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Part II: The Feasibility and the Consequences of a Mechanism-Type Structure for Light Based on a Non-Wave but Periodic Spreading in Free Space

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Abstract

In a previous article we draw the attention that the spreading of light at large distances (the whole space) is the only property which can decide by yes or no if light really spreads physically like waves, while the fit of the waves for describing the diffraction fringes is insufficient for this purpose. Indeed, the fringe space is too limited and hence, brings the possibility of misinterpretation. Hence, the experiment for the verification if light is spreading like waves at large distances is necessary in principle, and is crucial. However, very surprisingly and tragically, this experiment was totally missing in history. As described in detail in the previous article, this experiment uses the simplest diffraction case, in which a beam of light falls perpendicularly with its axis on the line and the plane of a straight edge. Practically, this experiment verifies if there is a dependence of the diffracted light at large distances in the geometrical shadow, on the changes in beam thickness traversal to a single straight edge, while the distribution of light along the straight edge remains the same. If this dependence exists, as the wave theory for light fundamentally predicts, then the wave approach to light is spreading physically true. If there is no dependence then light cannot behave physically like the waves do. We attempted this experiment for many years, but could not finish it because of the lack of resources to measure at 100m–500 m. Our detailed description and attempt for this experiment, presented in the previous article, will empower big labs to perform this absolutely necessary experiment. However, our previous article also shows the alternative experimental proof that the answer to how light spreads also comes from comparing the well-known wave results for the diffraction on macroscopic holes with relatively recent data for the diffraction on nanoscopic holes. This comparison clearly shows that light does not spread physically like the waves do, which clearly demonstrates the necessity of a new, mechanism-type, non-wave but periodic structure for light in free space. Such an alternative answer regarding the spreading of light also makes absolutely necessary to perform the above missing experiment, as a direct way that convinces anybody how light is spreading. The present article shows that such a new structure for light is feasible based on the concept of finely dispersed matter or dark matter, with immense consequences in physics. This would be the start for further developments, or for alternative and better developments.

Keywords:* *Light spreading at large distances; Missing experiment for light; Bi-structure - a mechanism-type non-wave structure for light

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I. Introduction

In Ref. [1], we recognize and document an unsolved fundamental problem for the nature of light. Namely we recognize that the spreading of light at large distances (the whole space) is the only property which can decide by yes or no if light really behaves physically like waves in propagation, while the fit of the waves for describing the diffraction fringes is insufficient for this purpose. Indeed, the fringe space is too limited and hence, brings the possibility of misinterpretation regarding the nature of light. Currently it is assumed that the wave approach is the physical one [2]. Hence, the experiment for the verification of how light is spreading at large distances is necessary in principle and it is crucial, but it is still missing. This experiment is as follows. A stable laser beam falls perpendicularly with its axis on a straight diffracting edge, where the distribution of light intensity along the edge can be maintained constant, while the distribution of light transversal to the edge can be substantially broadened. For each case of transversal distribution of light, the intensity of the diffracted light is measured in a set of points at large distances in the geometrical shadow. If the results show a dependence of the intensity of light on the beam thickness transversally to the diffracting edge, as the Maxwell equations and the wave diffraction integral for light predict, then the wave theory of light is physically true. If there is no dependence, then light does not spread like the waves do, and a new physical approach is necessary for light, that is a diffraction mechanism that takes place only in the material edges. Hence, this experiment is crucial, and can be done without any wave calculation for defining the measurement points because these points can be found by a simple but systematic practice of light measurements at small and large distances. However, the analytical and numerical wave calculations are instructive both as a full illustration of this approach and as a practical way to indicate the above measurement points.

In Ref. [1], we describe the method necessary for naturally recognizing this missing experiment for light and its results, instead of ignoring them for hundreds of years. Such a method would avoid repeating in the future this case of the missing fact, and the case of the missing crucial fact for heat: producing heat by mechanical action. From our lifetime work on light we found that both the case for light and the case for heat happened because the method of broad thinking on the major opposing views in a field, was not used, and is not used in the present time, in a systematic way in the university and in society in general. For the case of light, the major opposing views are those on the origin of the diffracted light - as waves both inside and outside of the diffracting edge, or only inside the diffracting edge. A simple broad thinking on these opposing views shows to the regular student that there is no verification on how light spreads at large distance, and that there is a clear need to recognize that the diffracted light is born only inside the diffracting edge. This recognition makes impossible for light to physically behave like waves in diffraction (because if it did, the diffracted light would also be produced around the diffracting edges). Only by using this broad thinking, we realized that there is a missing experiment at the foundation of light: how light spreads at large distances, as waves or not as waves? For heat, the opposing views were how the heat is produced in a body-only by its vicinity with a hotter body, or both by this vicinity and by mechanical action. If the student is taught and allowed to practice this broad thinking he/ she will see the missing fact/ experiment, and hence, the theories that are based on missing fact will not survive for a long time. On this line of thought, sooner or later this method will become a basic part in the education in science, for growing a scientist who has the big-picture knowledge, in excess to the method for fast thinking for detailed knowledge. The latter cannot grow a functional and wise big-picture for science and society.

In Ref. [1], we present a detailed description of the missing experiment for the verification of how light spreads at large distances. We designed and attempted this experiment for more than 10 years, with measurements up to 5 m distance in the geometrical shadow, from the diffracting edge. For these distances, we found no-dependence of the diffracted light on the beam thickness above the diffracting edge, which is in accordance with the wave integral prediction. Due to the lack of resources to measure at 100 m to

500 m, where the wave approach indicates the existence of such a dependence, we could not finish the experiment. But our documentation there for this experiment will empower bigger labs to develop and finish these measurements. However, Ref. [1], also shows that by using the method reported above, namely the broad thinking on the major opposing view, we found that alternatively, the proof for how light spreads in general, surprisingly comes by recognizing the real significance of relatively new experimental data existing for the diffraction on nanoscopic holes [3,4]. This experimental data comes from measurements which analyze the role of the edges in the diffraction on nanoscopic and microscopic holes in nanoscopic walls. We show that the data from these measurements provides a simple case of reduction to absurd for the wave approach to macroscopic holes, which proves/ demonstrates that light has physically a non-wave spreading. This proof makes necessary and important for the physics community to perform the above missing direct experimental verification, as a double-check for this proof. If correct, this proof/ demonstration makes necessary a new, non-wave but periodic, mechanism type structure for light. This situation would be similar but much more important than the case when the heat production by mechanical action was missing and then added in physics by the kinetic theory of heat, instead of the model of the caloric fluid for heat. A new mechanism type structure for light would remove the non-mechanism, physically impossible ideas like “light spreads like waves, but nothing oscillates”, while still allowing to use the wave approach as a formal way, valid for practical quantitative evaluations in the limited space of the diffraction fringe zones.

Again, this clear case of reduction to absurd for the wave diffraction of light shows that the wave approach has a formal (not physical) character for light, and makes necessary and important for the physics community to perform the missing experimental verification of how light spreads at large distances, as a double-check (double to the above case of reduction to absurd for the wave approach). This double-check would convince everybody on the necessity of a new, non-wave but periodic, mechanism type structure for light.

In the present paper we show the feasibility of a new, non-wave but periodic structure for light. This new structure is a mechanism-type structure that is based on the concept of finely dispersed matter (or dark matter) under motion. This is a kinetic approach that extends to light, the kinetic approach which is the basis for the understanding of heat. Such a development of a new structure for light requires the above method for broad thinking on the major opposing views and hence, for seeing the missing fact and for growing the necessary broad views.

We show in this paper that this structure is feasible and brings mechanism-type explanations for all the optical phenomena. Again, in this new structure light does not spread like the waves do. Such a change would be similar but much more important than the case when recognizing the heat production by mechanical action made necessary and feasible a mechanism-type model, which is the kinetic theory of heat, instead of the model of the caloric fluid for heat. In Section II of the present paper we show the necessity and the feasibility of a new structure for light, which we call a bi-structure. In Section III we present the applications of the bi-structure in optics, and in Section IV we suggest the broad consequences in physics of this bi-structure.

II. The feasibility of a non-wave, mechanism-type structure for light

This section is intended as a starting point for a broad discussion regarding the nature of light by using a broad thinking on the major opposing views on the origin of the diffracted light, to involve all the necessary issues. The current approach to the diffraction of light is a wave approach [2]. In this section we propose a non-wave but periodic structure for light that is, a mechanism-type structure which we call a bi-structure: one structure in free space and a different structure in matter. These two structures transform into each other on the surface of matter, depending on the direction of light propagation.

The necessity for a non-wave structure for light in free space:

Section I above describes the missing experimental verification of how light is spreading at large distance, and the proof that light does not spread as the waves do. These form the missing fact at the foundation of the current understanding of light. This is similar with the missing fact long ago, of how heat is produced by mechanical action, at the foundation the old caloric fluid understanding of heat. This missing fact for heat showed the necessity of a new type, mechanism-type understanding for heat. Similarly, the current missing fact for light shows the necessity for a new, non-wave, mechanism-type structure and understanding for light. In fact there is a great deal of evidence that strongly supports a non-wave approach. This evidence includes:

- The role of the bright spots on the diffracting edges, as the only source for the diffracted light, which is the fundament of the geometrical theory of diffraction (GTD) [5-7]. However, although GTD uses straight line rays for the light originating from these bright spots, GTD also uses the wave description for the light propagating on these rays, which physically is impossible because the waves spread away from such rays.
- In the statistical optics [8, 9] the statistical nature of the diffraction and image formation requires a statistical nature of the light beam that is, a discontinuous and random structure. Such a basic property cannot be offered by the continuous structure of a light beam in the wave approach, but is intrinsic and obvious for the bi-structure of light, as we propose in this paper

This new, non-wave structure for the spreading of light would offer a great positive change in physics, greatly extending the positive change brought by the kinetic theory of heat. We propose here the first steps towards such a new structure for light. Such steps are necessary to initiate a strong path of analysis and development for light and for consequences.

The starting point for a non-wave structure for light in free space:

In this non-wave, mechanism-type structure for light there are three fundamental requirements.

