The Fresnel Relations

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Abstract

This paper is written as the first of four mandatory repports during the course *Experimental Physics II*. In this experiment we will be working with the Fresnel relations, and an comparison of theory and experiment is the primorial purpose.

1 Introduction

We look at reflection and refraction of a beam of light at the surface of a transparent dielectric. The laws of relection and refraction (*Snell's law*) determine the directions of the reflected and refracted beams. But they are purely geometrical, and no information of intensity nor polarization is given. These are given by the *Fresnel Relations*. This exercise studies the Fresnel relations in detail, and experimental data will be compared with the well known theory of Snell's Law.

2 Theory

In this repport we are working with the Fresnel relations, which describe the amount of s- and p-polarized light transmitted and reflected through a dielectric surface, respectively. Generally we remind ourself of the relation between the incoming angle of our light θ and the outcoming angle of both the reflected light θ_1 and refracted light θ_2. The angles are measured from the normal of the dielectric surface.

The relation between the incoming and reflected beam is given by the simple relation:

$$\theta = \theta_1$$

The relation between the angle of the incoming beam and the refracted beam is given by Schnells law:

$$n_1 \sin\theta = n_2 \sin\theta_2$$

where n_1 and n_2 are the refractive indexes of our incoming material and the material in wich the light is refracted respectively.

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Polarization

The plane spanned by the normal vector to our dielectric surface $\hat{\mathbf{n}}$ and the wave vector $\mathbf{k}$, which is in the direction of the propagation of the light, is called *the plane of incidence*. The direction of the $\mathbf{E}$-field relative to this plane then determines the polarization of the light, if $\mathbf{E}$ is parallel to the plane of incidence the light is p polarized and if $\mathbf{E}$ is perpendicular to the plane of incidence then the light is s-polarized.

Light from normal light sources has a mixture of all possible directions of polarization but the generally any polarization can be given as a linear combination in a basis of electric field with s- and p-polarization. Using a polarizer one can filter one kind of polarization of a beam.

Fresnel relations

When our beam interacts with the surface a certain percentage of the light will be reflected as well as a certain percentage of the light will be refracted/transmitted through the dielectric. The percentage of light reflected is denoted R and the percantage transmitted is denoted T. As the light is either transmitted or reflected it is natural to conclude that:

$$R + T = 1$$

To make things easier for ourselfes we define $R = r^2$ and $T = \frac{\cos\theta_2 n_2}{\cos\theta_1 n_1} t^2$ where $r = \frac{E_1'}{E_1}$ and $t = \frac{E_2}{E-1}$ with E_1 denoting the magnitude of the incoming $\mathbf{E}$-field, E_1' denoting the magnitude of the reflected $\mathbf{E}$-field and E_2 denoting the magnitude of the transmitted $\mathbf{E}$-field. As the direction of the $\mathbf{E}$-field can be written in the basis of s- and p-polarization we can define our reflection and transmission indexes for p and s polarized light seperately. Our r_p, r_s, t_p and t_s given as functions of θ_1 and θ_2 are:

$$r_p = \frac{n_2\cos(\theta_1) - n_1\cos(\theta_2)}{n_2\cos(\theta_1) + n_1\cos(\theta_2)} = \frac{\tan(\theta_1 - \theta_2)}{\tan(\theta_1 + \theta_2)}$$

$$t_p = \frac{2n_1\cos(\theta_1)}{n_2\cos(\theta_1) + n_2\cos(\theta_2)} = \frac{2\cos(\theta_1)\sin(\theta_2)}{\sin(\theta_1 + \theta_2)\cos(\theta_1 + \theta_2)}$$

$$r_s = \frac{n_1\cos(\theta_1) - n_2\cos(\theta_2)}{n_1\cos(\theta_1) + n_2\cos(\theta_2)} = -\frac{\sin(\theta_1 - \theta_2)}{\sin(\theta_1 + \theta_2)}$$

$$t_s = \frac{2n_1\cos(\theta_1)}{n_1\cos(\theta_1) + n_2\cos(\theta_2)} = \frac{2\cos(\theta_1)\sin(\theta_2)}{\sin(\theta_1 + \theta_2)}$$

Then we find:

$$R_p = \frac{\tan(\theta_1 - \theta_2)^2}{\tan(\theta_1 + \theta_2)^2}$$

$$T_p = \frac{\sin(2\theta_1)\sin(2\theta_2)}{\sin^2(\theta_1 + \theta_2)\cos^2(\theta_1 - \theta_2)}$$

$$R_s = \frac{sin^2(\theta_1 - \theta_2)}{\sin^2(\theta_1 + \theta_2)}$$

$$T_s = \frac{\sin(2\theta_1)\sin(2\theta_2)}{\sin^2(\theta_1 + \theta_2)}$$

3 Experimental Setup

Logbook

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1 Problem

Research method #1

Optical detector...

Planning

Beamsize: We used a slit of variable width. $1, 2, 3, 4, 5$

Experimental Equipment Available

- Ruler
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- Collimating slits with 5 slits
- Polarizer with rotational mount
- Polarizer
- Collimating lens
- Rotational mount
- High sensitivity light sensor
- PicoScope

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