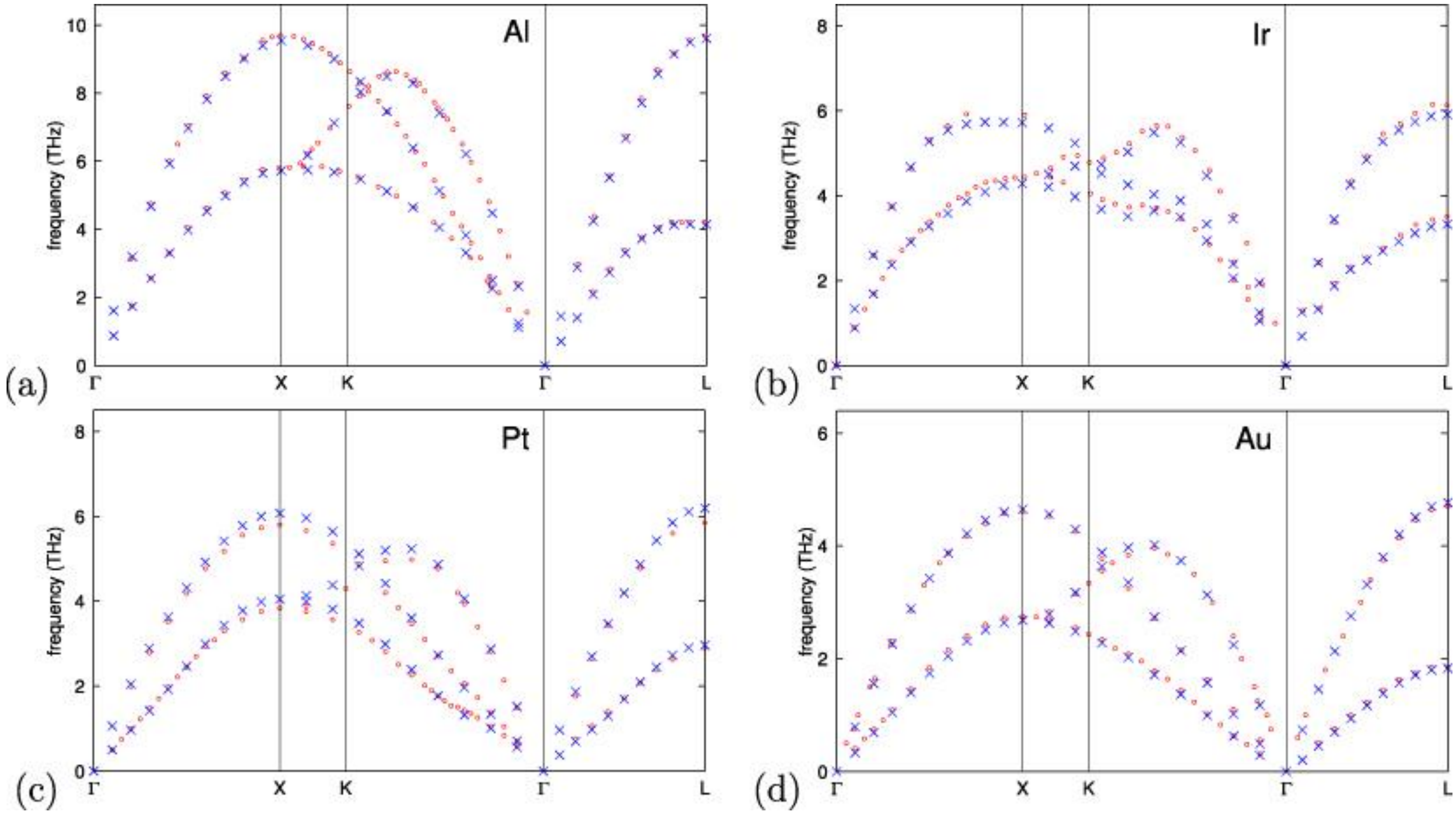


x-rays
electrons
neutrons
He
wavelength λ (Angstrom)
10^6
10^4
10^2
10^0
10^-2
10^-3
10^-2
10^-1
10^0
10^1
10^2
10^3
10^4
10^5
Energy E (eV)

