Advanced Materials Science and Technology; 2020;2:2
www.omniscient.sg

Original Research

Open Access

Omniscient Pte.Ltd.

Nano-refraction Analysis for Advanced Materials: A Theoretical Roadmap for Quantum Computers

Hassan Kaatuzian*

*Photonics Research Laboratory, Department of Electrical Engineering,
Amirkabir University of Technology, Tehran 15916343111, Iran

***Correspondence email:** hsnkato@aut.ac.ir

Abstract

We are now in the beginning of quantum supremacy to build Quantum Computers (Q.C.). So, a theoretical roadmap is required. It seems experimental works in Q.C. is ahead, in comparison with theory. In this study, Nano-Refraction (N.R.), as basic concept in developing Quantum Photonic Computers (Q.P.C.), is defined and discussed. N.R., is quite different from classical macroscopic refraction. It plays major role in photon deflection, when it travels in few atomic layers from the boundary between two transparent materials. Specifically, when we're looking for a theoretically intuitive explanation of how advanced materials work in atomic scales in atto-second regime. To explain N.R., mathematically, Quantum Electrodynamics (QED) may help. But QED, only can describe how N.R. occurs in Hilbert space and does not explain why it happens in Real space? Why attosecond optical pulses are squeezed in kilometers long optical fibers coiled in first reported development of Q.C. in 2020. Also, "Duality" has no reply in this area. For answering why?, in this paper, we'll use Quantum Photonic (Q.P.) theoretical analysis. Q.P., is based on Bohmian mechanics with intuition physics belief and "Causality". Bohm theory in shadow of Quantum Mechanics (Q.M.) has been mostly ignored and even boycotted during last 70 years. Q.P. corpuscular viewpoint of light, estimated both physically and mathematically with enough precision, that flight route of photons at first few molecular surfaces in boundary region is not refracted suddenly. As can be observed macroscopically in Snell's refraction equation. But instead, N.R. is happened gradually in attosecond regime (figure 2). Finally, it asymptotes to macroscopic refraction, in large space-time scales according to "correspondence" principle. Errors in our theoretical analysis using Montecarlo time domain simulation, compared with experiments, always are much less than or at most five percent.

Keywords

Nano-Refraction, Quantum Computer, Quantum Photonic Computer, Causality, Bohm Theory, Intuition Physics, Montecarlo Time Domain Simulation

1. INTRODUCTION

It's estimated that quantum computer can solve a problem that no classical computer could do in ultra short fractions of second [1]. It's quantum supremacy is necessary for future 6G wireless systems. Several teams in Google, IBM and NTT have recently claimed that they've built Q.C. versions that could squeeze several thousand pulses of light into kilometers long fiber cable coiled into a box few meters across [2,3]. Thanks to material engineering and discovering new material properties for development of Q.C. [1]: Non-volatile magnetic Random Access Memories (RAM) and ultrafast spin microprocessors made from advanced materials like Ferro-Magnetic metals (Cr, Co, Fe,…) or Magnetic Semiconductors (InCr, GaAs,…). But the theoretical approach to explain how such advanced materials work for quantum computing is still quantum mechanics (Q.M.) treatment, which is an incomplete theory [4]. Q.C., made from advanced materials, works in real space in laboratory, not in Hilbert space, as Q.M. states. It can at most describe optical phenomena mathematically. It may explain how, but does not state why? So a powerful more complete theoretical road map is required. It should be based on "Causality", not "Duality". We should justify basic optic principles like "Fermat" and "Snell's law" (see Figure 1),

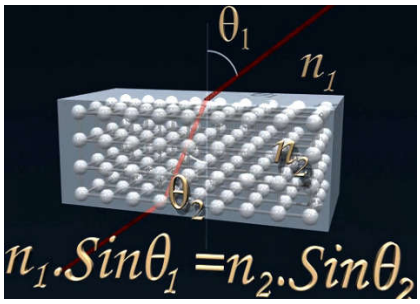

Fig. 1. Macroscopic relation for describing Refraction Phenomenon at the interface between different bulk transparent media which is called Snell's law. Nano-Refraction is different from Snell's law.

using intuition physics, not only mathematics. For Q.C. engineering, it's required that we've explicit visual perception about what's really (not virtually) happening during Refraction, Dispersion, Polarization… phenomena.

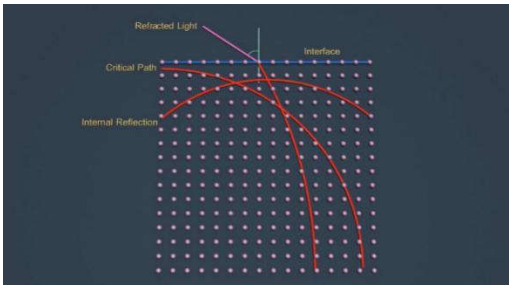

Fig. 2. Quantum Photonics predicts that flight route of photon in first few atomic layers from the interface is not abruptly refracted as in the case of macroscopic Snell's law. But it gradually refracts step by step because of variations of Short Range Interatomic Forces (S.R.I.F.) and asymptotes to the output angle. This is Nano-Refraction.

