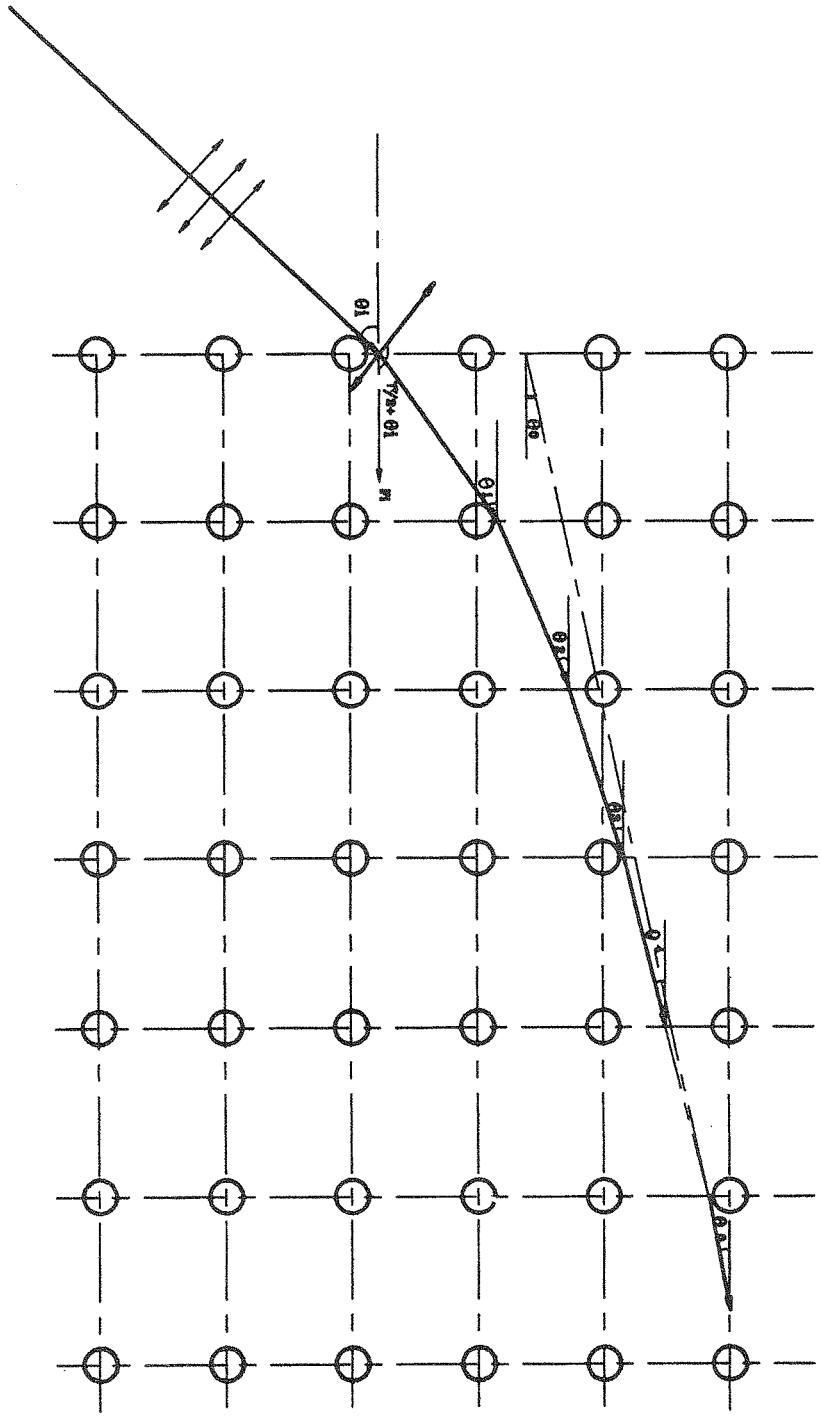

Fig. 5

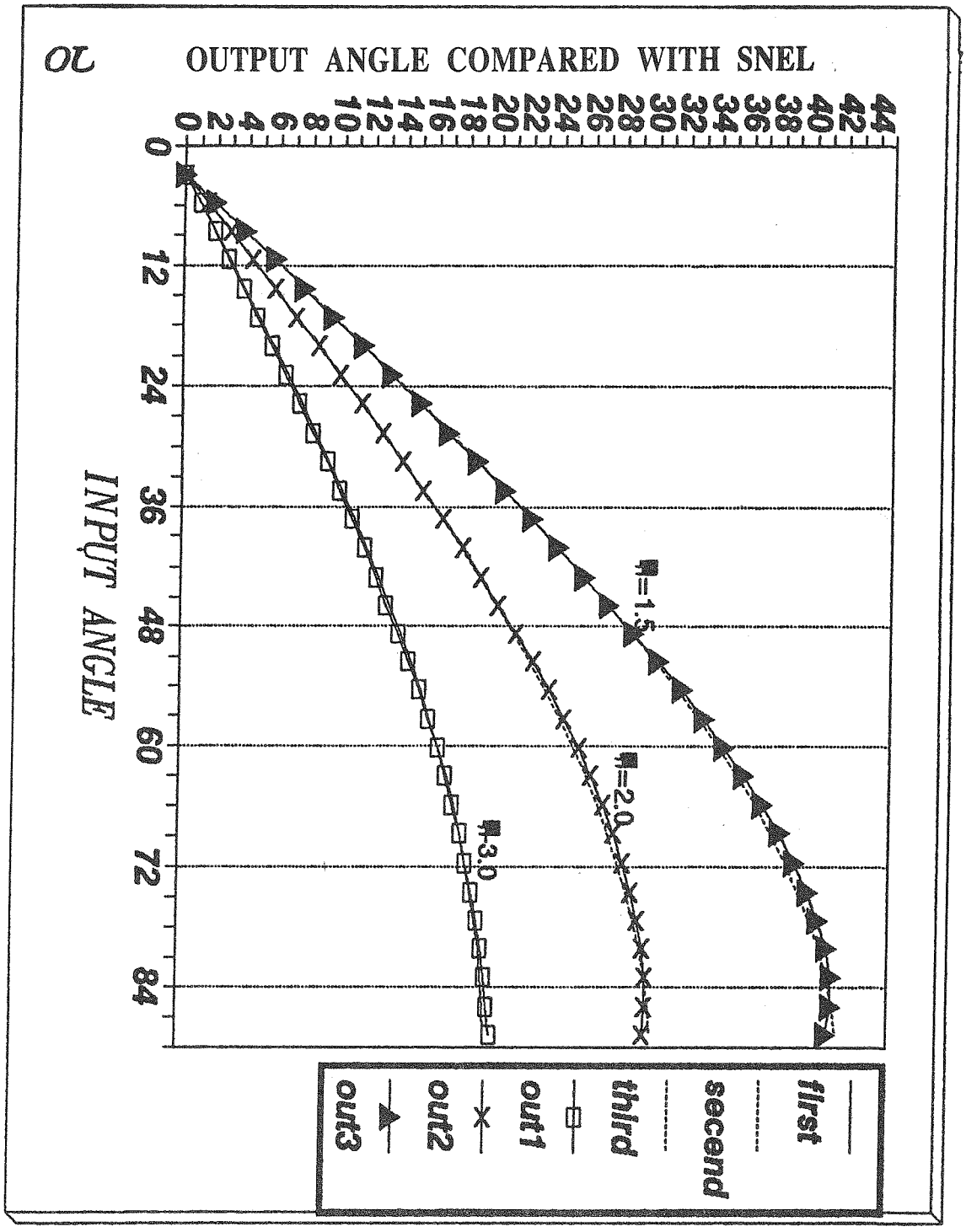
OUTPUT ANGLE COMPARED WITH SNEL
INPUT ANGLE
n=1.5
n=2.0
n=3.0
first
second
third
out1
out2
out3