- The first fundamental characteristic in this new structure is that light does not spread like the waves do. In this new structure, both the light in the fringe zones and the light at large distance in the geometrical shadow, are essentially an effect of the light originated in the edges. In GTD [5-7], the rays of light propagating from the edges are essential for producing the diffraction fringes. However, in GTD these rays are still based on the wave approach, which is physically impossible: the waves are essentially spreading and hence, cannot propagate as rays. In the new structure light must have entities which propagate in a certain direction, and can spread a little around it.
- In this new structure, a beam of light is discontinuous across its propagation direction, that is, it consists of entities/ trains of limited length which move in the beam direction.
- In this new non-wave structure for light, its entities/ trains must have a periodicity along the propagation line, and hence, each entity/ train carries a periodical momentum along its propagation. A beam of light with such a structure produces naturally forced oscillations, regular or resonant, and statistical effects when it falls on a surface of matter. Currently these oscillations are described with the electromagnetic equations for electron oscillations on a surface (the Lorentz model [10]), for plasmons, ultrasound and sound [11-14]. As a result, when two beams superpose on a surface of matter the interference phenomenon occurs. Based on these three fundamental requirements we shortly present here the feasibility for a new, non-wave but periodic, mechanism-type understanding for light, which we call the bi-structure.

The feasibility of a non-wave but periodic structure for light:

We propose the bi-structure of light based on the concept of finely dispersed matter or dark matter, and show that it offers easy, mechanism-type explanations and quantitative descriptions for all the optical phenomena. We claim that the light phenomena themselves are a clear way to recognize the physical existence of the finely dispersed matter or dark matter. This is similar with the evidence that the wind phenomena are a solid proof for the existence of the air.

A general discussion of the finely dispersed matter/ dark matter:

As a starting point for a mechanism-type understanding of light, it is necessary to discuss first the difference between the new concept of Finely Dispersed Matter (FDM) or dark matter and the disproved concept of ether, to conclude that the FDM concept is convincing. These two concepts are not similar at all. Let us start with the case of the ether. From the beginning, to support the high velocity of the waves for light, the ether had to have an impossible high rigidity [15]. Indeed, such rigidity has no drag effect on the bodies in universe. Because of this, it was absurd from the beginning, to assume that this ether exists and to look for it by the Michelson-Morley experiment. As a result of this impossible property, the MM experiment naturally did not indicate the existence of the ether. Without the ether as a support for the waves of light, the rationale reaction along history would have been to deny the existence of the waves themselves, and to look for a non-wave model, one that gives a mechanism-type understanding instead of postulated ideas (similar with the kinetic theory for heat, instead of the caloric fluid model). Instead, it was assumed that the light waves exist even without a medium that oscillates, which is the absurd idea that light propagates as waves but nothing oscillates. In the above context, our new structure for light (the bi-structure) assumes that light in free-space is based on periodic trains of bursts of FDM which have a simple steady motion in the direction of light propagation. This is the context that all bodies of matter are immersed, outside and inside, in an all-direction-moving-flux of FDM (dark matter), similar in a certain extent with a body immersed in air. The wind which we feel in the air is a solid proof that the air exists. Hence, the existence of a propagating light is the proof that the FDM (or dark matter) exists. Otherwise it is not possible. Therefore, the existence of the FDM is evident from the existence of light, and hence, the exiting FDM/ dark matter is not at all similar with the non-existing ether. If these are true, the FDM must be a major part in the structure of matter–atom and solid state. Otherwise is not possible. Moreover, as we also show in the next section, this FDM gives the physical mechanism for gravity, and hence, the gravity itself becomes a proof for the existence of FDM. Therefore considering the light phenomena and the gravity as simple proofs for the existence of FDM/dark matter, is in contrast with the insufficient base/ framework of the current discussions on dark matter [16-18]. In these discussions the dark matter is an elusive concept which could not be seen/ demonstrated yet [16], “We can only verify the existence of any form of matter if we can “see” it with our eyes, with telescopes, or with instruments that detect photon emissions from different frequencies of the radiation spectrum. Since we do not see dark matter, we can only conclude that if it exists, it does not interact with light, or photons, as the ordinary electrically charged matter does. Therefore, dark matter must only interact very weakly in collisions with ordinary matter such as electrons, protons, and neutrons, because otherwise we would already have detected in our laboratories and from the spectral lines emitted by atoms in stars. Hunting for elusive dark matter is now a multibillion dollar international industry. Experimental physicists in pursuit of this mysterious dark matter hope to detect it eventually as it interacts very weakly with ordinary matter.”

The structure of light based on finely dispersed matter/ dark matter:

In our attempt/ quest for a mechanism-type, non-wave but periodic model for light we propose that a light beam propagating in free space and in transparent matter is a bi-structure, that is a structure of two parts:

- A set of periodic trains of bursts of finely dispersed/ dark mater, in free space. The bursts have a limited transversal cross-section, and the number of bursts in a train (hence, the length of the train) can vary as dictated by the physical characteristics of the light production/ propagation in matter. The trains of bursts are randomly distributed across the transversal area of the beam. The number of trains per unit area in the beam light can vary and defines the intensity of the beam, and fluctuates which is the basis for the random aspects of light. Each burst of finely dispersed matter carries a momentum distribution oriented in the direction of light propagation, similar with a burst of wind. We show in the next subsection the quantitative descriptions of the momentum distribution carried by a train of bursts in the bi-structure model for light (Model 1).
- A set of Collective Longitudinal Electron Oscillations (CLEOs) which propagate in transparent matter, or absorbed in non-transparent matter. These two parts, one in free space and one in matter are transforming, by a strong resonant momentum transfer (a non-instantaneous effect), into each other on the surface of the condensed matter: From the periodic train of bursts into a CLEO (Model 2), or from a CLEO into a periodic train of bursts, depending on the direction of the propagation–towards the matter or outward from the matter. When a train of bursts impinges on the surface of body it produces, by its periodicity, a local and resonant momentum transfer (Model 2) to the electron population, and hence, produces collective longitudinal electron oscillations (a CLEO)–similar to the Lorentz model in electromagnetism. A CLEO propagates mainly forward in a transparent material, as the bi-structure part of light in condensed matter, or produces effects on the surface of a metal – reflection, photo effect for instance. At the exit surface from a transparent material, the arriving collective electron oscillations naturally throw in space a periodic train of finely dispersed matter. The non-wave but periodic structure in free space, and the interaction of the two parts through resonant momentum transfer, are the essential ideas of this bi-structure.

At this point we need to consider how a CLEO, which is produced on the entrance surface, produces the reflected light: a train of bursts emerging from the surface on the reflection direction. This need makes necessary the existence of a new fundamental fact: the surface electron layer is immersed in, and is in equilibrium with, a field of FDM/ dark matter. If this fundamental equilibrium exists then, a CLEO that takes place in the surface electron layer naturally throws in free space a train of bursts of FDM on the reflection direction as illustrated in Fig. 1 and Fig. 2. We explored if the need for such an equilibrium of condensed matter with FDM/ dark matter, also comes when a mechanism type model is searched for electromagnetic phenomena and for the atomic structure. We found that indeed, such a search brings this need. All these will inevitably be developed and become obvious mechanism-type models in the future.

The resonant interaction between the two parts of the bi-structure through momentum transfer replaces the instantaneous action of the electromagnetic field on electrons, by the action of periodic trains of bursts for the same purpose, namely for producing collective electron oscillations that propagate in matter, with direction changes dictated by the angle of the light incidence on the material surface. Hence, the idea is that the strong action of the electromagnetic forces, an action that has no mechanism, is replaced with the same effect (collective electron oscillations) by a time-taking resonant process based on momentum transfer. This transfer is a process that is based on a kinetic mechanism-type interaction, between a moving field of finely dispersed matter (dark matter) and particles like the electrons. Such a structure for light, discontinuous longitudinally and transversally can be tested in an imaging experiment by transforming a narrow beam into a strongly divergent beam that falls on a large array of very small light detectors, to study their random flickering as a function of intensity.

Besides these two main models for light, at least three other models are necessary. The third model (Model 3) describes the propagation of the collective electron oscillations in bulk matter (the bulk part of the bi-structure), as the basic form for the light propagation in matter. The fourth model (Model 4) presents the bi-structure mechanism for reflection and refraction. The first four models are necessary for describing in detail the propagation of light through free space and inside materials. The fifth model (Model 5), together with the first two models, shows the simple mechanism for light diffraction/ spreading across the macroscopic and nano-structure edges. It also shows the mechanism for the propagation of light and electron oscillations/ currents (plasmons) in surface nanostructures, in contrast with the formal electromagnetic wave approach. We show that these five models explain in a mechanism way the light phenomena in Optics, including the Michelson-Morley experiment, with broad consequences in Physics – for explaining the mechanism of gravity for instance.

The basic models in the new structure for light:

Model 1. The structure of light in free space:

This model gives a quantitative description of the propagation in the z direction here, of a beam of light in free space based on a number of parallel periodic trains of bursts of Finely Dispersed Matter (FDM). This is in direct contrast with the electromagnetic wave approach. There is a finite number of bursts in each train The distance between the centers of two bursts in the train is λ , and the distance between the edges of two neighboring bursts, on their axis line, is λ /2. If c is the propagation speed of a burst we can define $T=\lambda/c$, $\omega=2\pi/T$ and $k=2\pi/\lambda$ where T is the period in a train of bursts, that is the time necessary for the train propagation to repeat the momentum distribution at position z. ω is the time frequency with which the bursts repeat at the z position in space, and *k* is a space frequency.