For better understanding of quantum computation in Q.C., it's nano-refraction (N.R.) that should be justified. Since computation method in Q.C. is not symbolic as in the case of classic digital computers [1].It's based on quantum physics behaviors of Q.C. subsystems. We must try to know really what happens in attosecond time scale atomic dimensions. This scenario should be understood physically (not symbolically) for developing attosecond Quantum Photonic Computers (Q.P.C.). In this paper, we use Q.P. theory to explain why nano-refraction occurs. (See Figure 2). N.R. is completely different from refraction. It means estimation and manipulation of photon or

electron trajectories when travelling through atomic scale devices. It certainly requires time-domain nanoscopic studies even more powerful than Ab-initio technic. Since in addition to mathematical manipulations, it should deliver an intuitive and physical perception to engineers about what's happening in atomic-attosecond world [4].

Quantum Photonics (Q.P.) postulates are mainly based on Bohmian mechanics, developed at fifth decade of 20'th century. It is reviewed In section (II) and demonstrated that it's different from Q.M. Similarities between Q.P. and Bohm theory will be discussed in section (III). In section (IV), we'll explain about hidden variable and it's major role in N.R. Finally in section (V), Q.P. physical model for justification of N.R. will be described. The paper will be concluded in section (VI)

2. BOHMIAN MECHANICS INSTEAD OF QUANTUM MECHANICS

Bohmian Mechanics is related directly to scientific work of late David J.Bohm [5]. Although his quantum viewpoint has been introduced to scientific literature for more than 70 years, it has not been mentioned until recently, because of dominant Copenhagen interpretation of Quantum Mechanics, principally the work of Niels Bohr [6,7]. In Bohmian Mechanics, there is no chance at all. Every physical object invariably does exist in some particular domain of space. In addition, Bohm theory consists of a single set of basic physical laws that applies the same way to every physical object that exists. It assumes particles are the sorts of things that are located in fixed particular places [8]. Moreover, Bohm interpretation about what the world is made of, is more understandable in comparison with Copenhagen interpretation. In Bohm's account, wave functions (ψ) are physical things, not merely mathematical objects. It treats wave functions like classical force fields, such as magnetic and gravitational fields. It pushes the particles around, to navigate them, along their proper courses [8,9,10].

The evolution of (ψ) in time, can be described precisely by standard linear differential quantum mechanical equations of motion. Physical situations of all particles in the world at any time and it's wave function, can be computed with certainty from situations of them at any earlier time. Any uncertainty, is a matter of ignoring of some fundamental laws of the world. It means there exists "Hidden Variables".

Bohm's theory includes three major elements: First is a deterministic law (Schrodinger's equation) that explains, how wave functions evolve over time. It is:

$$i\frac{h}{2\pi}\frac{\partial}{\partial t}\psi(x_1...x_{3N},t) = H\psi(x_1...x_{3N},t) \tag{1}$$

"h": Planck's constant, "i": imaginary number $\sqrt{-1}$, "ψ": wave function, "H": Hamiltonian mathematical operator, "N": total particles numbers in the system, $x_1...x_{3N}$: spatial coordinates of those particles and "t": time. The Hamiltonian operator explains the energy of the system. The deterministic law of particles motion is the second element:

$$\frac{dx_i(t)}{dt} = \frac{j_i(x_1...x_{3N},t)}{\left|\psi(x_1...x_{3N},t)\right|^2} \tag{2}$$

Where: $x_1...x_{3N}$ represent particles' actual spatial coordinates, $\frac{dx_i(t)}{dt}$: change rate of x_i at time t, and j_i components of probability current density. The subscript "i", ranges from 1 to 3N. [8]

The third element is a law similar to classical statistical mechanics. It says one is given (ψ) of a certain system, but no information about particles positions. For calculating particles motions in the future, it's necessary to know the probability of particles current locations at some positions $(x_1...x_{3N})$ which is defined as $\left|(\psi(x_1...x_{3N})\right|^2$. If by measurement, we obtain particles positions, the law indicates that we can use this information to "update" probabilities through a mathematical procedure which is called: "straightforward conditionalization".

It's interesting to be mentioned that mathematics behind Bohmian mechanics is similar to mathematics behind quantum mechanics. But world's interpretation of them are quite different. First, according to "causality", second according to "Duality".

3. SIMILAR VIEWPOINTS OF Q.P. WITH BOHM THEORY

There are several similarities between Q.P. and Bohmian mechanics. In both , chance has no role. Every thing does occupy special location in space. In other words, basic laws that describes behaviors of physical objects, can also be applied to nano-scopic or atomic physical objects, if only we model the whole scene correctly and take into account the observer's role of error producing. In more precise simulation models, based on classical or relativistic physics, The observers are assumed to be ideal (no perturbation because of measurements).