Fig. 4

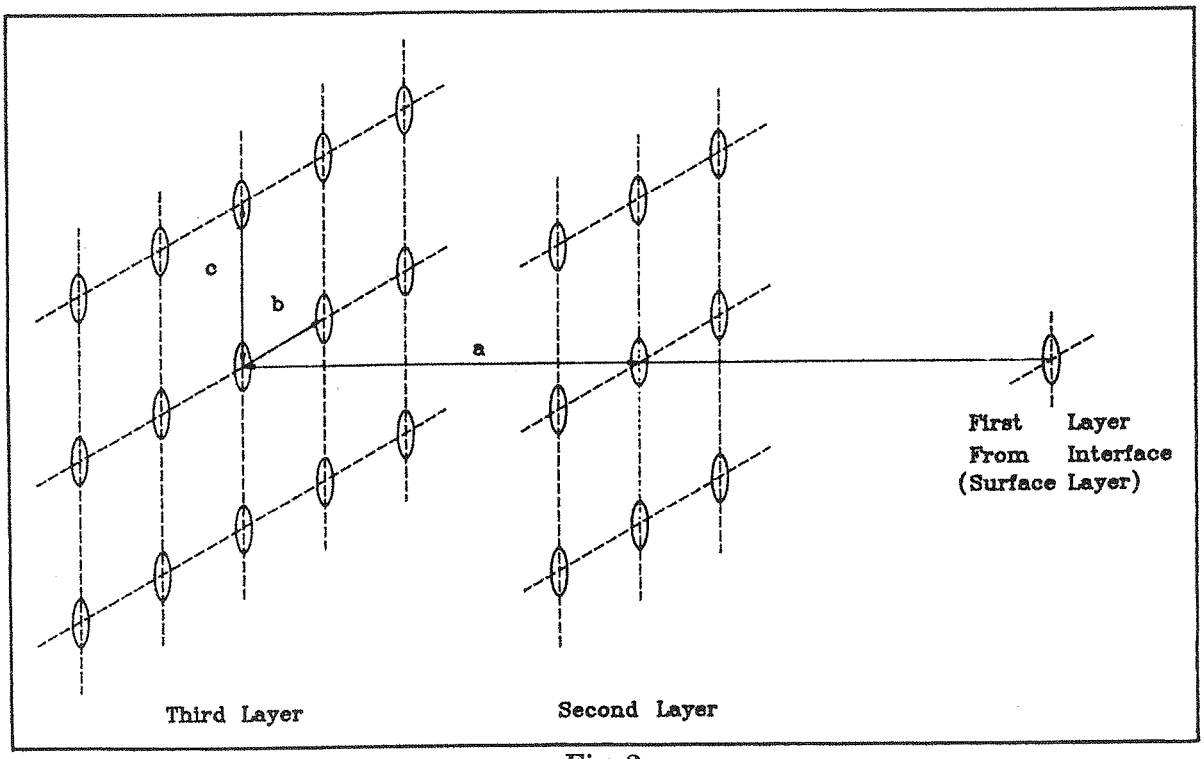
c
b
a
First Layer From Interface (Surface Layer)
Third Layer
Second Layer

Fig. 2

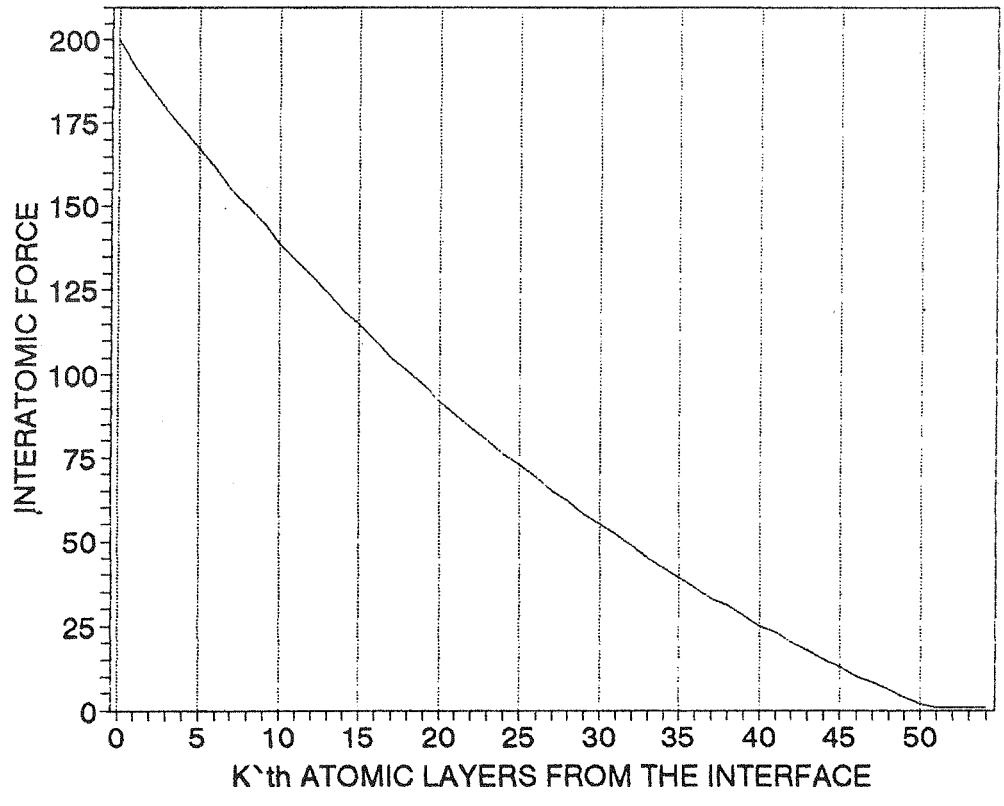
INTERATOMIC FORCE
200
175
150
125
100
75
50
25
0
0
5
10
15
20
25
30
35
40
45
50
K`th ATOMIC LAYERS FROM THE INTERFACE