Each burst carries a distribution of momentum, oriented longitudinally on the propagation direction. In time, a practical form will be found for the momentum distribution carried by a burst. For now the momentum for a burst could be described by the positive part of a cosine. Therefore, the propagation of the momentum carried by the bursts of a train propagating in the z direction can be described by a non-wave but periodic expression for the momentum density per unit of the transversal area to the train,

$$p(z,t)=A\times pc(kz-\omega t+\varphi) \tag{1}$$

Here the quantity A is a positive constant for the momentum density on a traversal area S around the axis z of the train, and is zero outside of this area. “pc” stands for the cosine values when cosine is positive or zero, and equals zero when cosine is negative. φ is a phase constant that allows a delay for such momentum propagations. Hence, $p(z,t)\times S$ is the effective momentum on the axis of the train propagation. Then, the expression for the effective momentum of the train, that is a distribution along the propagation axis of a train of bursts, is

$$p(0,0,z,t)\times S=A\times S\times pc(kz-\omega t+\varphi) \tag{1'}$$

where S is an effective transversal area for a burst of FDM Interestingly, this p(0,0,z,t) although is not a plane wave, and has only positive or zero values, it satisfies a wave equation along the direction z of propagation of the periodic train of bursts. (In comparison a plane wave satisfying the wave equation for the electric field in the electromagnetic theory, has both positive and negative values, oscillating transversally to the propagation direction z in free space.) A similar form for the momentum density of a train propagating on the $\vec{k}=(0,0,k_z)$ direction, with decreasing values traversal to propagation, would be

$$p(x,y,z,t)=A\times pc(k_z z-\omega t+\varphi)\exp(-x^2/a^2-y^2/b^2) \tag{1''}$$

where a and b are parameters which define a limited transversal area for the bursts.

The intensity of the beam of light is determined by the number N of trains of bursts per unit time and surface along the propagation direction of the beam, which is a fluctuating number, and by the effective momentum along the propagation direction z, eq. (1”).

The intensity can be approximated by,

$$I = \gamma \times N \times c \times p(0,0,z,t) \times S \tag{2}$$

where *c* is the speed of light, and γ is an adjusting constant. This is because the transversal average of $c \times p(0,0,z,t) \times S$ is the energy for a burst at a given (z,t). Notice that I/c can be experimentally determined from measurements of the dependence of the momentum loss by producing pressure. In time this model for the momentum will become better.

A divergent beam of light, such as a laser beam, is composed of trains of bursts which propagate in the directions $\vec{k}$ involved by this beam. An expression for the momentum of a laser beam requires the summation of the momentums, with expressions similar to (1"), for all the all trains involved.

Polarization:

In the bi-structure, the polarization of light can be simply understood in the terms of the traversal cross-section (form) of the bursts in the trains of the finely dispersed matter of a beam of light. A round cross-section for the bursts defines an un-polarized train/ beam, while an ellipsoidal cross-section (1") explains the polarization of the train/ beam. A non-polarized beam can also be a mixture of randomly oriented lightly-polarized trains.

Superposition principle:

In the wave approach there is no influence/ change when two beam of light superpose/ intersect: After the intersection the two beams are theoretically the same. This is because in this approach there is no material support for the propagating waves. In the bi-structure approach when two beam of light intersect they might influence each other but only in some very small extent. Indeed two bursts of FDM moving through each other might result in some reciprocal change. But even there would be such a change the trains of bursts of FDM are discontinuously distributed across the propagation direction of the two beams of light and hence, there will be only a very small fraction of intersections.

Model 2. Electron oscillations on the surface of condensed matter:

The above periodic momentum (1–1") causes, when it falls on a surface of condensed matter, the following effects: Collective Longitudinal Electron Oscillations (CLEO) and/ or a current of electrons, propagating inside the material. All these depend on the characteristics of the trains of bursts and of the material. For non-conductive materials which are transparent to light, the propagation of CLEO dominates. For quasi-free electrons the momentum transfer will produce a forward motion of electrons that is, a current of electrons in the material, or photoelectrons outside of the surface. In metals such currents dominate over the electron oscillations At this time, lacking a better insight regarding this momentum transfer, we assume for the force acting on a single electron on a material surface, an expression for this force that is proportional to the above momentum, similar with a time derivative,

$$f(\omega,t) \approx \alpha A \times pc(\omega t) \geq 0 \tag{3}$$

where α is a proportionality constant (1/sec) and "pc" stands for positive part of cosine as in Eq. 1.This force exerted by a burst through momentum transfer to a bounded electron is only in the forward direction (*z* here) and is localized spatially in the traversal area of the burst. In the steady state regime, the bounded electrons move towards the bulk of the material when they receive momentum from the incident bursts, and move outward in the pause between the arrivals of two consecutive bursts. Because of the periodic nature of action by the incoming train of bursts, resonance phenomena in the forced oscillations occur when adequate electron binding energy is present. When the frequency is large the magnitude of the effect of the force (3) is large and produces forward moving electrons. Hence, the bi-structure produces, on the material surface, asymmetrically forced collective electron oscillations and/ or current in the forward direction which is the z axis here. However, in their propagation inside matter, these asymmetric collective electron oscillations naturally become symmetrical oscillations. The equation for the asymmetric electron oscillations from the bi-structure is,

$$m\ddot{z}(t)+b\dot{z}(t)+kz(t)=\alpha A\times pc(\omega t) \tag{4}$$

where m is the oscillator mass, b is a damping constant, k is the elastic binding constant for the oscillator.

A good insight on the resonant and asymmetric electron oscillations produced on the surface by the bi-structure can be obtained by comparing it with two cases of symmetric forced oscillations. The case of the electromagnetic approach and the case of mechanical approach. In the electromagnetic approach for light propagation in materials the following equation (Lorentz model) is used [10] for producing transversal electron oscillations in the plane of the material surface (perpendicular on the propagation direction which is z here).

$$m\ddot{x}(t)+b\dot{x}(t)+kx(t)=F(\omega,t)=eE\cos(\omega t) \tag{4'}$$

Here m and e are respectively the mass and the charge of the electron, E is the electrical field which is assumed here along the x direction, b is a damping constant, and k is the elastic binding constant for the oscillator. If $k=0$ we have the case of free or quasi-free electrons. In mechanics [19] a linear and symmetric forced oscillation along the z axis (longitudinal oscillation) is given by a periodic force along z:

$$m\ddot{z}(t)+b\dot{z}(t)+kz(t)=F(\omega,t)=F_m\cos(\omega t) \tag{4''}$$

Again, here m is the oscillator mass, b is a damping constant, k is the elastic binding constant for the oscillator and F is the external periodic force.

Both the mechanical and the electromagnetic phenomena show that the amplitude of the oscillations grows at high values (resonant oscillations) when the external force (mechanical or electrical) has the frequency ω close to the natural frequency of the oscillator which is $\omega_0=\sqrt{k/m-(b/2m)^2}$. If $b=0$ then an infinite amplitude occurs at $\omega=\omega_0=\sqrt{k/m}$. In practice, a non-zero b is always present. It is relatively easy to verify that the expression for the symmetric longitudinal mechanical oscillations from eq. (4”) is:

$$z(\omega,t)=(F_m/m)\left[1/\sqrt{(\omega^2-\omega_0^2)^2+b^2\omega^2}\right]\cos(\omega t-\delta) \tag{5}$$

A similar expression is true from the electromagnetic approach (Lorentz model).

We could not find the exact solution to eq. (4) for an asymmetric oscillation. However, an asymmetric oscillation naturally becomes close to symmetric as it propagates in the material. These collective longitudinal electron oscillations have the energy to propagate in a transparent material – see Model 3, and to be reflected as trains of FDM bursts back in the free space, by the surface of a transparent material or of a metal surface, see Model 4 [20-23].

Model 3. The structure of light in condensed matter:

This model describes the propagation in a macroscopic body of light that falls normal on the surface of this macroscopic body. In the electromagnetic approach the propagation of light in a transparent material without electrical charges and currents, and without magnetization, is described by traversal waves. In the bi-structure approach the Collective Electron Oscillations (CLEOs), produced by the incident trains of light on the surface of a macroscopic body are mainly in the direction of the beam propagation. We describe shortly below the propagation of these CLEOs in a continuum of electrons in a transparent material. The equations for this propagation, i.e. for the propagation of the light beam in condensed matter, should be similar with the equations used for charge density waves (plasmons) [11,12], and for sound and ultrasound [13,14]. A CLEO equation for the longitudinal/ dilatation/displacement *s* along the normal to the surface of the electron population in the simplest case – the homogeneous plane-wave case, is as follows,

$$\frac{\partial^2 s}{\partial t^2} = v_{ew}{}^2 \nabla^2 s - B(\vec{r})\frac{\partial s}{\partial t} - D(\vec{r}) \times s \tag{6}$$

Here, s is the displacement of the elementary volume in a homogeneous electron population that behaves as an elastic medium. Here an elastic displacement propagates with the speed $v_{ew} = \sqrt{Y_d / \rho_e}$ in the elastic medium of electrons with the density ρ_e and bulk modulus Y_d. *B* is a dumping coefficient, and *D* brings a variation in elasticity. For an infinite one-dimensional geometry with constant B and D we can easily verify that an elementary plane-wave solution propagating in the positive z direction is,

$$s(z,t) = A \exp i(kz - \omega t + \varphi)\exp(-Bt/2), \tag{7}$$

where $k = (1/v_{ew})\sqrt{\omega^2 + B^2/4 - D}$ and φ is phase constant. In the case of the bi-structure, the constant *A* in this wave can be taken as zero outside of a limited transversal area *S*, as in eq. (1), in order to define a CLEO with limited transversal area (an oscillating tunnel) generated by a train of FDM bursts propagating in direction z and falling on the surface of the transparent material. Alternatively such an oscillating tunnel could be described by,

$$s(z,t) = A \exp i(kz - \omega t + \varphi)\exp(-Bt/2)\exp(-x^2/a^2 - y^2/b^2) \tag{7'}$$

For *B* = 0 and *D* = 0 we have the standard relation $k = \omega / v_{ew}$ for the perfectly elastic medium and hence, the oscillations have the speed,

$$v(z,t) = -iA\omega \exp i(kz - \omega t + \varphi) = A\omega \sin(kz - \omega t + \varphi) - iA\omega \cos(kz - \omega t + \varphi) \tag{7''}$$

The kinetic energy per unit volume for a plane-wave in a homogenous body is,

$$E_{kin} = (1/2)\rho_e (v_0)^2 = (1/2)\rho_e A^2 \omega^2 \tag{8}$$

where $v_0 = A\omega$. Hence, the intensity of a plane-wave beam of light (energy per unit surface and unit time) in a transparent matter is,

$$I(z,t) = (1/2)\rho_e A^2 \omega^2 v_{ew} \tag{8'}$$

Based on these expressions for the intensity in a plane wave (continuous) propagation one can develop a quantitative description for the intensity of a bi-structure beam of light (a discontinuous non-wave structure) in a transparent material.