This is the case in Q.P. theory where conventional physical laws still should be valid and applicable. But with a rather complex and cumbersome mathematical manipulation for a real- material. [11,12]. If the observer is not ideal, but a real measurement instrument, it's perturbation should be considered. A Distinction between "measurement" and "simulation". It means what observes and what is observed [13].

Bohm's Theory, entails That There's a kind of neglecting definite facts about the world, when we do not take into account the effects of errors caused by real observer. So a violation of physical law occurs. This is also the case in fifth theory of light (Q.P.). We see the observer and observed object simultaneously in the scene. But when we simulate, the observer is assumed to be ideal. Then we'll not be worried about violation of physical law. For this reason, the development of a Bohmian replacement for relativistic quantum field theory will also be underway with ultimate success [4].

In Q.P., particles initial conditions, initial wave functions and initial positions are as important as in Bohm Theory. Moreover, (ψ) functions are both mathematical and physical entities. The intuitive picture of the world, about what's really observed in molecular scale atto-second world. Q.P., has intuitive answers for Hidden variables both in classic and relativistic mechanics. Short Range Interatomic Forces are good examples for hidden variables to be taken into account.

3.1 Main Components of Quantum Photonics

Q.P., is based on Quantum Theory. Moreover, it describes optical phenomena "really", not "virtually". According to correspondence principle, It encompasses previous four optical theories and delivers intuitive picture about atomic world, where quantum mechanics could not. A viewpoint very similar to Bohmian Mechanics as we previewed in section (2). There are 4 main postulates in Q.P, as follows:

A. Estimation of physical shapes of molecules in Real Materials (R.M.) using Schrodinger equation.

B. Evaluation of physical shape of crystal-lattice structure in (R.M.), using X-ray diffraction interferometry and laboratory measurements.

C. Quantitative estimation of Short Range Inter-atomic Forces (S.R.I.F.) between molecules in (R.M.). SRIF, can be calculated mathematically using coulomb's law, Vandervals, Covalence and Ionic bondings for a lattice shape.

D. Analysis and simulation of interaction between electron and photon. Photon will be tracked in atto-second time and atomic space scales. There's a powerful time-domain statistical dynamic method called "Montecarlo" for this analysis [4,14].

3.2 Meaning of "photon" in Q.P.

The notion of photon initially grew out of an attempt by Max- Planck in 1900, to resolve a long- standing

riddle concerning the spectrum of Black- Body radiation. In 1905, Albert Einstein extended the notion of quantization by considered the light itself to be a collection of photons. This enabled him to successfully explain the Photo-electric effect [15]. From a Quantum Photonics viewpoint, light is assumed to be a stream of billions of photons, travel through the space and strike the interface between any two different non-absorbing media. Some of them transmit (refract) and others reflect, from the interface. In addition, the atomic or molecular structure and intra- molecular forces (S.R.I.F.), at different media must be taken into account in computation of speed of light, there and also the rate of light angle deflection in refraction and reflection phenomena. So, we have characteristics for photons in fifth theory of light, (Q.P.), as follows: [4]

a) A single photon has it's own Electric and Magnetic fields.

b) Photon's energy is according to Planck's formula: $(E = h.\upsilon)$.

c) Photon carries momentum and orbital angular momentum.

d) Photon has zero dimension, zero rest mass and zero potential energy.

e) Photon velocity in vacuum is always $C_o = 3\times10^8$ m/sec. It's speed in transparent materials, reduces, because of retardation, caused by photon annihilation for a very short time, then recreation and re-emission after every encountering with matter.

f) Although photons demonstrate wave like behaviors in Macroscopic space- time scales, a single photon assumes to be a particle, carries energy with periodic fluctuations of it's field. (frequency: υ)

g) Photon has field penetration depth. Means the distance at which photon can interact with matter.

h) Photon's field penetration depth is in the order of it's space repetition $(\lambda = c/\upsilon)$.

3.3 Q.P. Interpretation of Electron Polarization

Although Electromagnetic theory is a powerful tool for analyzing wave- matter interaction, it's based on experimental parameters (n, $\in$,…). These parameters can be obtained in a physical manner using the classical Debye's polarization equation [16]. Quantum Mechanics can also explain the nature of these parameters, but only mathematically [16,17,18]. The results of both approaches are similar and according to the electronic polarization of atoms, due to the applied fields.

The electronic polarization of atoms when an external field is applied, causes electron displacement of atoms. This displacement and electronic polarization (α_e) has already been obtained both classically by Debye [19]:

$$\alpha_e(w) = \frac{e^2/m}{\omega_o^2 - \omega^2} \tag{3}$$

and quantum mechanically by Van Vleck [16], and Greenway [17]:

$$\alpha_e(\omega) = \frac{e^2}{m}\sum_{j\neq o}\frac{f_{jo}}{\omega_{jo}^2 - \omega^2} \tag{4}$$

Where $\omega_{jo} = (E_j - E_o)/\hbar$ and "j" refers to j'th excited level. The system has number of resonance frequencies (ω_j).

