Contribution to the Study of Optical Properties of a Dielectric Medium (Atomic Vapor) Using the Lorentz Model

H. Benosman, T.Benouaz, A.Chikhaoui
Department of Physic, Faculty of Science
B.p119 University Abou Bekr Belkaïd, Tlemcen 13000, Algeria.

Abstract

Optical properties of a dielectric medium consisting of an atomic vapor are investigated theoretically using the model of elastically bound electrons. This model describes the interaction of an electromagnetic field with the bound electrons to the vapor atoms [7]. In this paper, we propose a formalism which takes into accurate the effect of the number of electrons on the vapor index. We use the approximation of free electrons (no interaction between free electrons).

Keywords*:* *atomic vapor, electromagnetic field, Maxwell's equation, elastically bound electron, refraction index.*

1. Introduction

The atomic vapor is considered as not very dense dielectric medium comprising N atoms per unit of volume [1]. By supposing that the atom has several electrons of the same mass m , of the same load and of the same own pulsation (thus, for example, all the outer-shell electrons of an atom can have the same behavior) [2]. These loads are likely to move under the action of the electric field of an electromagnetic wave. In our study, one is interested has to determine the optical properties of the medium while being based on the Lorentz model [5] and to study the influence of the electrons number on the index of the vapor.

2. Détermination of the atomic vapor index

1) Model of the elastically bound electron:

Within the framework of this model, the electron is subjected to:

An elastic force of recall, proportional to its displacement $\vec{r}$ compared to its position of balance:

$$\vec{f} = -m\omega_0^2\vec{r}. \tag{1}$$

Where

$\vec{r}$: radius vector of the electron.

ω_0 : own pulsation of the electron.

m : mass of the electron.

A force intended to account for the dissipative phenomena of energy:

$$\vec{f} = -m\gamma\vec{v}. \tag{2}$$

A force of LORENTZ created by the electromagnetic field of the wave, where neglecting us, for the non relativistic electron, the influence of the magnetic term [6]:

$$\vec{f} = -e\vec{\mathrm{E}}. \tag{3}$$

This model describes the movement of the electron which east governs by a differential equation of the form:

$$\left(\omega_0^2 - \omega^2\right)\vec{r} + j\gamma\omega\vec{r} = -\frac{e}{m}\vec{\mathrm{E}}. \tag{4}$$

The solution of this equation presents the displacement of the electron:

$$\vec{r} = \frac{-e/m}{\omega_0^2 - \omega^2 + j\gamma\omega}\vec{\mathrm{E}}. \tag{5}$$

In the vapor no charged and no conducting, the Maxwell's equations are written [3]:

$$\begin{cases} div\vec{D} = 0 & rot\vec{\mathrm{E}} = \dfrac{-\partial\vec{B}}{\partial t} \\ div\vec{B} = 0 & rot\vec{H} = \dfrac{\partial\vec{D}}{\partial t} \end{cases}. \tag{6}$$

The equation of propagation of the electric field in the medium is given by:

$$\Delta\vec{\mathrm{E}} - \varepsilon_0\mu_0\frac{\partial^2\vec{\mathrm{E}}}{\partial t^2} = \mu_0\frac{\partial^2\vec{p}}{\partial t^2} - \frac{1}{\varepsilon_0}grad\,div\vec{P}. \tag{7}$$

The electron forms with the core a dipole of dipole moment $\vec{p} = -e\vec{r}$ and consequently a polarization of the medium:

$$\vec{P} = \frac{\varepsilon_0\Omega^2}{\omega_0^2 - \omega^2 + j\gamma\omega}. \tag{8}$$

Where $\quad \Omega^2 = \dfrac{Ne^2}{m\varepsilon_0}$