Three axis spectroscopy

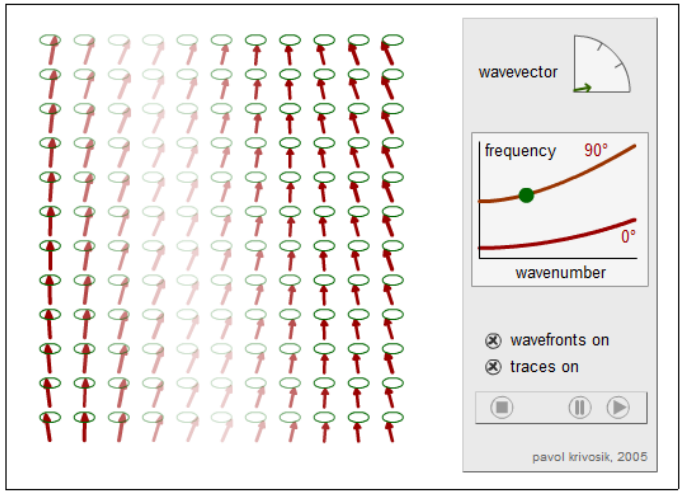


Inelastic neutron scattering



o: experiment
x: theory

Spin Wave Basics



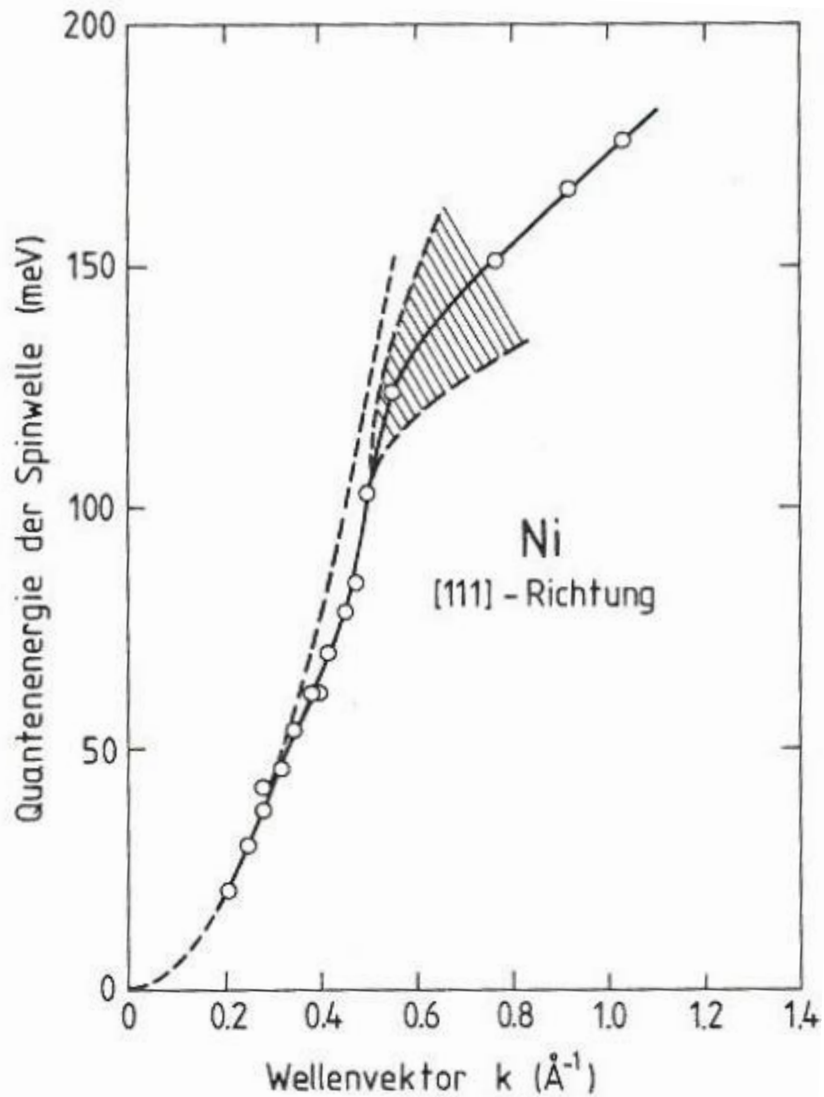
Spin wave is a propagating, wave-like excitation of magnetic moments in a magnetic sample. This animation illustrates the basic concept of this phenomena in an infinite isotropic medium. For a brief introduction and theoretical background see "Magnetic excitations in solids," C. E. Patton, Phys. Rep. 103, 251 (1984), Section 2.1.

Due to various interactions between magnetic moments, the frequency of their precession in an external magnetic field depends on the wavevector of the spin wave. This dependence is called a *spin wave dispersion*. In this example, all moments (dark red arrows) are initially aligned along the magnetic field direction that points "up".

Start animation with a "play" button. Yo can pause () or stop () animation at any time. You can now change the wavevector of the propagating wave by dragging a dark green arrow in the circular sector labeled "wavevector". You can see wavefronts that propagate in the direction of the wavevector (these are nicely visible for a propagation under 45 degrees). The wavelength of the spin wave is inversely proportional to the magnitude of the wavevector (wavenumber). For a zero wavenumber the wavelength is infinite and the spin wave becomes *uniform precession*. Below the wavector sector is a sketch of the spin wave dispersion for an infinite isotropic media. Lines represents limits of the direction of the wavevector propagation with respect to the field. The bottom line represents spin waves that propagate in the direction of the field (at 0° angle). The top line corresponds to spin waves that propagate perpendicularly to the direction of the magnetic field (90°).

Example: Magnon in Ni

Abb. 8.13. Experimentelle Werte für die Dispersion von Spinwellen an Nickel in [111]-Richtung nach Mook und Paul [8.6]. Die Messungen erfolgten bei $T = 295$ K. Die gestrichelte Linie zeigt eine Abhängigkeit der Quantenenergie proportional zu k^2. Abweichungen davon ergeben sich infolge der Austauschwechselwirkung auch zwischen entfernteren Nachbarn und bei Eintritt in den Bereich der Einelektronenanregungen. Die verkürzte Lebensdauer der Spinwellen führt dann zu einer Lebensdauerverbreiterung der Spektren (*schraffierter Bereich*)



Magnon by inelastic neutrons: α-$MnMoO_4$