Transfer of light by substance.

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This article explains how the speed of light is reduced in the substance from the positions of corpuscular theory.

We suppose the quanta to have properties that make them interact with the atoms of substance during propagation. As a result of each interaction act the quantum "delays" inside the atom and is reradiated through some time. In optically isotropic environment the direction of reradiated quantum movement coincides with initial.

The proposed mechanism allows explaining simply and evidently the phenomena of light transfer in the experiments of Fizeau with the moving liquid and in the astronomical experiments of Airy on star aberration.

Introduction.

When studying the laws of the nature both fundamental and phenomenological theories are successfully used, so there aren't only established facts but only seeming and associating in human consciousness with known natural phenomena in the basis. So, for example, in wave optics we have the concept of the light waves extending similarly to spherical waves of perturbation in the elastic environment. Despite of doubtfulness of existence of such waves the theory developed on the basis of this assumption successfully enough explains a plenty of the optical phenomena connected with propagation of light. However it isn't possible to explain a lot of the phenomena, concerning interactions of light with substance, within the limits of wave optics.

That is the lot of other theories, when the new experimental data appears to break their framework. For their explanation development of new theories begins, the previous experimental data are generalized, attempts to explain them from the point of view of the new uniform theory are done. But, as the previous theories are constructed not on quite proved assumptions they frequently contradict each other that does not allow to unite them in the uniform theory. Therefore there are situations when for an explanation of the phenomena even in the same areas of physics it is necessary to use various, sometimes contradicting each other theories. One of the examples can be the history of corpuscular-wave dualism genesis. An initial source of contradictions in this history, in our opinion, was absolutization of Huygens principle introduced by the author only as an auxiliary means of geometrical optics methods.

Today there's no cause to doubt of existence of separate quanta of light. It is well-known, that only after return to corpuscular theory of light Planck managed to explain in 1900 the law of radiation of a black body, having accepted that radiation is the statistical process having quantum character. The hypothesis of quanta has been picked up by Einstein who has distributed it on elementary processes. According to Einstein the propagation of light in space takes place by separate portions - quanta of light.

It would seem, from this time, and also with each new acknowledgement of quantum laws, the confidence should appear and grow that all without exception optical phenomena can be explained within the limits of only corpuscular theory as having fundamental character. However even today we can't refuse those settled representations, according to which such phenomena as rectilinear propagation, the interference and diffraction of light, can be explained only within the frameworks of the wave theory.

A critical reader will probably object, that today there is a quantum theory which, having united advantages of corpuscular and wave theories, allows to explain all without exception the known experimental facts. Unfortunately, for the present it is necessary to ascertain the following: the quantum theory explains physics of the phenomena not so much, how many is engaged only in the description and prediction of results of experiments. Besides it doesn't lack contradictions itself. We should recall that period in history of physics when, despite of the obvious successes reached by the quantum theory in the beginning of the twentieth century, Einstein, one of its founders, has refused to accept it in the form it remains till today because of its descriptive style without an explanation of causal mechanisms of occurring processes.

In the given work authors offer an explanation of the mechanism of reduction of speed of light in optically dense environments on the basis of only corpuscular theory of light. Their further development allows to pass to an explanation both interferential and diffraction phenomena.

Plausibility of the offered mechanism is proved by a simple and evident explanation of the mechanism of light transfer in experiments of Fizeau and Airy, and also some other experimental facts.

At writing of the given work we used well-known data. More detailed information can be found in works [1-11] which have been used by us in comparisons and the analysis of facts of their interest.

1. Propagation of light in the still substance

In the given work we make the assumption that the separate quantum of light in the isotropic environment propagates rectilinearly with a speed of c/n. Here c is the speed of light in vacuum, n is the refraction index of substance. As this moment does not contradict experiment it can be postulated. Optically dense environment is considered as vacuum with the atoms of substance distributed in it.

As the speed of light has the strictly certain value in vacuum, it is also postulated, that its reduction up to value c/n occurs due to interaction of quanta of light with atoms of substance. It is supposed, that in each act of interaction the separate quantum of light "is absorbed" by atom of substance and through some final interval of time Δt is "reradiated" by atom in an initial direction. It is obvious, that here under "absorption" and "re-radiation" we imply not that it is usually meant in the standard theories.

The postulated moments are in full conformity with Einstein's proposal that both absorption with radiation, and propagation of light in space occur by the final portions.

Let's express the speed of propagation of light in isotropic substance through the parameters of environment and light.

Let N is the concentration of atoms of substance;

σ - section of interaction of quantum of light with atom of the substance, accompanied with "absorption" and «re-radiation» of quantum;

Δt - time between the moments of "absorption" and «re-radiation» of quantum of light.