The final result obtained from the above equations is estimation of index of refraction of materials which is also related to the refraction angle (Snell's law) [20]. But these results (from perturbation theory and quantum mechanics) are only valid in stable states. Therefore, this electronic polarization is really a static polarization and will no longer be valid in transient states (say in the range of much less than one femtosecond, or in atto-second, the time required for electron- photon interaction in atomic scales).

Q.P. explains photon- matter interaction according to corpuscular nature of light. A dynamic electronic polarization for electrons of atoms in transient states at a very short fraction of time, has been assumed. In this approach, light consists of a stream of billions of photons, striking the interface 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 = $\hbar$ k). The material's atomic structure has also been taken into account, in calculations. The photons interact step by step with the atomic layers of the dielectric material, so that it causes some delay for photons to travel inside a dense transparent material.

3.4 Nano-refractive Index in Q.P.

Relation (5), expresses total time it takes photon to travel inside a media [4,21,22,23]: (see also Figure 3)

$$T = \frac{L}{C_0} = \sum_{i=1}^{N} \tau_{di} \tag{5}$$

"L" is the material length. Travelling time of photon in vacuum between molecular layers as the sum of time that photon spends to pass through the intermolecular (inter-atomic) empty space ($\frac{L}{C_o}$) and photon- matter interactions ($\sum_{i=1}^{N} \tau_{di}$). Refractive index is the ratio of Co (vacuum speed of the light) over the average speed of light in the medium for large N (number of interactions), so:

$$n = \frac{C_o}{C} = 1 + \frac{C_o}{L} \sum_{i=1}^{N} \tau_{di} \tag{6}$$

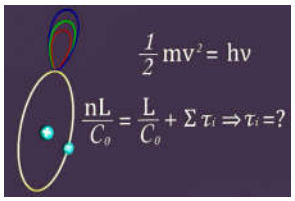

Fig. 3. During Photon-electron interaction, photon is annihilated and it's energy as kinetic form will be transferred to electron for a short time. Then photon is recreated.

If now, we assume " τ_d " as the average retardation time per interaction, "d", as the average free pass between two successive interactions, we will have:

$$n = 1 + \frac{C_o}{d} \tau_d \tag{7}$$

(where: $\tau_d = \frac{\sum_{i=1}^{N} \tau_{di}}{N}$; and $d = \frac{L}{N}$)

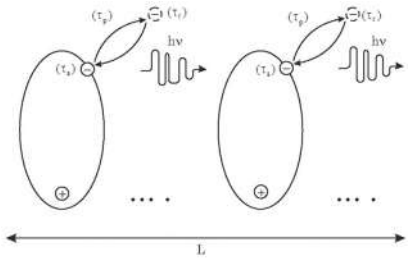

Fig. 4. Photon-Electron interaction with molecular layers of a transparent typical solid, based on Quantum Photonics and Bohm Theory.

As can be seen in Fig. 4, initially, photon is annihilated and delivers it's energy to the electron in the lowest energy level and perturbs it. Energy of annihilated photon is not sufficient to transfer the electron to a higher stable

energy state. So, the perturbed electron returns to it's initial orbital state after a transit time, which we can name it (τ_p) , finally the photon recreates.

At last, the retardation time (τ_d) for a more precise evaluation, may be considered as summation of photon annihilation (τ_a) , electron perturbation (τ_p) and photon recreation times (τ_r) (see Figure 4) and [22]:

$$\tau_d = \tau_a + \tau_p + \tau_r \tag{8}$$

These quantitative parameters may be considered as functions of wavelength. For simplicity as first- order approximation, we assume τ_a and τ_r as negligible coefficients on the order of zepto-seconds. Since according to Quantum Photonic treatment, (τ_p) will be in the range of atto-seconds [4,24,25].

4. HOW TO OBTAIN HIDDEN VARIABLE INTERATOMIC FORCES (FIK)

Although, in this section, the inter-atomic force (F_i) has been obtained for typical tetragonal or orthorhombic lattice structures with lattice constants a, b, and c , F_i, can also be calculated for other crystal structures in a similar way. We'll explain here, our method of calculating F_i and the nano-scopic refraction formula.

