Optical Absorption

Outline
Quantization
Photons
Electrons
Magnetic effects and Fermi surfaces
Linear response
Transport
Crystal Physics
Electron-electron interactions
Quasiparticles
Structural phase transitions
Landau theory of second order phase transitions
Superconductivity
Exam questions
Appendices
Lectures
Books
Course notes
TUG students
Making presentations

Optical properties of insulators and semiconductors

In an insulator, all charges are bound. By applying an electric field, the electrons and ions can be pulled out of their equilibrium positions. When this electric field is turned off, the charges oscillate as they return to their equilibrium positions. A simple model for an insulator can be constructed by describing the motion of the charge as a damped mass-spring system. The differential equation that describes the motion of a charge is,

$$m\,\frac{d^2x}{dt^2} + b\,\frac{dx}{dt} + kx = -qE.$$

Rewriting above equation using $\omega_0 = \sqrt{\frac{k}{m}}$ and the damping constant $\gamma = \frac{b}{m}$ yields,

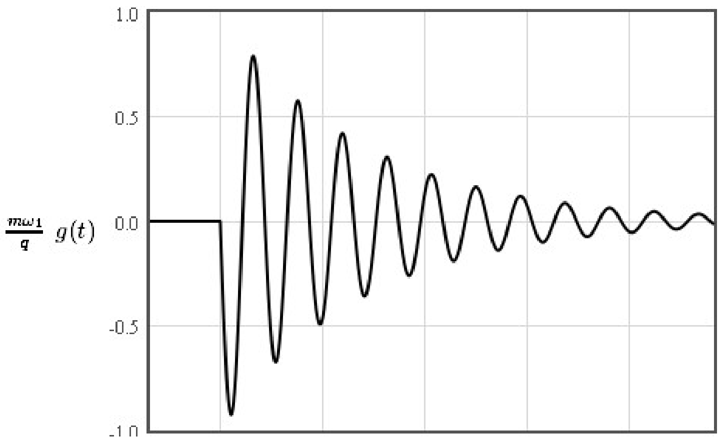
$$\frac{d^2x}{dt^2} + \gamma\,\frac{dx}{dt} + \omega_0^2 x = -\,\frac{qE}{m}\,.$$

If the electric field is pulsed on, the response of the charges is described by the **impulse response function** $g(t)$. The impulse response function satisfies the equation,

$$\frac{d^2g}{dt^2} + \gamma\,\frac{dg}{dt} + \omega_0^2 g = -\,\frac{q}{m}\,\delta(t).$$

The solution to this equation is zero before the electric field is pulsed on and at the time of the pulse the charges suddenly start oscillating with the frequency $\omega_1 = \sqrt{\omega_0^2 - \frac{\gamma^2}{4}}$. The amplitude of the oscillation decays exponentially to zero in a characteristic time $\frac{2}{\gamma}$.

