TECHNISCHE UNIVERSITÄT WIEN
Fakultät für Elektrotechnik und Informationstechnik
Prof. Dr. Gottfried Strasser

Vorlesung: Do 10:15h - 12:00h, EI 9 Hlawka HS
Übungen: Do 13:00h - 18:00h, Seminarräume 351 (Gusshausstraße 27-29) & 362 (Floragasse 7)

Halbleiterphysik

Wintersemester 2017/18

Übungsblatt 2

(all exercises with documents)

Example 5: Photoelectric effect

Nickel has a work function of $W_A = 4.6\,\mathrm{eV}$ and is illuminated by monochromatic light.

a) Explain the photoelectric effect by means of a sketch (kinetic energy of the electrons vs. frequency of light)

b) How large is the veloctiy of the photons and electrons for $\lambda = 250\,\mathrm{nm}$.
(Hint: $h = 6.626 \cdot 10^{-34}\,\mathrm{m^2 kg/s}$ and $m_e = 9.11 \cdot 10^{-31}\,\mathrm{kg}$)

c) How large is the outgoing electric current assuming a luminous power of $10\,\mathrm{mW}$ and a wavelength of $\lambda = 250\,\mathrm{nm}$? Consider an energy conversion efficiency of 2%.

Example 6: Reflection

A radiowave is given by:

$$E_i(x,t) = E_0 \sin\left(\frac{2\pi}{\lambda}(x - c_0 t)\right). \tag{1}$$

It possesses an electric field strength of $E_0 = 1\,\mu\mathrm{V/cm}$ and a wavelength of $\lambda = 3\,\mathrm{m}$. Coming from $x = -\infty$ the wave impinges at $x = 0$ upon a metallic boundary and is totally reflected.

a) Which general mathematical ansatz is required for the reflected wave $E_r(x,t)$?

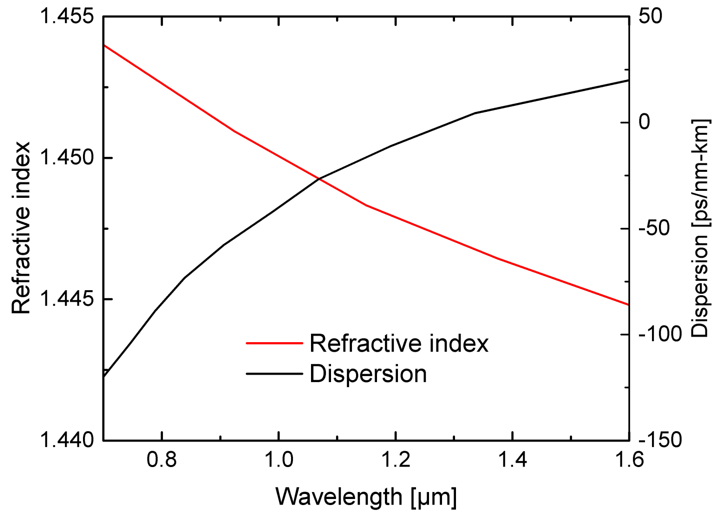
b) Demonstrate that the superposition of the incoming and reflected wave results in a standing wave for $x < 0$.
(Hint: The reflected field needs to disappear in the metal.)

c) What are the distances between nodes and antinodes of the wave and the boundary?

d) How large is the electric field in the nodes and antinodes?

Example 7: Dispersion in a waveguide

A light pulse with a central wavelength of $\lambda = 1.1\,\mu\text{m}$ propagates within a waveguide with the following dispersion relation:



a) Estimate the phase velocity directly from the graph.

b) Determine the group velocity. Therefore, formulate the term $1/v_g$ and extract the slope of the refractive index $dn/d\lambda$ from the graph.

c) At the beginning the light pulse possesses a duration of $\tau_p = 10\,\text{ps}$. The width of the frequency spectrum is given by the Fourier analysis as follows $\Delta\omega = 1/\tau_p$. How long is the pulse after $s = 50\,\text{km}$ with the waveguide paramter $\frac{d^2k}{d\omega^2} = 15\,\text{ps}^2/\text{km}$? The resulting pulse width is given by $\Delta t = t_1 - t_2$ mit $t_i = \frac{s}{v_{g,i}}$, $i = 1, 2$.

Example 8: Infinite square well potential

An electron is located in an infinite square well potential (V$\rightarrow \infty$) with a width a.

(a) Provide the solution of the time-independent Schrödinger equation in the well for the 3 lowest eigenenergies Ψ_1, Ψ_2 und Ψ_3 (without scaling)? Sketch the wavefunctions.

(b) Since the Hamilton operator is Hermitian, the eigenfunctions are orthogonal to each other. This means

$$\int_{-\infty}^{\infty} \varphi *_n (x)\varphi_m(x)dx = 0 \tag{2}$$

for $m \neq n$. Calculate the scaling of the eigenfunctions if the solutions of the Schrödinger equation are not only orthogonal but also orthonormal. This is that the integral in equation 2 equals 1 for $m = n$.
Hint: Substitute $2 \cdot \sin^2(x) = 1 - \cos(2x)$.