While an atom is inserted inside a crystal, "ψ" functions of atoms are perturbed. It's because the neighbor atoms, induce electric field on atom's electron, causes distortion of orbits and it's energy levels splitting. This field is called crystal field and can be treated by Perturbation theory, a common approach in submicron scales based on quantum mechanics. According to Perturbation theory, the potential in the presence of applied field becomes:

$$V = V_o(r) + V'(r) \tag{9}$$

Vo(r): atomic potential, $V'(r)$: potential due to the field. For details of such method of calculation, refer to quantum mechanic books [26,27,28].

the results are:

$$E_n \cong E_n^{(o)} + \langle n|V'|n\rangle - \sum_m{}' \frac{|\langle m|V'|n\rangle|^2}{E_m^{(o)} - E_n^{(o)}} \tag{10}$$

and:

$$\psi_n \approx \psi_n^{(o)} - \sum_m{}' \frac{|\langle m|V'|n\rangle|^2}{E_m^{(o)} - E_n^{(o)}} \tag{11}$$

Energy and wave function for any level "n" in the absence of field (stable state) are assumed to be $E_n^{(o)}$ and $\psi_n^{(o)}$ respectively. Now a restoring force makes atom move around it's stable state in crystal lattice.

For simplicity, electrons of atoms in a typical lattice, are assumed to form uniform, negatively charged sphere around the nucleus. If Fo be inter-atomic force between mother atom (interacting with incident photon) and it's nearest neighbor at distance "a": constant lattice, we'll have (see fig. 5.a): [29]

$$F_O = \frac{\text{Constant}}{a^r} \tag{12}$$

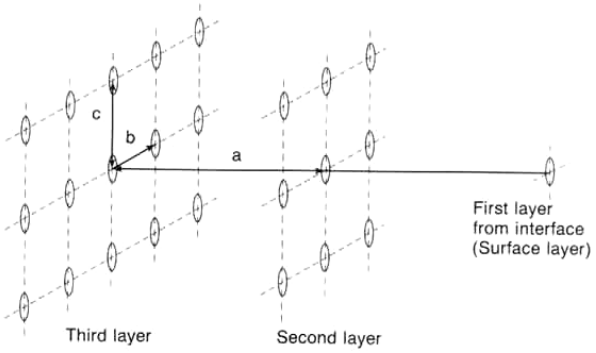

Fig. 5. a A typical Orthorhombic or Tetragonal Crystal Lattice.

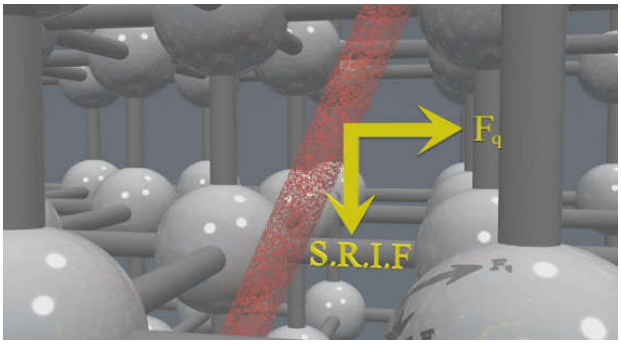

Fig. 5.b Coulomb Mother Nucleus Force and SRIF in a Typical Orthorhombic or Tetragonal Crystal Lattice.

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:

$$F_p = F_o.\left(\frac{1}{p^r} + \sum_{m=1}^{\infty} \frac{2.p.a^{r+1}}{(a^2 + m^2.c^2)^{\frac{r+1}{2}}} + \sum_{n=1}^{\infty} \frac{2.p.a^{r+1}}{(a^2 + n^2.c^2)^{\frac{r+1}{2}}} + \sum_{m=1}^{\infty}\sum_{n=1}^{\infty} \frac{4.p.a^{r+1}}{(a^2 + n^2.b^2 + m^2.c^2)^{\frac{r+1}{2}}}\right) \quad (13)$$

In equation(13), p = 1,2,3…. and "r", should be greater than two. Since in atom's coulomb's force, r, becomes two. But "r" should also be less than 6 (Vandervals Forces) [30].

Now, we can calculate total interatomic force while photon interacts right at the interface surface (first layer). Then the same force when photon interacts with second layer and so forth. So, the total interatomic force, when photon interacts with i'th layer from the interface surface, will be estimated as follows:

$$F_{ii} = F_i + F_{i+1} + ...F_p + ... \quad (14)$$

or:

$$F_i = F_o.\left(\sum_{p=i}^{\infty} \frac{1}{p^r} + \sum_{p=i}^{\infty}\sum_{m=1}^{\infty} \frac{2.p.a^{r+1}}{(p^2.a^2 + m^2.c^2)^{\frac{r+1}{2}}} + \sum_{p=i}^{\infty}\sum_{n=1}^{\infty} \frac{2.p.a^{r+1}}{(p^2.a^2 + m^2.b^2)^{\frac{r+1}{2}}} + \sum_{p=i}^{\infty}\sum_{m=1}^{\infty}\sum_{n=1}^{\infty} \frac{4.p.a^{r+1}}{(p^2.a^2 + n^2.b^2 + m^2.c^2)^{\frac{r+1}{2}}}\right) \quad (15)$$

See also Figure(5.a) and Figure(5.b). "m,n,p" are integers.[4,29,30] See also Figure(6).