We have to recognize that with this new structure for light that is, with the bi-structure, the finely dispersed/ dark matter becomes a necessary and obvious part of the structure of condensed matter. And hence necessarily, a CLEO transfers a part of its momentum to the surrounding finely dispersed matter.

That is, a CLEO produces by its periodicity, along its propagation in the transparent matter, a forward propagation of the surrounding/ embedding finely dispersed matter (FDM). A study of this phenomenon is necessary for understanding the details of light behavior at the entrance and exist surfaces in condensed matter.

The above formulae show that at the entrance surface in condensed matter the speed of light decreases from the speed *c* in free space to the speed v_{ew} of CLEO in condensed matter. This is because in free space we have only a linear propagation while in condensed matter we have a propagation of oscillations. As a result, the constant k in Eq. (7-7”) increases and hence, the wavelength decreases while the oscillation frequency ω and the period T remain the same. At the exit surface from the transparent material the reverse process to that at the entrance surface occurs. The CLEO naturally produces a train of bursts which propagate linearly outward from the exist surface. Here the speed v_{ew} of CLEO increases towards the free space value c of light. If so, the value of k in Eq. (7-7”) decreases and hence, the wavelength increases while the oscillation frequency ω and the period T remain the same.

In optical fibers the longitudinal collective electron oscillations described by eqs. (7, 7’) are the driving force of the light propagation. At the end of the optical fiber the CLEOs throw in free space trains of bursts of FDM. With this concept, the mechanism of the propagation of light is easy to comprehend in comparison with the propagation of light based on a transversal/longitudinal electromagnetic field.

Model 4. Reflection and Refraction of light:

This model describes the bi-structure mechanism for reflection and refraction on the surface of a transparent material, and the mechanism for reflection and absorption on a metal surface – see **FIG. 1** and **FIG. 2** below:

- A flat surface for a transparent material has first an elastic layer of electrons which normally oscillate perpendicular to this surface. But under this layer, there is the regular structure of the transparent material where the electron population is bound in the atomic structure, as an elastic medium which can properly oscillate and propagate the collective electron oscillations described in the bi-structure of light.
- A flat metal surface is also characterized by an elastic and denser surface layer of electrons which oscillate normally perpendicular to this surface. Under this layer there is the regular metal structure of atoms surrounded by quasi-free electrons which cannot oscillate with frequencies in the light range, and hence, cannot propagate such electron oscillations inside the material.

Reflection mechanism for the interface air-to-transparent material:

In a transparent material the reflection has the following mechanism. The bound electrons on the surface see **FIG. 1**, which oscillate normally on the perpendicular direction to the surface, are pushed by the horizontal component of the periodic pressure of the incident train, to collectively oscillate on the symmetric reflection direction that corresponds to the incident train of bursts - see **FIG. 2**.

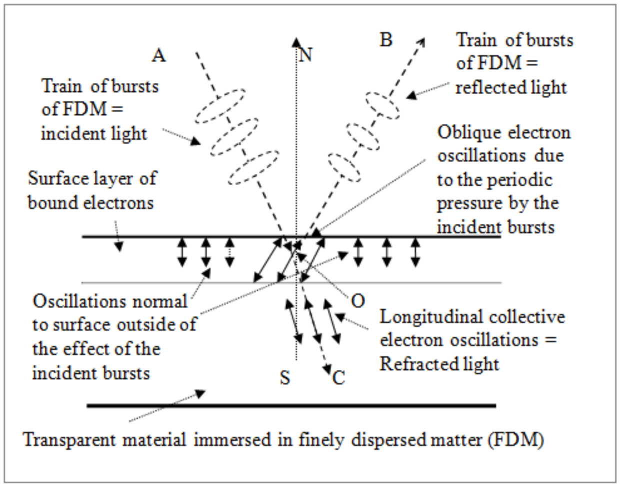

FIG. 1 **The reflection and refraction on the surface of a transparent material in the bi-structure approach.** $\theta_1 = angle(AON)$ **= Incident angle ,** $\theta_2 = angle(SOC)$ **= Refraction angle. The incident light from free space is composed of periodic trains of bursts of finely disperse matter (FDM). Each train transforms on the surface of a transparent material into a reflected train of bursts of FDM, and in a refracted collective longitudinal electron oscillations which propagate into material. For a metal, the refracted light, which would be based on the longitudinal collective electron oscillations – CLEOs, does not exist.**

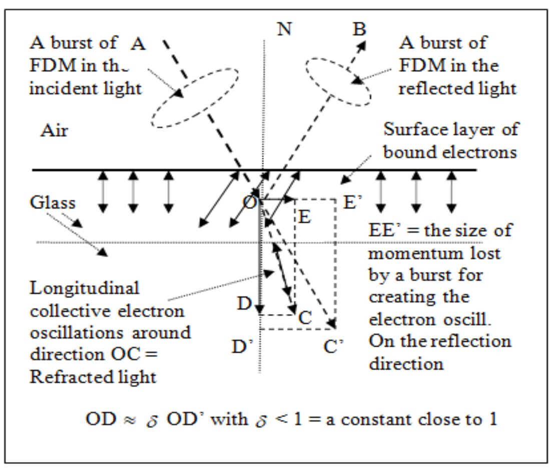

FIG. 2 **The refraction mechanism from air to transparent material. The light incident angle is** θ_1=angle(AON)= angle (D'OC')**. The light refraction angle is** $\theta_2 = angle(DOC).\vec{OC'} =$ **The total momentum carried by a burst of FDM.** $\vec{EE'} =$ **The total horizontal momentum lost by a burst of FDM for creating the oblique collective electron oscillations on the surface.** $\vec{DD'} =$ **The vertical momentum lost by a burst of FDM for creating the oblique collective oscillations on the surface.** $\vec{OD} = \delta \vec{OD'} =$ **where** δ **is a constant < 1.** $\vec{OC} =$ **The momentum penetrating the surface electron layer, available for creating the longitudinal collective electron oscillations (CLEOs) in the bulk of material.**

This symmetry is a result of the elastic behavior of the surface layer of electrons in the energy range of the incident bursts. The effect of the horizontal and vertical components of the burst momentum is also that the oscillation frequency on this reflection direction is the same as the frequency of the incident train of bursts. As discussed in Models 1 and 2, at the beginning this oscillation is an asymmetric CLEOs – more displacement forward directions than in the backward directions. When the frequency and energy of the bursts in the train increases (as for the X-rays case) the surface layer of electrons is no more elastic, and hence, the reflection has different characteristics or does not occur. Moreover, even in the elastic range of the incident light, there is a case where the reflection does not take place. Indeed, when the reflection direction is a little above the perpendicular to the incident direction, that is close to perpendicular on the refracted direction, the reflected light disappears when the incident light is polarized in the incident plane which is the plane AON. In this case the bursts falling on the electrons in the surface layer, have a larger size in this plane and hence, their flat action prevents the electron oscillations on the reflection direction. Naturally, such an effect does not happen when the polarization of light is perpendicular on the plane of incidence AON that is when the size of the bursts in the light trains is bigger on this perpendicular direction.

Polarization by reflection:

Polarization by reflection can be explained in a mechanism-type way by the bi-structure. Indeed, the above process of reflection shows that the reflection process is diminished when the polarization of the incident trains is in the plane AON which is perpendicular on the reflecting surface. This is because the CLEO (which propagates in the plane AON) can not be produced properly when the size of the incident bursts (in the plane AON) covers more space than the distance between the centers of two bursts in the train (that is the “wavelength” λ). Bt it can be produced if the beam is polarized in the plane perpendicular on plane AON. Hence an unpolarized beam of light (which has trains of burst polarized both in the plane AON and in the plane perpendicular on AON) becomes by reflection polarized only in the plane perpendicular on AON.

Refraction mechanism for the interface air-to-transparent material:

In contrast with a metal surface, in the case of a transparent material the incident train produces a refracted light that is, CLEOs which propagate forward in the homogeneous transparent material. The direction of this propagation is a result of the following process – see **FIG. 2.** If the train of bursts falls perpendicularly on the surface of the transparent material, then the refracted CLEO propagates in material along this incident perpendicular direction, because of the symmetric resistance transversal to this direction. For an oblique direction of incidence, the effect of the normal direction for the oscillations of the surface electron population is to change the angle of propagation of the FDM bursts, from the incident direction to the refraction direction – see Fig. 2. Indeed, a part of the horizontal component of the momentum of a burst is lost by its action like a wind on the normal direction of the collective electron oscillations of the surface electrons. This effect is material dependent that is, it is dependent on the optical property of the material. However, the normal-to-surface component of the momentum of a burst also changes but in a smaller extent while passing transversally through the thin surface layer of electrons, as compared with the change in the horizontal momentum component. As a result of this loss mainly on the horizontal direction, a part of the incident train of bursts penetrates under the surface layer on the refraction direction (not on the incident direction), that is in the bulk part of the transparent material. In this bulk region there is a symmetric resistance across this refraction direction, and hence, the train of bursts propagates linearly on the refraction direction, and produces the CLEOs which are the basis of light in condensed matter. From **FIG. 2** we have, $\tan\theta_1 = OE'/OD'$ and $\tan\theta_2 = OE/OD$, where $OD = \delta\times OD'$ with $\delta < 1$.Hence,

$$\tan\theta_1 / OE' = \delta\times\tan\theta_2 / OE \tag{9}$$

$$\tan\theta_2 = \tan\theta_1 \times (OE / OE') / \delta$$

Here the ratio OE/ OE'< 1 is a characteristics of the momentum fraction (on the horizontal direction) lost by an incident burst of FDM in the surface layer of the transparent material. Also $\delta < 1$ but is closer to 1 than OE/ OE' because it characterizes the momentum loss on the normal direction to the surface, while OE/ OE' characterizes the momentum loss on the horizontal direction for moving the vertical oscillations of the surface electrons to the oblique/ reflection direction. Hence (OE/ OE')/ δ can be taken as the ratio of two "refraction indexes" n_1, n_2 with $1 \le n_1 < n_2$ for our case. Hence,

$$\tan\theta_2 = \tan\theta_1 \times (OE / OE') / \delta = \tan\theta_1 \times (n_1 / n_2) \tag{9'}$$

The angle of incidence θ_1 goes from small values up to 90^0. Hence, $\cos\theta_2 \approx \cos\theta_1$ for relatively small incident angles, and hence,

$$\sin\theta_2 \approx \sin\theta_1 \times (OE / OE') / \delta = \sin\theta_1 \times (n_1 / n_2) \tag{9''}$$

which is the Snell's law of refraction.