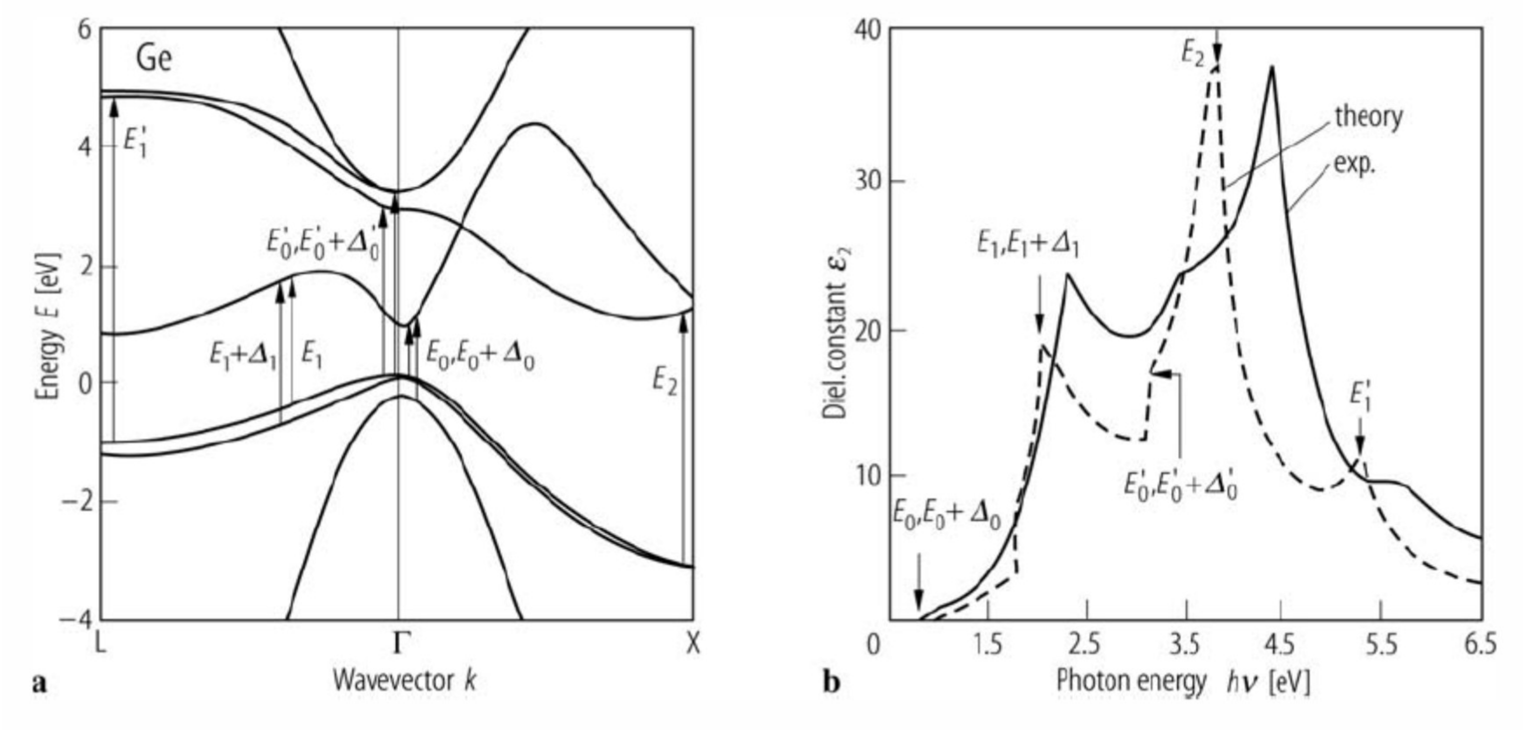
$$g(t) = -\,\frac{q}{m\omega_1}\,\exp(-\,\frac{\gamma}{2}\,t)\,\sin(\omega_1 t).$$



Inter- and intraband transitions

When the bands are parallel, there is a peak in the absorption (ε")

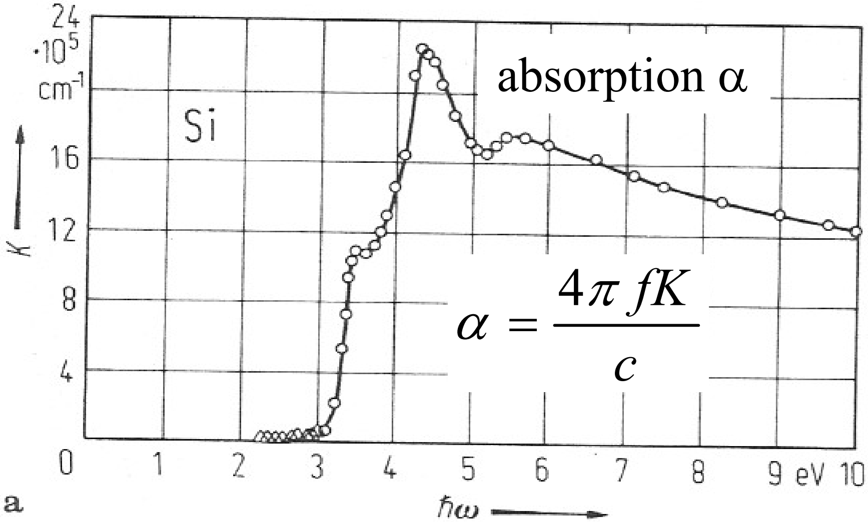
$$\hbar\omega = E_c(\vec{k}) - E_v(\vec{k})$$



Optical spectroscopy has developed into the most important experimental tool for band structure determination. - Kittel