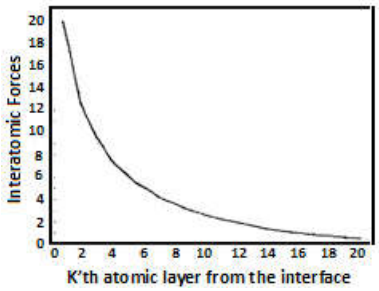

Fig. 6. Interatomic force in K'th layer from the interface for a typical crystal lattice. As can be observed, this force reduces exponentially to zero when "K" becomes enough large. For polycrystalline and even amorphous transparent solids, above results can be extended easily too.

5. Q.P. PHYSICAL MODEL FOR NANO-REFRACTION

According to Nano-Refraction (N.R.) based on Q.P., light strikes at the interface and interacts with electrons of medium at surface layer. It causes orbit of electron perturbs. These electrons bear transient states. Their flight routes are determined by resultant of columbic nucleus force (F_{cn}), inter-atomic force (F_i), and also depend on the incident light angle (θ_i).

We have demonstrated that photons, while moving through k'th layer from the interface surface, deviate in an angle with the amount of ($\Delta\theta$) and we can suggest the following equation, (see Figure (7)):

$$\mathrm{tg}(\Delta\theta) = \frac{F_{ik}.\sin(\theta_i)}{F_{cn}.\cos(\alpha) + F_{sl}} \tag{16}$$

and:

$$\cos(\alpha) = \cos(\beta).\cos(\theta_i) \tag{17}$$

F_{cn}: coulombic nucleus force, F_i: inter-atomic force in the K'th layer and F_{sl}: inter-atomic force at surface layer. [4,29]

Equation (16), is our proposed N.R. relation according to Q.P. theory. Using this equation, photons trajectory at the interface can be predicted. Electrons of those atoms at the interface, bear rotational torque, because of two perpendicular forces in Figure 7. First: Interatomic force F_i,

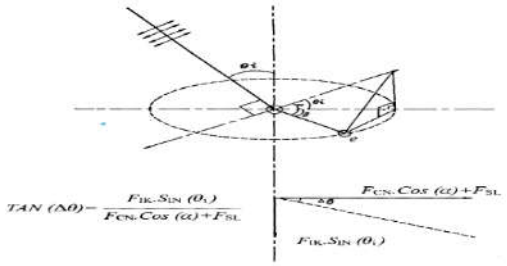

Fig. 7. Incident photon strikes at interface and interacts with bounded electron of an atom in it's flight route deviates.

second: coulomb mother nucleus force (F_{cn}). This torque makes electrons to rotate by " $\Delta\theta$ ", in every atomic layer.

$\Delta\theta$, asymptotes to zero in layers far from interface surface, inside the material.

In equation (16), for small incident angles ($\theta_i \approx 0$), the surface layer inter-atomic force (Fsl) will be neglected, in comparison with the term Fcn.cos(α), and we'll have:[4]

$$tg(\Delta\theta) \approx \frac{F_{ik}}{F_{cn}.\cos(\beta)}.tg(\theta_i) \tag{18}$$

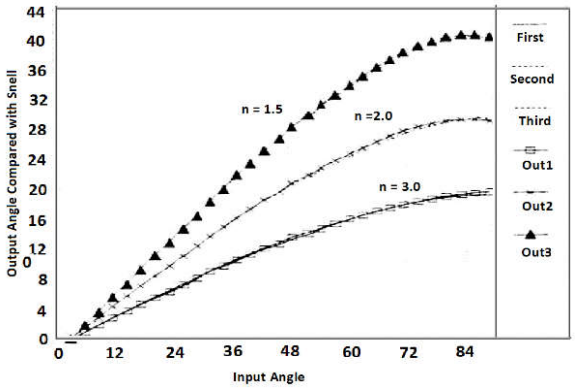

Fig. 8. Simulation results for three typical orthorhombic or tetragonal transparent crystals with different refractive indices (n= 1.5,2,30. "out 1,2,3", are Q.P. output angles and "first, second and third" are according to Snell's law.

For large incident angles ($\theta_i \approx \pi/2$), we can not neglect the effects of Fsl. This is because Fcn.cos(α) asymptotes to zero and the Fsl coefficient will have dominant effect:

$$tg(\Delta\theta) \approx \frac{F_{ik}}{F_{sl}}.\sin(\theta_i) \tag{19}$$

using equations (16) to (19), we can relate nanoscopic coefficients such as Fcn, Fsl and Fik to the macroscopic coefficient "n": the refractive index.

Using equation (16) to (19), and (12) to (15), a time domain Montecarlo [31] simulation demonstrates the photons angle deflection, when traveling through the interface surface between two different media. We have continued this procedure for 50 atomic layers from the interface surface and compared it with macroscopic results of Snell's law. (see plots of Figure (8) and Table-1 and Table-2).