Refraction mechanism at the interface of a transparent material with air:

The mechanism of light refraction at the exit surface from a transparent material is similar with the above line of thought. Above we show that this refraction direction is a result of a surface phenomenon: A loss mainly in the horizontal component of the total momentum of a FDM burst, in its action to push the surface electron oscillations to change their direction from perpendicular on the surface to the reflection direction. As a result of this loss, the direction of the total momentum of the bursts is changed, from the incident direction of light, to the refraction direction. On this refraction direction the new total momentum of the bursts produces, at the entrance in the bulk of the transparent material, a Collective Longitudinal Electron Oscillations (CLEOs) which propagate in the material on the refraction direction. Model 3 above, shows the propagation of these CLEOs in the bulk of a transparent material.

At this exit surface from a transparent material a main fraction of the vertical component of the total momentum of CLEOs is lost by their propagation in the more limited space for vertical oscillations of the surface electron population, see **FIG. 3**. At the same time the fraction of the loss in the horizontal component of the total momentum is smaller. Hence, the total momentum of a CLEO changes the direction, from the incident direction to the refracted direction. This fraction loss is characteristic to the surface, and hence, it can be characterized simply by a ratio of refraction indexes. As for the entrance surface, this leads to the Snell's law of refraction for the exit surface from the transparent material, similar to eqs. (9-9") above. A reflection towards inside of the transparent material, is also produced by the incoming CLEOs towards the exist surface, due to the elasticity of the exist surface. If this is also included, then the reflection/ refraction at the exist surface of a transparent material, is very similar with the reflection/ refraction at the entrance surface in the transparent material.

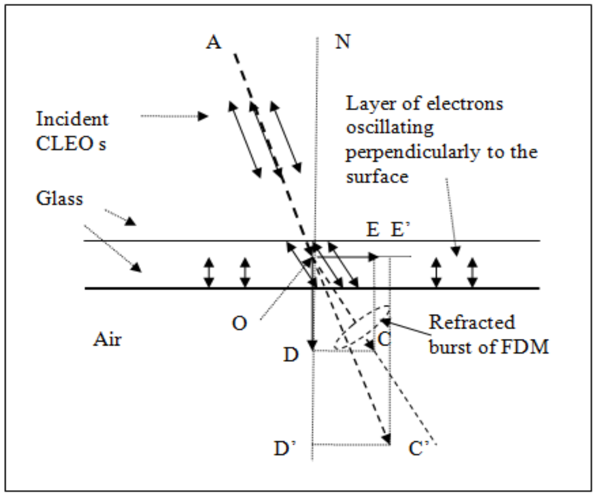

FIG. 3 **Refraction at the exit surface from a transparent material to air. Light propagates inside the transparent material and reflects and refracts at the interface with air. The light incident angle is θ_1 = angle(AON)=angle(D'OC'). The light refraction angle is θ_2=angle(DOC)×** $\vec{OC'} =$ **The momentum carried by an incident CLEO on the surface (glass-air) electron layer,.** $\vec{EE'}$ **= The horizontal momentum lost by an incoming CLEO, due to the stronger elasticity of this layer.** $\vec{DD'} =$ **The vertical momentum lost in the surface electron layer, by a CLEO.** $\vec{OD} = \delta \vec{OD'} =$ **where** δ **is a constant < 1×** $\vec{OC} =$ **The effective total momentum for creating a refracted FDM burst.**

Note 1. A special case of refraction occurs when a beam of light is produced by a source immersed in water and propagates towards the water surface. Both a reflected light (towards the inside of water) and a refracted light towards outside of water are produced. The latter is at a refraction angle larger than the incidence angle. In this case when the incidence of the light beam on the water surface is at a critical angle, the refracted light reaches 90^0 and hence, the refracted light disappears for angles of incidence equal or greater than this critical angle.

Model 5. The mechanism for the diffracted light:

This model gives a physical mechanism for producing the diffracted light by a material edge, **FIG. 4**. In this case the incidence angle of light on a material surface is very small. As a result a complex propagation of CLEOs takes place on the edge surface through its nanoscopic, microscopic and macroscopic terminal shapes. As illustrated in **FIG. 5**, this propagation forms the luminous spot in the edge diffraction over the top surface of the edge. This propagation of CLEOs interacts by periodic momentum transfer with the surrounding Finely Dispersed Matter (FDM) and produces diffracted light tangentially to the macroscopic form of the edge, in each segment of it. That is, this propagation of CLEOs produces trains of bursts moving outside along the tangential directions. We show that this model is directly applicable to describe the diffraction cases on both a macroscopic edge and a nanostructure edge and hence, a comparison of these two cases is essential for a mechanism understanding of the behavior of light in diffraction.

A more detailed description of this model is as follows. When a periodic train of finely of FDM (with limited traversal area) falls perpendicularly on a material edge, the following process takes place. A streamline of Collective Electron Oscillations (CLEO) propagates first on the surface towards and across the top of the edge, **FIG. 5**. Then it propagates on the other side of the edge that is, in the geometrical shadow. For a non-conducting material there is also a propagation inside the material, while for a metal edge there is an attenuation that stops the electron oscillations to propagate inside the material. Along the streamline propagation on the surface through its terminal microscopic and nanoscopic shapes the CLEOs also spread laterally and hence, the size of the luminous spot increases laterally during the propagation.

Along this propagation on the surface there are two kinds of attenuations. One due to the intrinsic dumping of these oscillations, and one due to the production of trains of bursts of FDM in a direction tangential to the surface. These two dumping actions make the intensity of the CLEOs to significantly decrease as the streamline advances on the edge surface in the geometrical shadow. What is the overall form of the diffracted light by the edge? Here we consider only a linear propagation of a cleo that is, only in the (y,z) plane and not in the plane (x,z). The latter is more complex and needs to be considered in a separate work. The result of the streamline of CLEO on the top of the diffracting edge is that a periodic train of complex FDM bursts (diffracted light) is produced around the diffracting edge, including in the geometrical shadow–see the quasi-cylindrical forms B_1 and B_2 in **FIG. 5**. The intensity of this diffracted light strongly decreases as its angle of propagation increases towards the deeper directions in the geometrical shadow. This is because of the decrease of the intensity of the electron oscillations along their propagation on the top of the edge. This way for forming the diffracted column of light present in the edge diffraction is essentially dependent on the material and spatial form of the edge. In Section III we show that this bi-structure approach to the diffracted light can clearly explain the diffracting fringes for the macroscopic edges by superposing the rays of periodic trains of bursts of FDM, from the different segments of the diffracting edge, with the trains of FDM bursts passing through the free space above the diffracting edge. But here we discuss only the basic mechanism of the diffraction process.

For a nano-structure edge, like in the diffraction on well- controlled holes in thin, sub-wavelength edges [3, 4], the edge itself is basically a flat surface and the direct transmission of the bursts through the edge material plays a major role. In this case the streamline of collective electron oscillations is basically a straight line through the edge and hence, the diffracted light produced in this case is a forward transmission of light that is, not a broad column of diffracted light. This approach brings a simple and clear mechanism-type explanation for the diffraction of light on nano-structure holes [3, 4].

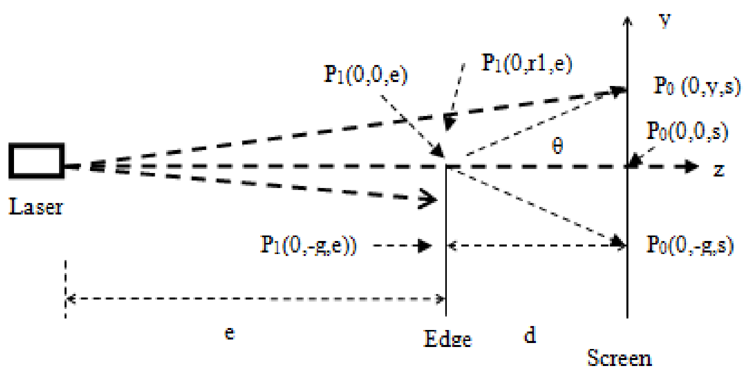

FIG. 4 **Single straight Edge diffraction where θ can be positive (directly illuminated area) or negative (geometrical shadow).**

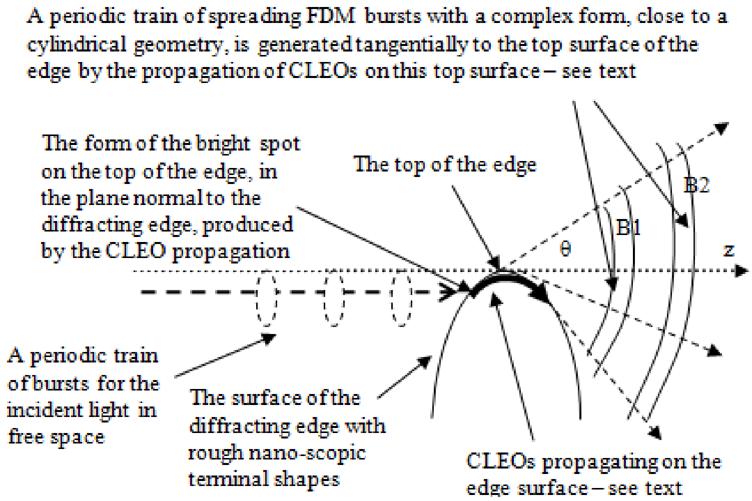

FIG. 5 **The diffracted light by a single incident train of bursts. The incident train of FDM bursts on a diffracting edge produces a propagation of a CLEO on the top of this edge. In turn this propagation produces in each of its points, tangentially to the edge surface, a periodic contribution to the train of spreading FDM bursts outside of the diffracting edge, a train which is also periodic. This train defines the bright spot on the edge and hence, the diffracted light during the diffraction process. The size of this bright spot increases as the CLEOs propagate towards, across and beyond the top line of the diffracting edge. The complex and spreading form of each burst covers a broad space in the directly illuminated zone and the space of the geometrical shadow. These bursts of diffracted light have the same periodicity as the incident train of bursts has and hence, they interfere on a screen in the directly illuminated area, with the trains of FDM bursts coming directly from the laser, to generate the diffraction fringes.**