Fig. 3

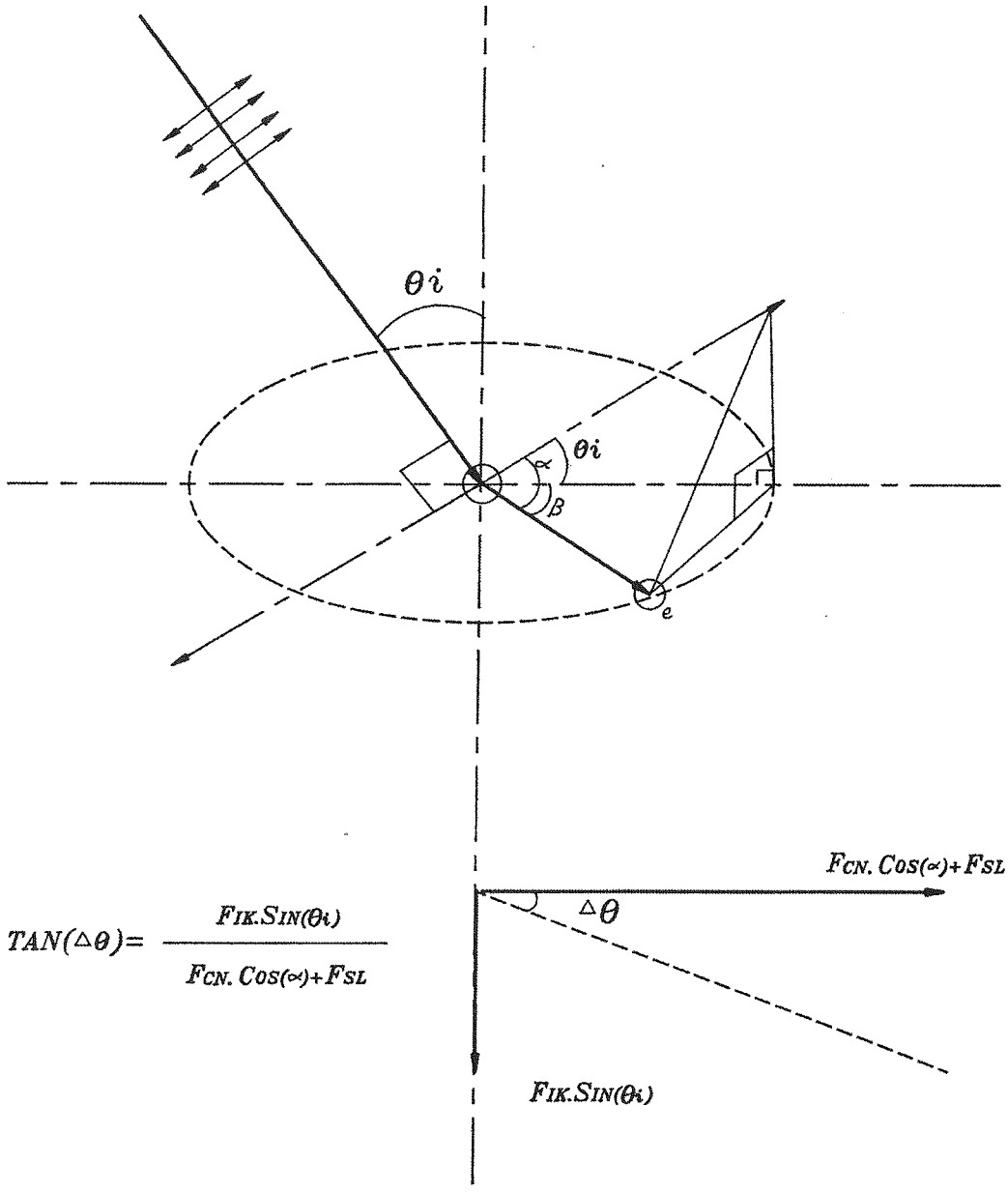

Fig. 1

The output and critical angles have been computed and compared successfully in macroscopic scales with the results obtained from the snell's law.(tables I&II and FIG.4)