TABLE I Q.P. SIMULATION RESULTS IN COMPARISON WITH SNELL'S LAW (N=1.5)

Imput angle (deg.)	Output angle photonic treat.	Output angle Snell's law
10	6.65	6.64
20	13.19	13.18
30	19.50	19.47
40	25.43	25.3
50	30.8	30.7
60	35.39	35.26
70	38.94	38.78
80	41.09	41.03
85	41.30	41.61

TABLE II PREDICTION OF CRITICAL ANGLE ACCORDING TO Q.P. HERE WE'VE DONE CALCULATIONS AND SIMULATIONS FOR 50 ATOMIC LAYERS FROM THE INTERFACE SURFACE.

Refractive index (n)	Snell's critical angle	Photonics critical angle
1.5	41.8	41.8 + 2.5%
2	30	30 + 4 %
3	19.47	19.47 + 5 %

Tables I and II and also Figures 8 and 9, show the final results obtained in simulations based on Q.P.- physics-mathematics model described before. Simulation results are estimated for three typical orthorhombic transparent material with three different refractive- indices (n = 1.5,2,3). The calculations in nanoscopic and atomic scales are based on equations (16) to (19) and equations (12) to (15), as stated before.

The output and critical angles have been computed and compared successfully in macroscopic scales with the results obtained from Snell's law (Tables (2) and also fig. 1)

It's been shown that the flight route of photons in first few molecular layers from the surface is not refracted as observed macroscopically. Instead nano-refraction occurs gradually step by step. It asymptotes to the output angle value. See also Figure 9.

Q.P. interpretation, emphasizes on Corpuscular nature of light that proves Fermat principle and also can be applied to other optical properties such as polarization and dispersion.

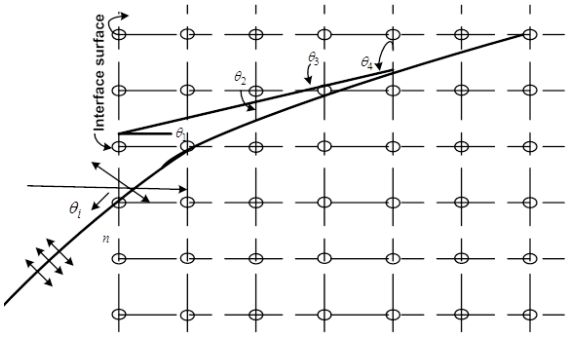

Fig. 9. According to Q.P. predictions, photon's flight route at the interface and few atomic layers around it, happens gradually that is different from macroscopic refraction, based on Snell's law. It suggests nano-refraction occurs.

6. CONCLUSION

It's more than 25 years we're seriously working on this new theoretical approach that is called Quantum Photonic Atto-second treatment. It's based on Bohmian Mechanics[14] and can explain both physically and mathematically nano-atto scales optical phenomena. We've already successfully estimated the refractive index of real material [25], dispersion [32], electro-optic effect [33] and polarization [34]. Even in the area of nonlinear optics, we've justified phase matching phenomenon in (SHG) or Second Harmonic Generation [35]. Also Laser Induced Breakdown (LIB) phenomenon and Multi-photon Ionization(MPI), have already been successfully justified using this treatment [36,37].

Now, in this paper, we've tried to justify Nano-Refraction using Quantum Photonic atto-second viewpoint. As seen the results, it does not contradict with any previous optical theories, according to "Correspondence" principle. Q.P. is related directly to postulates in Bohmian Mechanics.

As reported in this study, quantitative results based on Montecarlo time-domain simulations, demonstrate minimum errors at most 5 percent in comparison with experiments and previous theories in macroscopic scales. In addition it expresses a new intuitive viewpoint in nano-atto space-time scales.

For theoretical estimation of photon trajectories inside a Q.P.C., quantum mechanics will not help. But there's still a kind of dominant dogma about Q.M. in today's modern scientific literature. A huge amount of resistance against any idea that violates duality. In realization of Q.C., satisfaction of politicians and their interests in duality does not work. Also we're not trying to write a scenario for Hollywood. Even not for any more philosophical debate. In this paper, we've proposed a new area for theoretical prediction of nano-refraction inside Q.P.C. It's a search for finding "Truth".

It seems that Q.P. approach may also be examined to some other nano-optical phenomena as nano-reflection, nano-photo-refraction, nano-diffraction and some other nonlinear nano-optical properties inside the matters that quantum computers should be made from.

SUPPORT AGENCY

This work is supported financially by the Deputy Research of Amirkabir University of Technology, Tehran, Iran.