Here we attempt a simplified quantitative description of the above general description of the model for producing the diffracted light by a macroscopic edge. Generally, a macroscopic edge is not a combination of flat surfaces but displays a myriad of terminal shapes (nanoscopic, microscopic and macroscopic shapes). However, from a practical point of view of the propagation of the CLEOs we can describe their traversal shape over the edge by a function $y = y(z)$ where z is perpendicular on the plane of the edge, y is along the height of the edge, and the function y(z) is continuous and has a continuous derivative. A reasonable choice for y on a sharp edge is a parabola with the tip placed on the top of the edge and with the branches along the sides of the edge $y(z) = a(z - z_e)^2 + b$, where $z_e = e$ in **FIG. 4**, is the position of the diffracting edge along the z axis, and a and b coefficients chosen to fit as closely as possible the form of the edge. If so, the length *l* on this curve starting at a point z_0, where the incoming train of bursts hits the diffracting edge, and ending at a point z_1 is,

$$l(z_0, z_1) = \int_{z_0}^{z_1} \sqrt{1 + (y'(u))^2}\, du \tag{10}$$

Where $y'(u) = 2a(u - z_e)$ Eq. (7) in the Model 3 above suggests that we can replace $Bt/2$ with $\alpha \cdot l$, to characterize how the CLEO propagates and attenuates along the curve $y = y(z)$. Then the intensity of the Collective Longitudinal Electron Oscillations

(CLEO) along the curve $y = y(z_1)$ can be described approximately by

$$I_{cleo}(l) = A\exp(-\alpha \times l) = A\exp(-((\alpha_{cleo} + \alpha_b)l) \tag{11}$$

where $A = I_{cleo}(0)$. Here α is the total attenuation coefficient of the surface oscillations both by the edge material dumping of the CLEO (α_{cleo}), and by the dumping from producing trains of bursts (α_b) in free space, tangential to the curve $y = y(z)$. For a point $(0, y_1, z_1)$ where $y_1 = y(z_1)$ this tangential direction is given by the angle $\theta(l)$ with $\tan\theta(l) = y'(z_1)$.This train of bursts in free space arrives on the screen at the distance *s-z₁* in the point $(0, y_2, s)$ where $y_2 = y_1 + (s - z_1)\tan\theta(l)$. Reversely, for any given point $(0, y_2, s)$ on the screen, what is the above point $(1, y_1, z_1)$? The coordinates z_1 and y_1 and the slope $\tan\theta$ of the straight line that passes through this point and is tangent to the curve $y = y(z)$ on top of the edge, can be found by solving the following three equations $y_2 = y_1 + (s - z_1)\tan\theta$, where $y_1 = y(z_1) = a(z_1 - e)^2 + b$ and $\tan\theta = y'(z_1) = 2a(z_1 - e)$. For b=0 the result is $z_1 = s - \sqrt{s^2 - C}$ where $C = 2se - e^2 + y_2 / a$ from which y_1 and $\tan\theta$ can easily be calculated. For a very thin or nanoscopic edge a first approximation could be $z_1 = e$, $y_1 = 0$ and $y_2 \approx d \cdot \tan\theta(l)$ - see Fig. 4. The amplitude of the momentum of the train of bursts arriving at point $(0, y_2, s)$ could be related to the intensity lost by a CLEO on the curve $y = y(z)$ at point $(0, y_1, z_1)$, namely as $I_b(l) = A\alpha_b \exp(-(\alpha_b + \alpha_{cleo})l)$.

When all the trains in the incoming beam are considered for straight edge diffraction, a columnar diffracted light is formed [15] on a screen. It extends from the directly illuminated area (which includes the diffraction fringes) to the geometrical shadow. A practical description of the intensity of light in each point (0, y_2, s) in this column requires an expression *f(s,θ)* for the dependence of the number of trains of the bursts generated on the diffracting edge at point $P_1(0, y_1, z_1)$, and arriving on a screen at point $P_0(0,y_2,s)$ with $y_2 = y_1 + (s - z_1)\tan\theta$. The case is complicated in general as described below in a simplified way. In time a better quantitative description will grow.

a) As discussed above, the form of the diffracted light emergent from the propagation of a CLEO generated by an incident train of bursts on the top surface of the diffracting edge, is not a straight-line train of bursts as in the incoming beam of light towards the edge. Rather, it is a periodic train of expanding quasi-cylindrical bursts–see the forms B_1 and B_2 in **FIG. 5**. The periodicity of such a train is the same on all its directions. But as y2 decreases from values in the directly illuminated area to the directions in the geometrical shadow, an increasing delay occurs for the bursts of the train arriving at this y2. This is because they are produced later in the process of the CLEOs propagation. Because of this delay, the form of the bursts in the train is not perfectly cylindrical even in the directions around the incident beam. Also, these quasi-cylindrical bursts end at high positive in the directly illuminated region, and also they end at angles deep in the geometrical shadow. Moreover, both the CLEO on the top of the edge and the bursts generated by it, expand/ spread in some extent on the horizontal direction (x in **FIG. 4** and **FIG. 5**) in their propagation. By this expansion a quasi-cylindrical diffracted train of FDM bursts covers a larger horizontal area of the screen and can interfere with the narrower trains of bursts coming directly from the laser beam.

First what is a quantitative description of the diffracted light that is, of the momentum of a single train of FDM bursts moving from $P_1(0, y_1, z_1)$ to $P_0(0,y_2,s)$ without a spreading in the horizontal *(x)* direction? If $\vec{k} = (2\pi/\lambda)\vec{u}(\theta)$ and $\omega = 2\pi/T$ where $\vec{u}(\theta)$ is a unit vector on the direction from $P_1(0, y_1, z_1)$ to $P_0(0,y_2,s)$, then the train momentum density per unit of the transversal area to the train, on this direction is

$$p(r,\vec{k},t) = A \times pc(kr - \omega t + \varphi(\vec{k})) \quad (12)$$

Here, as in Eq. 1, the quantity A is a positive constant for the momentum density on a traversal area S to the line P_1P_0, and is zero outside of it. “pc” stands for the cosine values when cosine is positive or zero, and equals zero when cosine is negative. A point $P= P(0,y,z)$ on the line P_1P_0 is defined by $r = \sqrt{(y-y_1)^2 + (z-z_1)^2}$. For $y = y_2$ and $z = s$ this point P becomes the point P_0. Finally φ is a phase difference between different directions $\vec{k}$ due to the delay in the starting time for the diffracted trains generated at longer l (see eq. 10) by the CLEO along the curve $y = y(z)$. Second, a momentum spreading on the horizontal (x here) direction is not strictly necessary and answering this question can be done later. The amplitude of the momentum of the train of bursts arriving at point $(0, y_2, s)$ is determined by the intensity lost by a CLEO on the curve $y = y(z)$ at point $(0, y_1, z_1)$ to produce FDM bursts that is, $\alpha_b I_{cleo}(\theta) = \alpha_b \cdot A\exp(-((\alpha_{cleo} + \alpha_b)l)$, which is the modulus of the corresponding part of the derivative of eq. 11.

b) For a mechanism understanding of the edge diffraction intensity it is strictly necessary an adequate summation of the contributions to the diffracted light from all the trains of bursts falling in different places on the diffracting part of the edge. A working expression could be found for the complicated dependence for the above $f(s,\theta)$ by considering only one incident train on the edge at a point $(z_0, y(z_0))$. This train produces a streamline of CLEOs which propagates and attenuates along the curve $y=(z)$. This attenuation generates in each point $(0, y_1, z_1)$ a contribution in the direction $\tan\theta = y'(z_1)$ to the complex diffracted train of bursts. For a point $(0, y_1, z_1)$ we can find $l(z)$ from the above expression (10). Then the intensity of the diffracted light leaving the edge at $(0, y_1, z_1)$ on the tangent direction, and arriving at the position (s,θ), could be approximated by the modulus of the corresponding part of the derivative of eq. 11 multiplied by the average number N of trains per unit area falling on the diffracting part of the edge. If so, we can take

$$f(s,\theta) \approx \alpha_b N \times I_{cleo}(\theta) = \alpha_b N \times A\exp(-((\alpha_{cleo} + \alpha_b)l) \quad (13)$$

Note 2. The process of transformation of the incident bursts in CLEO on the edge, the process of the edge propagation for these CLEO, and the processes of bursts production by these CLEOs, all bring a supplemental phase delay φ in excess to phase delay due to the longer path from the point P_1 on the diffracting edge to the point P_0 on the screen (as compared with the path for light coming to P_0 directly from the laser), see **FIG. 4**. Naturally this supplemental phase delay brings a displacement of the diffraction fringes for the single edge diffraction, which is not predicted by the regular wave application for this case, as we show in Section III. Such a phase delay and fringe displacement are not present for the case of macroscopic slit/ hole diffraction because there the fringes are formed by the superposition of trains coming from two or more edges, not from one edge and from laser.

