

Solid State Optics

Lukas Hein, Elias Schwarzkopf

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Versuchsdurchführung: ?? . ?????

Protokollabgabe: ?? ??

1 Introduction

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2 Theory

2.1 Plane parallel layer

The investigated semiconductor samples can in first approximation be described as a plane parallel layer 1 with a thickness d and refractive index N_2 which acts like a fabry-perot interferometer. Light is simplified

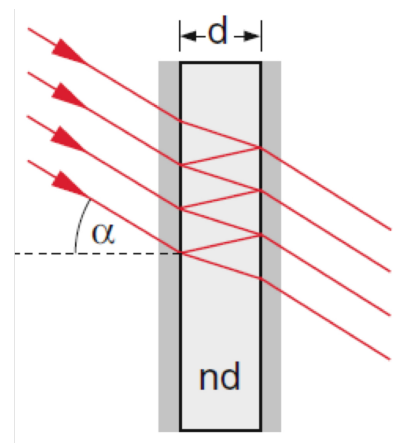


Abbildung 1: Simplified illustration of the measured samples as a plane parallel plate with thickness d and refractive index N_2 . The surrounding air is described with a refractive index $N_1 \approx 1$ [?]

as beams. Every incoming beam is partially reflected and partially transmitted at the first interface. The total power reflectivity R_1 is described with:

$$R_1 = \left| \frac{1 - N_2}{1 + N_2} \right|^2 \quad (1)$$

without considering the phase shift of the reflected beam. Like shown in the illustration, the total power reflectivity of the second interface R_2 consists of the incoming beams and the beams reflected at the first interface within the material. Additionally, the absorption of the material is considered. Therefore, R_2

is described with:

$$R_2 = R_1(1 - R_1)^2 \cdot e^{-2\beta d} \quad (2)$$

with the absorption coefficient β and the total power reflectivity R_1 of the first interface. The assumption that the reflection of the first interface is the same as the reflection of the second interface is in reality not correct. Disturbances like roughness of the interfaces or the absorption of the material lead to a different reflection coefficients of the two interfaces. Considering this and the phase of the light, the total power reflectivity R is described with:

$$R = \left| \frac{(e^{i\frac{2\omega}{c}N_2d} - 1)(1 - N_2)}{e^{i\frac{2\omega}{c}N_2d}(1 - N_2) - (1 + N_2)} \right|^2. \quad (3)$$

ω is the angular frequency of the light and c the speed of light. The phase shift of the light is described with $e^{i\frac{2\omega}{c}N_2d}$. In contrast to 2, equation 3 shows a periodic modulation of the reflectivity because of interference. The difference between the maxima of the modulation can be calculated with:

$$\Delta\nu = \nu_{m+1} - \nu_m = \frac{1}{2dN_2} \quad (4)$$

The refractive index N_2 can be calculated either with equation 4 or with

$$N_2 = \sqrt{\epsilon} \quad (5)$$

using the square root of the dielectric function ϵ of the material. The dielectric function ϵ is described in the drude model as:

$$\epsilon = 1 - \frac{\omega_p^2\tau^2}{1 + \omega^2\tau^2} + i\frac{\omega_p^2\tau}{\omega(1 + \omega^2\tau^2)} \quad (6)$$

with ω_p as the plasma frequency:

$$\omega_p = \sqrt{\frac{N_e e^2}{\epsilon_0 m^*}} \quad (7)$$

and τ as the relaxation time of the electrons. m^* is the effective mass of the electrons and N_e the charge carrier density.

For semiconductors, ϵ_{sem} can be calculated as:

$$\epsilon_{\text{sem}} = \epsilon_{\text{LP}} + i\frac{\sigma}{\omega\epsilon_0} \quad (8)$$

with σ as the conductivity of the semiconductor:

$$\sigma = \frac{N_e e^2 \tau}{m^*} \frac{1}{1 - i\omega\tau}. \quad (9)$$

The lattice contribution ϵ_{LP} is described as:

$$\epsilon_{\text{LP}} = \epsilon_\infty \left(1 + \frac{\omega_{\text{LO}}^2 - \omega_{\text{TO}}^2}{\omega_{\text{TO}}^2 - \omega^2 - i\Gamma\omega} \right) \quad (10)$$

with ϵ_∞ as the high frequency dielectric constant, ω_{LO} as the longitudinal optical phonon frequency, ω_{TO} as the transversal optical phonon frequency and Γ as the damping constant.

3 Set-Up

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4 Bibliography

Literatur

- [1] Meschede D., *Gerthsen Physik*, Springer Verlag, 25th Edition, 2018. Modified by Lukas Hein and Elias Schwarzkopf.