The quantum of light will stay in the structure of atoms for some time $\tau(L)$ in the case of still substance and optical path L.

$$\tau(L) = N\sigma L\, \Delta t \quad . \tag{1.1}$$

Total time $t(L)$ for which the quantum of light in substance will pass distance L, will make the value

$$t(L) = \tau(L) + L/c = N\sigma L\Delta t + L/c = (L/c)(N\sigma\Delta tc + 1)\ , \tag{1.2}$$

where L/c - time of passing the distance L in vacuum by light.

Time $t(L)$ can be expressed also through a refraction index n

$$t(L) = \frac{L}{c/n} = \frac{n\,L}{c} \quad . \qquad (1.3)$$

Comparing (1.2) and (1.3), we have

$$n - 1 = N\sigma \Delta t\, c \quad . \qquad (1.4)$$

Considering section of interaction σ of quantum of light with atom of substance and time Δt to be dependent on energy of quantum (or frequency of light ω) it is possible to write down the following dispersive formula

$$n(\omega) = N\sigma(\omega)\Delta t(\omega)c + 1 \quad . \qquad (1.5)$$

The clear physical sense of the received formula does attract attention. It is obvious, for example, that with reduction of number of atoms N in the unity volume of environment (that is equal to reduction of pressure for gases) the refraction index decreases, in a limit aspiring to unity.

The formula (1.4) shows linear dependence of a difference (n - 1) from concentration of atoms of substance.

Having transferred in (1.5) the unity to the left part and having divided both parts on N, we come to equality

$$[n(\omega)-1]/N = \sigma(\omega)\Delta t(\omega)c \, , \qquad (1.6)$$

which is similar to the formula for the specific refraction received on the basis of representations of classical physics. It tells that the specific refraction of substance does not change with the change of its density. Experimental data confirm the constancy of the specific refraction of gases for a wide range of pressure, and this concurrence is admitted surprising by many authors as the conventional dispersive formulas have been deduced for conditions of only low pressure. From the formula (1.6) it can be seen, that this constancy is a direct consequence of positions offered in given work and is kept until $\sigma(\omega)$ and $\Delta t(\omega)$ are constants, that, in turn, should depend on properties of concrete substance.

Behaviors of a molecular refraction and a refraction of substances with complex structure thus receive even more evident explanation, which also can be interpreted by the formula similar to (1.4):

$$(n - 1)_{\Sigma} = \sum_{i=1}^{k} N_i \sigma_i \Delta t_i c = \sum_{i=1}^{k} (n - 1)_i \quad , \qquad (1.7)$$

where $(n - 1)_{\Sigma} = \sum_{i=1}^{k} (n - 1)_i$ - excess of a parameter of refraction over unity for a gas mix or molecular gas with k diverse atoms in structure of a molecule; N_i - concentration of separate components in a gas mix or atoms in molecular compound.

Thus, according to our assumptions the physical sense of the formula of a molecular refraction tells that reduction of speed of light is a result of superposition of influences of all components of environment due to a delay of quanta of light by them.

Not less evidently it is possible to explain the optical anisotropy of substances on various directions. For this purpose in the formula (1.4) it is necessary to assume angular dependence of section of interaction $\sigma(\omega)$ of quanta of light with atoms of substance concerning optical axes of a crystal of this substance.

2. Propagation of light in a moving substance.

In case of reliability of postulated positions they should find acknowledgement in corresponding experiments with moving environments.

2.1 Propagation of light in the direction of moving liquid.

Let L is the length of the cavity; t - time for which the quantum of light will pass the distance from the left end of the cavity up to the right; c - speed of light in vacuum; $c\ (v)$ - speed of propagation of light relative to the cavity; Δt - time of staying for quantum of light in the structure of atom for one act of interaction ("absorption" - "radiation"); σ - section of interaction of quantum with atoms of moving substance.