Again the trains produced on the diffracting edge, by the incoming beam, fall on a screen at the distance d from the edge, and hence, the regular columnar diffraction spot is formed. The position of the fringes in this diffraction column, can be calculated by using a train of bursts on the path between $(0, y_1, z_1)$ and $(0, y_2, s)$ (or approximately between (0,0,e) and (0,y_2,s)) and a second train of bursts from the laser on the path between $(0, y_2, e)$ and $(0, y_2, s)$. A complete description of the intensity of light in this column, including in the fringes, requires the expression f(s,θ) for the number of trains of bursts generated $(0, y_1, z_1)$ on the diffracting edge, an arriving at the point $y_2 = y_1 + (s - z_1)\tan\theta$ on the screen. This case is complicated in general because it is necessary an adequate summation of the contribution of the diffracted light produced by the many trains of burst falling on the diffracting edge. To illustrate this difficulty, and to make practical this approach, standard forms for the traversal shape $y = y(z)$ and for the corresponding f(s,θ) are necessary for describing in detail both the position and the intensity of the diffraction fringes, and they can be developed. However, without this f(s,θ) the bi-structure approach can be used to describe the position of diffraction fringes, see Section III for the case of the straight diffraction edge.

In the Geometrical Theory of Diffraction, GTD, the intensity of the diffracted light along lines/ rays originating from the diffracting edge, is taken from the prediction of the wave diffraction integral for the regular experiments of diffraction of thin/ thick beams, at low and large distances from the diffracting edge [21, 22]. GTD also assumes that the diffraction of thick beam of electromagnetic waves is correct, including the case of the plane wave, and proposes expressions for the diffracted rays emerging from the edge which fit with the electromagnetic diffraction integral–see below a case. Because of this, GTD can provide good intensity, as the wave theory does, in the geometrical shadow at small distances from the edge and small angles with the direction of the incident beam of light on the diffracting edge, but not at large distances and bigger angles. There GTD predicts incorrectly, as the electromagnetic wave theory of diffraction does, a dependence on the beam thickness traversal to the edge. For the plane wave case the GTD expression for f(d,θ) in the geometrical shadow, fits with the electromagnetic prediction, [21, 22]

$$f(d,\theta) = \frac{(1+\sin\theta)}{2\sqrt{\frac{\pi d(1-\cos\theta)}{\cos\theta}(1+\cos\theta)+1}} = \frac{1+(y/d)/\sqrt{1+(y/d)^2}}{2\sqrt{\pi(y^2/d)/\sqrt{1+(y/d)^2}+1}} \qquad (14)$$

where the parameters are defined in **FIG. 4** and y=d $\tan\theta$. It can be seen that for any *d* finite, the amplitude ratio for the edge diffracted light goes to zero as $|y|$ goes to infinity. However, for any *y* finite, this amplitude ratio goes to 0.5, as *d* goes to infinity, as in the electromagnetic approach, which is not physically possible if the diffracted light in the geometrical shadow is born only in the diffracting edge and hence, when light is not physically a wave, or does not physically behave like a wave in diffraction. Hence, a better expression for f(d,θ) needs to be designed in GTD. For instance,

$$f(d,\theta) = \frac{1+(y/d)/\sqrt{1+(y/d)^2}}{2\sqrt{\pi(y^2/d)/\sqrt{1+(y/d)^2}+1}}\frac{1}{\tau d+1} \qquad (14')$$

where τ is a coefficient to be fitted from experiment. In this case the amplitude ratio goes to zero as *d* goes to infinity for any finite *y*.

Note 3. As can be seen from this Model 5, using the bi-structure for the diffraction fringes is more complicated quantitatively (because of the complications to describe the processes inside of the top of the diffracting edges, than using for this purpose the wave approach. This advantage for the wave approach shows that although the waves are a formal model, the waves can still be used in the future, for practical quantitative results in the fringe zones. However, overall the wave approach leads to big complications and misunderstandings for light itself and for phenomena like electromagnetism, gravity and atomism.

Note 4. In the Geometrical Theory of Diffraction (GTD) – the luminous spot on the diffracting edge is also the origin of the diffracted light. However, in GTD the linear rays of light, originated in the diffracting edges, are still described by waves. This is because GTD does not recognize that there is a missing fundamental verification of how light spreads at large distances and that there is already proof that light does not spread like the waves do, and hence, that light needs physically a non-wave approach.

III. Applications in Optics of the Bi-Structure

The Models 1-5 above show that this bi-structure explains in a mechanism-type way the optical phenomena of light propagation, polarization, reflection, refraction and diffraction. Here we show the application of the bi-structure to the special cases of edge diffraction, photo-effect, the Michelson-Morley experiment, etc. In Section IV we discuss the broad consequences of the bi-structure approach for light: The mechanism type approach for the gravity, with its extraordinary contribution: the mechanism by which the gravity produces the heating of planets, especially of those which have a large dimension.

This bi-structure approach forms a kinetic approach for light, as a parallel to the kinetic theory of heat in condensed matter. If this model works, then the presence of the FDM (finely dispersed matter or "dark matter") in this kinetic approach for light makes it necessary to also apply it to the heat structure in free space, to the electromagnetism and to the atomism.

The case of the Arago – Poisson spot:

Which was considered a crucial support for the wave approach. In this case of diffraction, a beam of light is hitting perpendicularly on the plane of a small disc, at the disc center. As a result a bright spot forms in the geometrical shadow behind the disc and along the beam axis. In the bi-structure this happens simply because the diffracted train of FDM bursts formed along the disc periphery (see Model 5) has the same path difference for each point all along the axis of the beam (which passes through the center of the disc, perpendicularly on the plane of the disc).

The Michelson-Morley experiment:

The bi-structure offers a trivial/ mechanism-type explanation of the Michelson-Morley (MM) experiment, with a major consequence for the speed of light/ relativity theory [15]. In the bi-structure model, the light coming to the beam splitter in this experiment becomes localized Collective Longitudinal Electron Oscillations (CLEOs) in this splitter, as the real source of the light towards the mirrors in the MM experiment. Hence, the bursts of finely dispersed matter (i.e. the light beam) have naturally the same speed towards the two mirrors of the experimental apparatus, one in the direction of the earth motion, and one in the direction across the earth motion. If so, the motion of the earth cannot have any influence on the fringes, i.e. there cannot be any fringe displacement when the apparatus is rotated. This is a simple, mechanism-type explanation of the result that there is no fringe displacement in the MM experiment. No "ether as a support for the electromagnetic waves", no its rejection, and no independency of the speed of light from the motion of reference system, as it is necessary in the wave structure of light.

The photoelectric effect:

As explained above when a sequence of bursts hits a surface of condensed matter, it generates an oscillation of bound electrons by a periodic and resonant momentum transfer [15]. When the frequency and the momentum transfer is large enough the electron does not continue to oscillate but rather is pushed out of its binding place and becomes free – a photo-electron. In the case of a metal the binding energy of the conduction electron is small such that a photo-electron can be easily freed and its energy can still increase by momentum transfer from the incoming bursts. But this increase in energy of the freed electron is limited by three factors: the limited length of the train of bursts, the limited traversal size of the bursts, the scattering of the freed electron by the surrounding electrons and atoms. The latter removes the electron from path of the propagation and action of the bursts. Because only one train/ sequence of bursts is responsible for a photoelectron, the intensity of light (which is determined by how many sequences of bursts hit a unit surface per second) is not a contributing factor for the energy of photoelectron, as indeed the law of the photo-effect requires [15]. Notice that this prediction is in accordance with the experiment but is in contradiction with the prediction of the wave approach. Moreover, since each burst from the train that acts on a given electron, transfers to it about the same momentum, it follows that the maximum energy of the photoelectron outside of the metal surface should naturally be proportional with the frequency ν of the bursts,

$$((1/2)mv^2)_{\max} = h\nu - \phi \ , \tag{15}$$

where ϕ is the binding energy of the electron to the surface, or the energy necessary to remove a free electron from the surface, and *h* is also a constant. Both these constants are determined experimentally. This application of the bi-structure not only describes the photoelectric effect but also allows to establish the link between the bi-structure and the electromagnetic approach. This is because in the photoelectric experiment [15] we have,

$$((1/2)mv^2)_{\max} = eV_0 \ , \tag{15'}$$

where V_0 is the stopping potential in the photoelectric experiment [12]. However, the physical meaning of the electron will change as the bi-structure concepts will grow in time.

Hence, the bi-structure offers a mechanism-type approach to the photoelectric effect, with no need for the dualism of wave-photon, that is we show that the bi-structure eliminates the need for the wave-particle duality. This means that the bi-structure explains not only the diffraction/ interference of light but also explains in a simple, mechanism-type way the photoelectric effect:: the action of light on a metal surface (a cathode), an action that creates free electrons (the photo-effect) and hence, a current in a diode-type circuit. From this type of explanation it becomes apparent that in the bi-structure approach to light, the concept of the photon and its absorption is just a metaphoric and un-necessary way to characterize the real phenomenon which is a periodic action of the incoming bursts on an electron to liberate it from its binding, in contrast with the wave picture of light absorption where the photon is a necessary but a mystery concept. Again, the physical meaning of the electron will change as the bi-structure concepts and consequences will grow in time.

The statistical optics:

Refs. [8,9] suggest that the statistical nature of the diffraction and image formation is basically due to the statistical nature of the light beam. Physically this would mean a discontinuous and random structure as the bi-structure has. Such a basic need cannot be offered be the continuous structure of a light beam in the wave approach.

Diffraction fringes for the case of the edge diffraction:

In the bi-structure model for diffraction, the formation of the diffraction fringes occurs when the intensity of the beam of light is sufficient that a significant number of the periodic trains of bursts coming directly form the laser, superpose with periodic trains coming directly from the diffracting edge – a random process. This is totally different from the electromagnetic approach for diffraction (which is the integral on the wave front above the diffracting edge), and requires a complex treatment of the production of the diffracted light in the edges, see model 5 in relation with the random character of a beam of light. However, as in the wave approach, a simplified way exists for a mathematical characterization of the spatial distribution/ position of the fringes at relatively large distances from the diffracting edges. Indeed, the periodic momentum carried by a train of bursts of limited transversal area, eq. (1), is simple to use for a simplified description of the diffraction fringes as described next.