It's been shown that the flight route of photons in first few atomic layers from the interface is not abruptly refracted as the case of macroscopic observations, but instead it gradually refracts step by step and asymptotes to output angle value (see FIG.5).

Photonic treatment emphasizes on particle nature of light and can be applied to other optical properties such as polarization, Dispersion and Reflection which will be introduced in near future.

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Tetragonal lattice structure with lattice constants: a;b;c,Fi can also be calculated for other crystal structures in a similar way. We'll explain here our method of calculations of Fi and microscopic refraction formula.

When an atom is placed inside a crystal, the wave functions(or atomic orbitals) of the atom are altered, because the neighboring ions exert an electric field on the atomic electron, which results in the distortion of the orbitals and spliting of the energy levels. This electric field is known as the crystal field. It's effect can be treated by perturbation theory, a common approach in submicron scales related to quantum mechanics. In perturbation theory, the potential in the presence of the applied field becomes:

$$V = Vo(r) + V'(r) \qquad (13)$$

Where Vo(r) is the atomic potential and V'(r) is the potential due to the field. the details of this method, may be found in books of quantum mechanics.[9,10,14,15] The results are:

$$E_n \cong E_n^{(o)} + \langle n | V' | n \rangle - \sum_m{}' \frac{|\langle m | V' | n \rangle|^2}{E_m^{(o)} - E_n^{(o)}} \qquad (14)$$

and,

$$\psi_n \cong \psi_n^{(o)} - \sum_m{}' \frac{|\langle m | V | n \rangle|^2}{E_m^{(o)} - E_n^{(o)}} \qquad (15)$$

Here $En^{(0)}$ and $\psi n^{(0)}$ are the energy and wavefunction for an arbitrary level n in the absence of the field. This results show the wavefunction of atoms inside crystal in a stable state. So that if one atom goes farther or closer to other atoms in crystal structure a restoring force make it back to it's stable state.

For simplicity, we assume that electrons of atoms in tetragonal lattice structures, form a uniform, negatively charged sphere surrounding the nucleous of atoms. let Fo be the interatomic force between mother atom(which interacts with photon) and it's nearest neighbor at distance "a" (constant lattice). Then Fp, which is the total interatomic force between mother atom and it's p th nearest atomic layer, will be obtained in the form of:

$$Fp = FO \cdot \left(\frac{1}{p^2} + \sum_{m=1}^{\infty} \frac{2 \cdot P \cdot a^3}{(a^2 + m^2 \cdot c^2)^{3/2}}\right. \qquad (16)$$

$$\left. + \sum_{n=1}^{\infty} \frac{2 \cdot P \cdot a^3}{(a^2 + n^2 \cdot b^2)^{3/2}} + \sum_{m=1}^{\infty} \sum_{n=1}^{\infty} \frac{4 \cdot P \cdot a^3}{(a^2 + n^2 \cdot b^2 + m^2 \cdot c^2)^{3/2}}\right)$$

Now we can calculate total interatomic force when photon interacts with first layer from interface surface:

$$Fil = F1 + F2 + \cdots Fp + \cdots \qquad (17)$$

Then the same force when photon interacts with second layer from interface surface:

$$Fi2 = F2 + F3 + \cdots Fp + \cdots \qquad (18)$$

and etc. So that te interatomic force, when photon interacts with i th layer from interface surface will be obtained:

$$Fii = Fi + Fi + 1 + \cdots Fp + \cdots \qquad (19)$$

or:

$$Fi = FO \cdot \left(\sum_{p=i}^{\infty} \frac{1}{p^2} + \sum_{p=i}^{\infty} \sum_{m=1}^{\infty} \frac{2 \cdot P \cdot a^3}{(p^2 \cdot a^2 + m^2 \cdot c^2)^{3/2}} + \sum_{p=i}^{\infty} \sum_{n=1}^{\infty}\right. \qquad (20)$$

$$\left. \frac{2 \cdot P \cdot a^3}{(p^2 \cdot a^2 + n^2 \cdot b^2)^{3/2}} + \sum_{p=i}^{\infty} \sum_{m=1}^{\infty} \sum_{n=1}^{\infty} \frac{4 \cdot P \cdot a^3}{(p^2 \cdot a^2 + n^2 \cdot b^2 + m^2 \cdot c^2)^{3/2}}\right)$$

see also FIGS. 2, 3.