It is obvious, that speed $c(v)$ can be expressed as $c(v) = L/t$. For this purpose we shall express time t through the parameters listed above. In time t the column of a liquid in the cavity will be displaced to the right on value $\Delta L = vt$. Therefore the quantum of light in time t will pass thickness of liquid $L - vt$ though the whole path in the cavity remains L. The number of atoms in structure of which the quantum of light moves with a speed v relative to the cavity, is equal $N\sigma(L\text{-}v\ t)$. Time of stay t' in the structure of these atoms we can find as

$$t' = N\,\sigma\,(L - v\,t)\,\Delta t\,. \qquad (2.1)$$

Total way L' of quantum in the structure of atoms of a liquid makes

$$L' = t'v = N\,\sigma\,(L - v\,t)\,\Delta t\,v. \qquad (2.2)$$

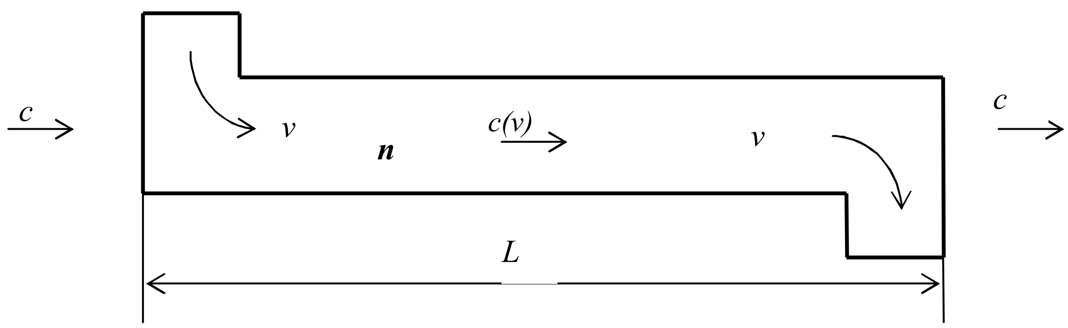

Fig. 1. To distribution of light in the moving substance. L – cavity length; v - speed of a liquid current with a refraction index n. Light propagates in the direction of liquid movement relative to the cavity with a speed $c(v)$.

Other part of the path of length

$$L'' = L - L' = L - N\,\sigma\,(L - v\,t)\,\Delta t\,v \qquad (2.3)$$

the quantum of light passes in vacuum with a speed c. Therefore time t'' of passing this part of the path is equal

$$t'' = \frac{L''}{c} = \frac{L}{c} - \frac{(L - tV)}{c} N \sigma \Delta t\, v\,. \qquad (2.4)$$

Time *t* will make the value

$$t = t' + t'' = N \sigma (L - v\, t)\, \Delta t + \frac{L}{c} - \frac{(L\text{-}tV)}{c} N \sigma \Delta t\, v\,. \qquad (2.5)$$

Let's convert last expression to this type:

$$t + N \sigma \Delta t (L - v\, t)\, (v/c - 1) = L/c\,, \qquad (2.6)$$

from which, having removed the brackets *(L - v t)*, we come to the expression

$$t\, [\, 1 - v\, (v/c - 1\,)\, N \sigma \Delta t\,] = L\, [\, 1/c - (\, v/c - 1\,)\, N \sigma \Delta t\,]\ . \quad (2.7)$$

After that we can write the expression for the speed

$$c(v) = L/t = \frac{1+v(1-v/c)N\sigma\Delta t}{1/c+(1-v/c)N\sigma\Delta t}\ . \qquad (2.8)$$

Knowing, that $N \sigma \Delta t = (n - 1)/c$ (see 1.5), last expression can be transformed into

$$c(v) = \frac{c+v(1-v/c)(n-1)}{1+(1-v/c)(n-1)}\ , \qquad (2.9)$$

or

$$c(v) = \frac{c+vn-v-v^2n/c+v^2/c}{n-vn/c+v/c} = \frac{c^2+vcn-vc-v^2n+v^2}{cn-vn+v}\ . \qquad (2.10)$$

Making division of a multinominal into a multinominal at 2.10, we come to the final expression for the speed *c(v)*.

$$c(v) = c/n + v(1 - 1/n^2) - v^2/n^2c + v^2/n^3c - v^3/n^2c^2 + 2v^3/n^3c^2 - \ldots \quad (2.11)$$

Analyzing last expression, we notice, that first two members at 2.11 are known expression for speed of light in the moving environment, for the first time found by Fizeau in its classical experience. Other members at 2.11, from the third, under condition of $v \ll c$ are much less in comparison with previous. Therefore it is possible to consider, that with a high degree of accuracy we have an equality

$$c(v) = c/n + v(1 - 1/n^2)\,. \qquad (2.12)$$

2.2. Astronomical experiment of Airy

When watching the stars there is a periodic displacement of their image in a telescope due to the periodic movement of the Earth around of the Sun with linear speed *V*. This phenomenon has received the name of a star aberration.