REFERENCES

[1] Kaatuzian H.. Toward quantum photonic computers, thinking may not be realized by digital computers. Book chapter. https://doi.org/10.1007/978-3-030-33495-6_38. Springer Nature Switzerland AG. October 20th, 2019. pp.490-503.
[2] Crane L. All aboard the quantum band wagon. Conference report Q2B practical Quantum Computing, January 04th 2020. New Scientist page.10.
[3] Gent E. Huge optical computer could not out pace quantum computing. January 04th 2020. New Scientist page.10.
[4] Kaatuzian H. Quantum Photonics. A Theory for Attosecond Optics, First Edition Amirkabir University Press 2012.
[5] Bohm D. Quantum Theory, Dover 1951, reprint Prentice Hall 1989.
[6] Golshani M. Philosophical viewpoints of Contemporary Physicist, Amirkabir Press, in Persian, 1990.
[7] Golshani M. From Physics to Metaphysics, Institute for Humanities and cultural Studies Publication, Tehran, 1997.
[8] Albert D. Bohm's Alternative to Quantum Mechanics, Scientific American,p.32-39, 5 (199).
[9] Albert D. Quantum Mechanics and experience, Harward University Press, 1992.
[10] Bell J. Speakable and Unspeakable in Quantum Mechanics, Cambridge University Press, 1987, 2004.
[11] Bohm D. Causality and Chance in Modern Physics, 1957, 1961, reprinted by University of Pennsylvania Press in 1980.
[12] Kaatuzian H. Photonics vol.2, in Persian, 4'th printings, AKU Press, 2018.
[13] Wheeler J.A., Zurek W.H., (edited). Quantum Theory and Measurement, Prinston University Press, 1983.
[14] Kaatuzian H. Quantum Photonics. An Authentic Concept for Attosecond Optics. J. Laser opt. Photonics 2017. vol.4. Issue 2. (suppl). DOI: 10.4172/2469-410X-C1-012.

[15] Saleh B., Teiche M. Fundamentals of Photonics, Wiley Interscience, 2007.
[16] Chu B. Molecular Forces, Lectures of P. Debye, Interscience Publisher 1967.
[17] Van Vleck G.H. Theory of Electric and Magnetic Susceptibilities, Oxford University Press, 1932.
[18] Greenway D.L., Harbake G. Optical Properties and Band Structures of Semiconductors, Pergamon Press, NewYork 1968.
[19] Debye P. Polar Molecules. Dover. NewYork, 1945.
[20] Omar M.A. Elementary Solid state Physics. Addison Wesley, 1975.
[21] Hecht E., Zajak A. Optics. Addison-Wesley publishing co. 1987.
[22] Meyer-Arendt J.R. Introduction to Classical and Modern Optics. Prentice-Hall Inc.1984.
[23] Ohtsu M. A Highly Coherent Semiconductor Laser. artech-House. Boston. London. 1992.
[24] Kaatuzian H., Bazhdanzadeh N., Ghohroodi Ghamsari B. Microscopic Analysis for Normal Dispersion based on Quantum Photonics Treatment. CSIMTA 2004. Cherbourg. France 2004.
[25] Kaatuzian H. Photonic interpretation of refractive Index. Taejon. Korea SPIE proceedings. volume 2778 ICO-17. 1996.
[26] Yariv A. Quantum Electronics. John Wiley & sons. 1989.
[27] Solymar L., Walsh D. Lectures on Electrical Properties of Material. Oxford university Press. Oxford. 1975.
[28] Fromhold A.T. Quantum Mechanics for Applied Physics and Engineering. Academic Press. 1981.
[29] Adibi A., Kaatuzian H. Photonic Treatment. An Authentic Concept, Optoelectronics Devices and Technologies. Mita Press. Vol.10. No.3. pp.421-430. 9 (1995).
[30] Wang S. Solid – State Electronics. McGraw Hill. 1966.
[31] Lunstrum M. Dattas. Physical device Simulation in a Shrinking World. IEEE Circuits & Devices. 8 (1990).
[32] Wahedy zarch A., Kaatuzian H., Ajdarzadeh Oskoei A., Amjadi A. Simulation and estimation of normal dispersion phenomenon in an acentric organic crystal (NPP) by the quantum photonic approach. (IOP Modelling Simul. Mater. Sci. Eng. 869–878 15 (2007).
[33] Wahedy zarch A., Kaatuzian H., Amjadi A., Ajdarzadeh Oskoei A. A Semiclassical Approach for Electro-Optics Effect. Optics Communications 281 (2008) 4033–4037 Elsevier. August 2008.
[34] Kaatuzian H., Amjadi A. Partial polarization of light in submicron photonic grating devices. San Jose. California. United States SPIE vol.4655. 2002.
[35] Wahedy zarch A., Kaatuzian H., Amjadi A. A semiclassical approach for the phase matching effect in the nonlinear optical phenomena. J. Opt. A: Pure Appl. Opt. 10 (2008) 125102 (9pp).
[36] Kaatuzian H., Amjadi A., Mardanpour H. Simulation of optical breakdown threshold by fast Laser Pulses. CSIMTA 2004. Cherbourg. France 2004.
[37] Kaatuzian H., Amjadi A., Mardanpur H. Microscopic simulation of laser induced breakdown. Optical Society of America. FIO 2003. USA. MT58. https://doi.org/10.1364/FIO.2003.