VII- CONCLUSION

Tables (I) an (II)and also figs.4,5, show the final results obtained in simulation based on our physical model described at former sections for three typical tetragonal transparent materials with three different refractive indices (n=1,5,2,3,).

The calculations in microscopic and atomic scales are based on equations (12) and (20).

terface between two dielectric media. These photons are assumed to have quantized energy according to planck's law (E=h.υ) with the momentum of p=h. k.

The material's atomic structure have also been taken into account in calculations. The photons interact step by step with atomic layers of dielectric material so that it causes some delay for photons to travel inside a dense transparent material. For this reason, we use a reduced factor called "n" or index of refraction for the speed of light in dense material in comparison with it's velocity in vaccum (Co=300000 km/s).

This photon-matter interaction in microscopic scales causes some delay inside a transparent dense media.

Let's assume a microscopic delay τ_i for i'th molecule of matter when interacting with photon travelling inside it. The whole retardation times for "m" molecule layers inside the crystal (with the length of "L") will be obtained as follows:

$$T=\frac{n\,.\,L}{Co}=\frac{L}{Co}+\sum_{i=1}^{m}\tau i \qquad (11)$$

In our previous works [7, 8] we introduced a physical model based on particle nature of light to estimate theoretically the index of refraction and phase retardation and their fluctuations in submicron scales for an aromatic organic double-refractive material called MNA (2-methyl- 4-nitroaniline). [See also ref. 12, 13, 16]

For the verification of the model, we used the Montecarlo method and found the probability density function (pdf) for electron-photon interaction in this material and simulate the phenomenon, step by step in every atomic layer of MNA crystal [17]. It has also been shown that the photonic treatment can describe successfully some important optical phenomena as longitudal and transversal electrooptic modulation of light in non- centrosymmetric crystal lattices.

In this paper we've considered the refraction phenomenon and angle of refraction from the photonic point of view. We've simulated the interaction in atomic scales for a typical Tetragonal crystal lattice (with arbitrary lattice constants a, b, c).

We've obtained a mathematical relation for calculation of angle of refraction which is based on photonic approach and will be explained in the following section. It is noticible that this procedure will be applicable to other crystal lattice structures.

V- The Physical Model

When the incident light strikes at the interface between two dielectric media and interact with surface layers electrons of a medium, it causes small perturbance in electron orbitals. It's been assumed that these electrons bear a transient stage at this moment and their flight routes are determined by the resultant of coulombic nucleous force (Fcn) and interatomic force(Fi) and are also depend to the angle of incident light (θ_i). We have shown that photons when travelling through the K' th layer from the interface region, deviate in angle with an amount of ($\Delta\theta$) and we can write: (see FIG. 1)

$$tg(\Delta\theta)=\frac{Fik\,.\,Sin(\theta_i)}{Fcn\,.\,Cos(\alpha)+Fs1} \qquad (12)$$

Where Fcn is coulombic nucleus force, Fi_k is interatomic force in k'th layer from the interface region and Fsl is surface layer force.

The equation(12) will be a macroscopic refraction relation which can predict the trajectory of photons travelling through the first few atomic layers of crystal interface. when photon interacts with atomic layers near to the interface surface, the electrons of those atoms bear rotational torques because of two main perpendicular forces exists: first: The Interatomic force Fi (see section (VI). Second: coulombic mother nucleus force (Fcn).This torque made electrons to rotate by "$\Delta\theta$" in every atomic layer asymptotes to zero in layers far from interface surface inside the material.