For the best understanding of the nature of this displacement figure 2 represents the special case, when the axis of a telescope coincides with the direction to the star *S'*. During the propagation of light along the OA distance the telescope is displaced on distance AA'. As a result the seeming image of star *S'* is situated on the angular distance α from the image *S* which would take a place in case of *V = 0*. The observable angle of the refraction thus is equal

$$\alpha_0 = \frac{AA'}{OA} = \frac{V}{c}, \qquad (2.13)$$

where *c* - speed of light in the air (here it can be accepted equal to the speed of light in vacuum).

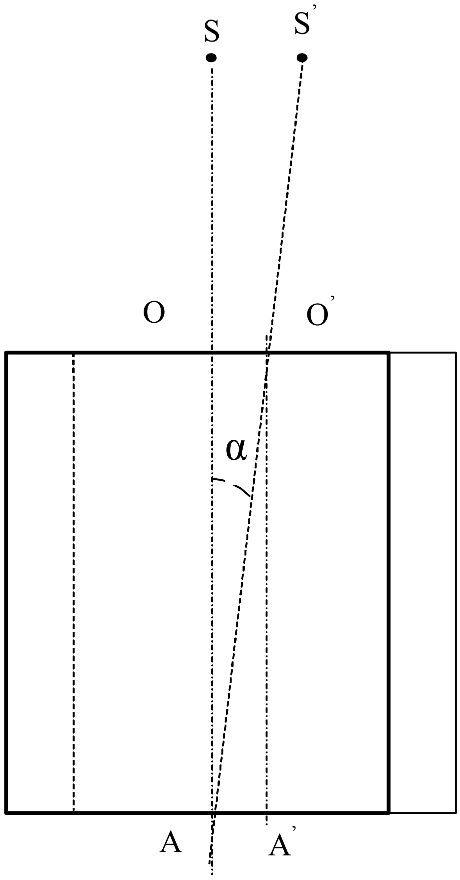

Рис.2 To the star aberration. SOA –path of a ray of light from star S; S'O'A-a seeming way of a beam; *S'* - a seeming position of a star; α - angle of aberration.

If we fill the pipe of the telescope with the substance with the refraction index *n* the speed of light in vacuum in expression 2.13 will be replaced on *c/n* and the angle of refraction will be equal

$$\alpha(n) = \frac{V n}{c}. \qquad (2.14)$$

However the experiment carried out by Airy, has shown, that the angle of aberration has remained unchanged, i.e.

$$\alpha = \alpha(n) = \alpha_0 = V/c.$$

Let's calculate the value of aberration angle α(n) according to the proposed property of quanta accepted above when explaining the Fizeau's experiment.

Let OA = L, where *L* is the length of a telescope pipe. The quantum of light in vacuum passes this way in time $t = L/c$. Filling the pipe with a refracting substance increases this time on

$$t' = \frac{Ln}{c} - \frac{L}{c} = \frac{L}{c}(n-1) \ . \qquad (2.15)$$

As we assumed above, this increase occurs due to stay of quanta of light in the structure of atoms of the substance. Hence, together with atoms of substance, quanta of light are displaced to the right in time *t'* on the value

$$t'V = \frac{L}{c}(n-1)V \ . \qquad (2.16)$$

Therefore the resulting transverse displacement of light will be equal

$$\Delta = \frac{VLn}{c} - \frac{L}{c}(n-1)V = \frac{VL}{c}, \qquad (2.17)$$

and the angle α *(n)* in the refracting substance of the telescope pipe will be equal

$$\alpha(n) = \Delta/L = VL/(cL) = V/c, \quad \text{so that } \alpha(n) = \alpha_o.$$

That is in the consent with the Airy's experiment result.

Discussion of the results. The conclusion.

The simple calculations presented above, lead us to quite certain conclusion that the offered mechanism of propagation of light both in still and in moving environments does not contradict available experimental data.

Moreover, such a mysterious phenomenon as light transfer by moving substance simply follows from the offered mechanism. Thus it is necessary to pay attention to that moment, that the resulting speed of light in moving substance appears to be the average speed of consecutive moving of quanta with the speed of light c in vacuum and with the speed V of moving substance in the structure of its atoms. So, when giving explanations to the results of Fizeau and Airy experiments we don't have to use the Lorentz sum of speeds which is considered to be the unique satisfactory way to explain the results of these experiences.

It is not excluded, that the proposed property of quanta really takes place. Then we deal with the property of quanta of light, that hasn't yet attracted the attention of the researchers. But consecutive and careful development of the theory in view of objectively existing and earlier negligible property of quanta should lead to a prediction of the new phenomena or to a new consistent explanation of set of the known phenomena. In particular, the explanation of diffraction phenomena turns out very interesting, because it doesn't neglect the opportunity to eliminate the diffraction on the edges of screens and diaphragms [12].

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