In a straight edge diffraction experiment, **FIG. 4**, a laser beam of light falls with its axis perpendicularly on a sharp edge and forms a luminous column on a screen at any distance from the diffracting edge in the direction of the light propagation. This column is perpendicular on the diffracting edge, and the part of this column with fringes is only in the directly illuminated area on the screen, while the non-fringe part is in the geometrical shadow of the diffracting edge. The fringes are caused by the superposition of the momentum transfer, from the laser beam and from the edge-diffracted beam, to the screen electron oscillations. If the travelling phase difference φ_e on the routes edge - screen point, and the traveling phase difference φ_l on the route laser - screen point is 2 $n\pi$ then maximum (enhanced) electron oscillations for the screen electrons occur. Minima in these screen electron oscillations occur when $\varphi_e - \varphi_l = (2\ n\ +1)\pi$. The phase difference for these maxima and minima $\Delta\varphi(y,d) = (\varphi_e - \varphi_l)\ =\ m\pi$ is related to the path difference by $\Delta\varphi(y,d) = kP_0(0,y,e+d)P_1(0,0,e) + \varphi - kP_0(0,0,e+d)P_1(0,0,e))$, where k==2π/λ. Here, the supplemental phase φ is the delay which occurs in the bi-structure approach due to the propagation of the Collective Longitudinal Electron Oscillations (CLEO) on the top of the diffracting edge–see Model 5 above. The process of producing CLEO on the diffracting edge takes time, and hence, there is an extra delay for the trains of bursts on the routes edge – screen. Then from Fig. 4 the phase difference is,

$$k(\sqrt{y^2+d^2}-d)+\varphi = kd(\sqrt{1+y^2/d^2}-1)+\varphi \approx kd(1+y^2/2d^2-1)+\varphi = k\,y^2/(2\ d\ ) = m\pi-\varphi \tag{16}$$

Or

$$m = \mathrm{y}^2/(\lambda d) + \varphi/\pi,$$

Or

$$y = \sqrt{\lambda d}\sqrt{m-\varphi/\pi} \tag{16'}$$

for d large as compared with y. Notice that the number of fringes n increases as the second power of y, as is predicted by the regular macroscopic wave approach to the edge diffraction. However, in contrast with the latter, that the position of the fringes is displaced by the presence of the phase differenceφ. This is verified experimentally as reported in [23, 24]. There it is found experimentally that,

$$y = \sqrt{\lambda d}\sqrt{m-1/4} \tag{16''}$$

A similar simplified analysis can be done for the circular aperture (hole) and for the two-edge slit (that is a one-dimensional slit). For the first case the phase difference, between two edge points across the aperture, is k w y / d = m π, where "w" is the width/ diameter of the aperture. Hence, y = λ d m /(2w), a linear dependence of y on m. In this case the extra phase difference due to the time lost in producing the electron oscillations in the edges, does not matter because the fringes are produced mainly by the interference of the light emerging from the diffracting edges, and because this extra difference is the same for all the points on the diffracting edge.

IV. Consequences for Gravity and for other Fundamental Phenomena

Understanding the mechanism of gravity:

This paper starts from the major weaknesses of the current understanding of light, which are:

a) Light spreads like a wave but nothing oscillates.

b) Light does not spread like the waves do at large distances.

These weaknesses show the necessity of a non-wave, mechanism-type model/ understanding for light. Then our paper shows the feasibility of such a non-wave, mechanism-type understanding/ model for the light phenomena, based on the concept of a moving

Finely Dispersed Matter (FDM), or dark matter. This is similar in a certain extent with the kinetic model for heat that is based on the motion of molecules. By this model the concept of FDM or dark matter enters in the area of directly observable reality, including with our own eyes, and leads to broad consequences. The consequences for gravity are very important for expanding a mechanism-type understanding in physics. We show that by assuming that an isotropic flux of finely dispersed matter, exists in each small volume in free space and which penetrate in good extent even through a large body of matter, has two important consequences.

a) Any two bodies of matter immersed in such a flux are pushed towards each other proportionally to their masses and inversely proportional with the square distance. This explains the gravity in a mechanism-type way in contrast with the postulation that gravity is an intrinsic property of matter that lasts for an infinity time, and hence, implies an infinite energy for any piece of matter. We show below the mechanism of this "attraction". Because of this "attraction" a star of big mass necessarily establishes a system of planets, and a planet can have a moon-type satellite.

b) For a single large body a fraction of the FDM is lost while it penetrates large distances in matter. This necessarily means that an energy is deposited as a heat inside the big bodies of matter, which grows the hot matter at the center of the planets for instance, and can make the shining of the stars (huge bodies). It is easy to recognize the link between FDM and this heating, but the mechanism of this heating inside of the big bodies of matter will need a considerable development.

We show below how the phenomenon of gravity can be related to a type of Finely Dispersed Matter (FDM).The requirements for a type of FDM as a basis for gravity are as follows.

1) In free space this penetrative FDM is a flow present in any point of the universe and passes in all directions.

2) It must penetrate even through bodies of big mass.

There is however, a momentum and energy transfer from the passing FDM to every point in such bodies of matter, i.e. a loss of FDM occurs. When two bodies are at distance r in such a field of FDM, they shadow each other by diminishing the flow of FDM coming on the inner distance and hence, each body diminishes the momentum transfer from the FDM in the other body on the path between them. As a result the two bodies are pushed towards each other. If the effective traversal areas of the two bodies are ΔS_1 and ΔS_2, then the solid angles that the two bodies see each other are $\Delta\Omega_2 = \Delta S_2 / 4\pi r^2$ and $\Delta\Omega_1 = \Delta S_1 / 4\pi r^2$ respectively. Hence, the two bodies are shadowing each other from FDM on the line between them, proportionally with these solid angles. At the same time the two forces are proportional respectively with the masses of the two bodies $m_1 = \rho_1 h_1 \Delta S_1$ and $m_2 = \rho_2 h_2 \Delta S_2$. Hence, the forces that push the two bodies towards each other are respectively and approximately,

$$F_1 \sim \rho_1 h_1 \Delta S_1 \times \rho_2 h_2 (\Delta S_2 / (4\pi r^2)) = k \times m_1 m_2 / r^2 \qquad (17)$$

$$F_2 \sim \rho_2 h_2 \Delta S_2 \times \rho_1 h_1 (\Delta S_1 / (4\pi r^2)) = k \times m_1 m_2 / r^2$$

where k and is a constant, h and ρ are respectively the effective thicknesses and densities for the two bodies, m are masses, and $F_1 = F_2$. Notice that $\Delta S \neq 0$ in order that $F \neq 0$. Hence the idea of point masses can only be an approximation.

Therefore the main prediction of the FDM approach is that gravity is not an intrinsic power of mater, but rather an effect of the motion of the FDM. It does not imply a time-infinite energy in the attraction power of matter. And as soon this FDM flow modifies, the gravitation modifies too. If this modification is large enough around a planet system, it would produce some climate change. These are in total contrast with the current theory of gravity.

The crucial experiment for the nature of gravity:

A way to verify this mechanism of gravity is to verify its prediction that FDM produces heat when it penetrates in a body of matter. The energy loss by the FDM is a source of heat in such a body of matter. This prediction would allow understanding clearly why the temperature increases in the depth of any big body, such as planets and stars. Such an effect is not predicted by the current theory of gravity. The experiment for verifying the heating effect of FDM and hence, verifying the existence of the FDM itself, is as follows. Given that the temperature increase in the first km of the earth depth is approximately 25^0 Celsius, we must build a cylinder of dense earth ground with 100 m diameter and 250 m height. If the surfaces of the cylinder are kept at constant temperature, then an increase in the temperatures on the vertical axis of the cylinder are a good indication of the heating by FDM.

Broad consequences in physics:

We also suggest that this new approach for light based on FDM, would have major consequences for understanding the atomism, condensed matter and electromagnetism. Indeed the presence of a moving FDM as fundamental entity in the Universe, and the periodicity and discontinuity in the structure of light must have enormous consequences for the basic concepts in these topics. Hence, a new, non-wave and mechanism-type structure for light will open a great positive change in physics, greatly extending the positive change brought by the kinetic theory of heat. Mechanism-type explanations will replace postulated views like “light spreads like waves but nothing oscillates” in many areas of physics.

A criticism of the atomism shows that the postulations of the atomic system must be given a mechanism-type support. A criticism of the electromagnetism suggested by the bi-structure (that is by a mechanism-type understanding of light) shows the limits and the missteps for the Maxwell equations:

a) The first misstep is as follows. The bi-structure approach to light through FDM suggests that the electric and magnetic actions of a body on another body are a result of a mechanism involving fluxes of finely dispersed matter between and around these bodies, and hence, the electric and magnetic fields as used in electromagnetism can be defined only for the action between the involved bodies, and not as entities in free space. If this would be the only misstep, then the current applications of electromagnetism could still be used both in macroscopic and microscopic material structures.

b) But there is a second misstep that limits or even prevents the current use of electromagnetism in microscopic/ nano material structures. This misstep is as follows. The current magnetic field is a clear non-physical construction: a vector that is not along the action (attraction or repulsion) produced by one wire with electrical current on parallel wire with electrical current. Indeed, for two parallel wires the magnetic vector at any point on a straight line between the two wires, is perpendicular on the plane defined by the two wires.

c) The idea of an electric charge that has an infinite lifetime means that any charged particle has an infinite energy in time, which clearly is not physically possible.

The need for criticism and development:

There is a strong need for criticism based on the broad views regarding light, especially on the Major Opposing Views (MOV) on the origin of the diffracted light and on other MOV. A continuous application in the University of the method for broad thinking on MOV is necessary in order to start/ initiate a clear path of analysis and development for light and for broad consequences in physics.

VI. Conclusions

This paper recognizes the necessity of a new, mechanism-type and non-wave structure for light. It also shows the feasibility of such a new structure for light. Developing a new, mechanism-type structure for light will be a long process, similar with the case when recognizing and performing the missing experiment for heat (namely the heat production by mechanical action) took a long time. We indicate in this paper a line for this development, based on the concept of Finely Dispersed Matter (FDM) or dark matter. There is a strong need for criticism based on broad views regarding light, especially on the major opposing views for the origin of the diffracted light.

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