VI - How to Obtain Interatomic Forces(Fik)

Although, in this study, the interatomic force(Fi) have been obtained for a typical

we assume $\hat{un}$ as the unit vector normal to the interface, the cross-product of it with $\bar{E}i$, $\bar{E}r$ and Et must have the following relation:

$$\hat{un}.\bar{E}_i + \hat{un} \,.\, \bar{E}_r = \hat{un} \,.\, \bar{E}_t \qquad (4)$$

from the equations 1 to 4 we'll obtain:

$$(K \,.\, r - \omega_i \,.\, t) = (K \,.\, r - \omega_r \,.\, t) = (K \,.\, r - \omega_t \,.\, t) \qquad (5)$$

with the assumption of (linear) forced vibrations at the frequency of the incident wave, we can deduce that ω_i, ω_r and ω_t are equal so that:

$$(K_i \,.\, r = K_t \,.\, r) \qquad (6)$$

and $(K_i - K_r)$ is normal to the interface. Thus k_i, K_r, K_t are all coplanar. As before the tangential components of K_i and K_t must be equal and consequently:

$$K_i \,.\, \mathrm{Sin}\,(\theta_i) = K_t \,.\, \mathrm{Sin}\,(\theta_t) \qquad (7)$$

but because $\omega_i = \omega_t$, we can multiply both sides by C/ω_i to get:

$$n_i \,.\, \mathrm{Sin}\,(\theta_i) = n_t \,.\, \mathrm{Sin}\,(\theta_t) \qquad (8)$$

which is snell's refraction law. "n_i" and "n_t" in equation (8) are macroscopic constant values called index of refractions. But these constants are no more be valid if we consider the physical phenomena at submicron and even in atomic scales. It has already been shown the refractive indices have considerable fluctuations about their mean values both in time and space [11,14]. So the snell's law in microscopic scales will no more be valid and electromagnetic treatment will not work. For this reason we must consider a new approach.

III - The Electronic Polarizability

Although, the electromagnetic theory is a powerful tool for analysing wave- matter interaction, it's based on experimental measurements. It doesn't explain the physical meaning of constitutive parameters (n, ε, μ, ...).

These parameters can be obtained in a physical manner using classical Debye's polarization equation [11, 14, 15, 19].

Quantum mechanics can also explain the nature of these parameters [14, 20, 21]. The results of both approachs are similar and according to electronic polarizability of atoms, due to external applied fields.

The electronic Polarizability of atoms, when an external field ε is applied, causes electrons displacements of atoms. This displacement and electronic polarizability (αe) have already been obtained both classically by Debye [19]:

$$\alpha_e(\omega) = \frac{e^2/m}{\omega_o^2 - \omega^2} \qquad (9)$$

and quantum mechanically by van vleck [20], and Greenway (21):

$$\alpha_e(\omega) = \frac{e^2}{m} \sum_{j \neq o} \frac{f_{jo}}{\omega_{jo}^2 - \omega^2} \qquad (10)$$

Where $\omega_{jo} = (E_j - E_o)/h$ and j refers to the j th excited level. The system has a number of resonance frequencies (ω_{jo}).

The final result obtained from above equations is the estimation of Index of refraction of materials which is also related to refraction angle [14]. (snell law)

But these results from perturbation theory and quantum mechanics are only valid in stable states. This electronic polarizability is really a static polarizability. These results will no more be valid in transient states and dynamic polarizability at a very short fractions of time, say in the range of less than one femtosecond, the time required for electron-photon interaction in atomic scales.

IV- The Photonics Treatment

Photonics, explains the photon-matter interaction according to particle nature of light. It's been assumed a dynamic electronic polarizability for electrons of atoms in transient states at very short fraction of times.

In this approach, light consists of a stream of billions of photons strike the in-

of averaging microscopic fluctuations of parameters as the material thickness becomes enough large. But in submicron photonic devices, these parameters fluctuates, both in time and space [7,8], so the personal behavior of few electrons and photons become important and we can not average their behaviors and use macroscopic physical rules.

For this reason, it'll be necessary to travel back into basic optic principles. But with a new treatment. This treatment which is called "PHOTONICS" has already been introduced by Hecht-Zajak [1] and Ohtsu [18]. It is the most powerful approach in comparison with classical macroscopic theories. unlike the previous approachs that doesn't explain the microscopic phenomena, this treatment will still be valid even in submicron scales [8]. Besides it delivers a rather complete visual perception about the microscopic physical phenomena.