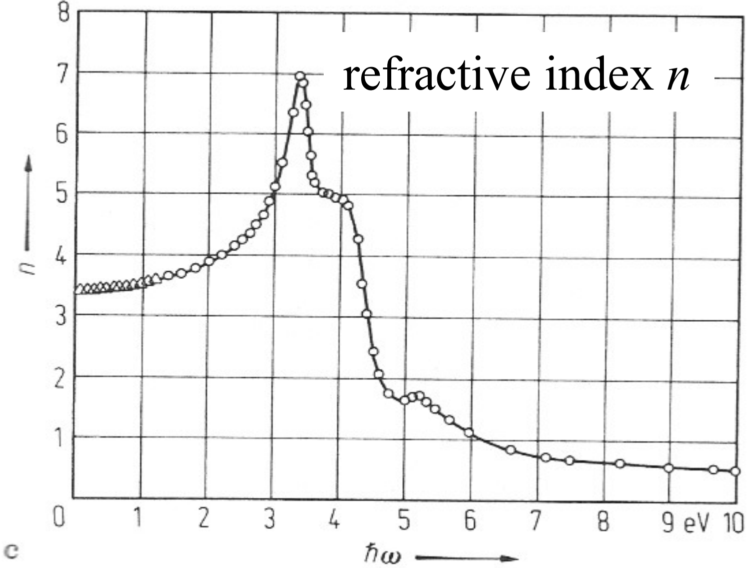
Dielectric function of silicon

$$\sqrt{\varepsilon(\omega)} = n(\omega) + iK(\omega)$$

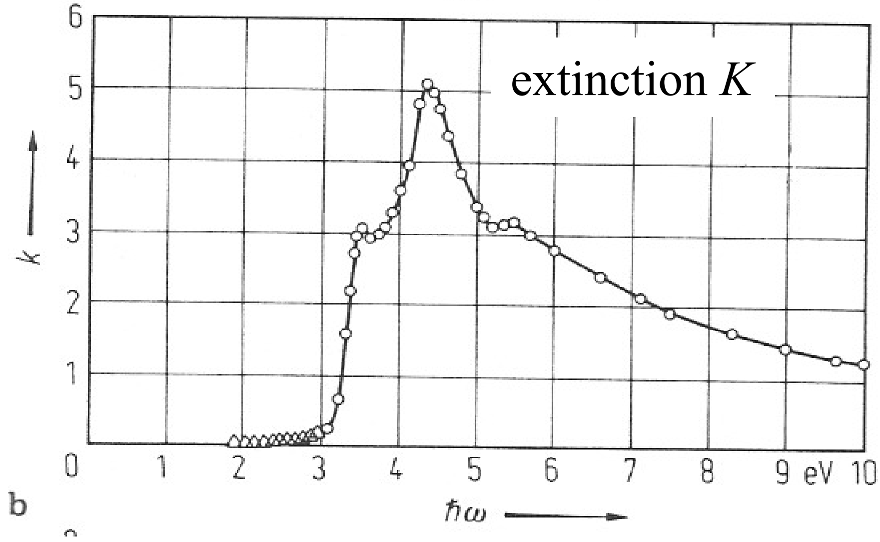


absorption α

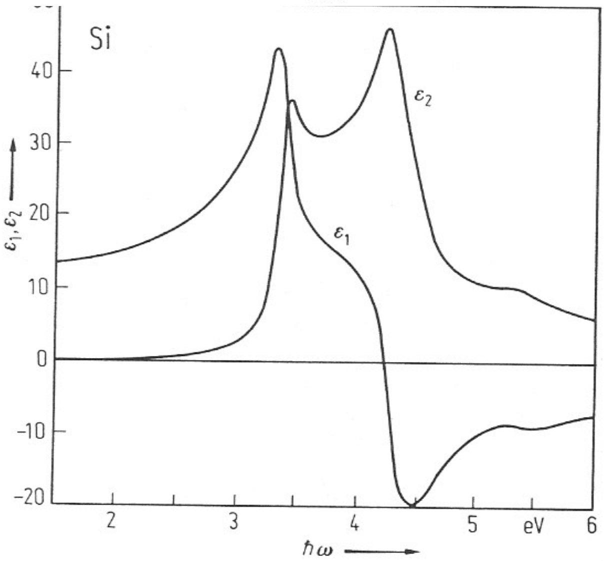
$$\alpha = \frac{4\pi f K}{c}$$



refractive index *n*



extinction *K*



Dielectric function of $BaTiO_3$