In Photonics, which is an authentic concept, light is assumed to be a stream of billions of photons that travel through the space and strike the interface between two different nonabsorbing media. Some of them transmit (reflect) and others reflects from the interface. In addition the atomic or molecular structure and the intramolecular forces at different media must be taken into account in computation.

In our researchs during last few years, we've successfully developed microscopic physical models based on photonic treatment to explain optical phenomena in dimensions of less than one micrometer[7,8].

In photonics, we assume that light consists of stream of photons and that one such photon strikes the interface between two dielectric media at an angle θ_i and is subsequently transmitted across it at an angle θ_t.

We show that if this were just one of billions of such quanta in a narrow laser beam it would conform to snell's refraction law. The advantages of photonic treatment is that the atomic or molecular structure of the media have been taken into account in calculations. In addition it can describe in detail the photon-matter interaction from a physical point of view in microscopic or atomic scales where the electromagnetic theory can say nothing about such a microscopic phenomena [1,6].

In section (II), we'll review the electromagnetic approach to explain the Snell's refraction law and the reason for a new treatment called"photonics". In section(II), we'll review the Electronic Polarizability theory of atoms when exposed to external electric field. This static polarizability that can be obtained both classically [19] and quantum mechanically [20,21], is in direct relation with Refraction phenomenon. The photonic treatment which is based on particle nature of light will be introduced at section (IV). The microscopic refraction equation will be offered at section (V). The method of obtaining interatomic or interamolecular forces (Fik) in refraction equation will be explained in section(VI). Finally, in conclusion section, we'll compare the results of Montecarlo simulation[17] based on photonics, with the snell's experimental law that show excellent agreement and accuracy.

II- Electromagnetic Treatment of Refraction Law

If we assume a planar monochromatic incident light wave(Ei), it has the form:

$$E_i = Eo_i . Cos (K . r - \omega_i . t) \qquad (1)$$

making no assumptions about their directions, frequencies, wavelength, phases or amplitudes, we can write the reflected and transmitted waves from the interface as: [1,3]

$$E_r = Eo . Cos (K . r - \omega_r . t + \Psi_r) \qquad (2)$$

$$E_t = Eo . Cos (K . r - \omega_t . t + \Psi_t) \qquad (3)$$

where ψ_r, ψ_t are the phase constants relative to Ei and if we choose the origin to be in the interface, the phase constants would both have been zero.

The laws of electromagnetic theory lead to certain requirements which say: The total tangential component of (E) on one side of the surface must equal that on the other. If

Photonic Treatment of Refraction Law Insubmicron Optoelectronic Devices

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Abstract

In this paper we'll introduce a physical model based on particle nature of light and call it PHOTONICS treatment to explain the Refraction optical phenomenon in atomic dimensions.

We haven't used neither Electromagnetic theory nor Stokes treatment- Which are based on wave nature of light. It's because none of these theories can explain the microscopic optical phenomena in submicron dimensions in atomic scales.

In photonics, photon particles strike at interface region of crystal with specified lattice structure and interact step by step with the electrons of atomic layers at the interface. For the verification of the model, we have used Montecarlo method and relevant statistical theory. The results of simulation have confirmed the validity of photonics approach to explain refraction phenomenon. This concept is totally an Authentic concept and is a powerful tool to solve problems in analysis and design of submicron VLSI optoelectronic devices.

I - An Introduction

The miniaturization of optoelectronic and Photonic systems offer unique opportunities to develop new treatments for analysing devices, Where the dimensions shrink from even micrometers to nanometers and angstroms.

In VLSI Optical Integrated Circuits (O.I.C), it' ll be necessary to deal with submicron optoelectronic devices, where the macroscopic physical laws and theories will be useless or at least must be modified. For example, the macroscopic Constitutive parameters: Permitivity (ε), Refractive index (n), Permeability (μ) and Conductivity (δ), lose the validity in submicron scales and will no more be constant values.

According to Maxwell's classical theory, the wave propagation at different environments can be estimated using wave equation in which the constitutive parameters are assumed to be constants [3,4,5,6]. This is also the case for refractive index (n) parameter related to linear and nonlinear optical phenomena as Refraction (Snell's law), Reflection (Fresnel's Equations) [1], Dispersion (Cauchy, sellmeier and Helmholtz equations) [2], Electrooptic effect and Second Harmonic Generation in noncentrosymmetric crystals[9,10].

In all of the above relations, the assumption of constant macroscopic constitutive parameters are coming from the viewpoint