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Dark Matter in the Optical Laboratory

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Abstract
In astronomy and cosmology, as well as in theoretical physics, dark matter is a hypothetical form of matter that does not participate in electromagnetic interaction and is therefore inaccessible to direct observation. The non-participation of dark matter in electromagnetic interaction in experimental physics allows the optical laboratory to create a situation in which the presence or absence of dark matter can be established. The aim of this work is to interpret the scattering of laser radiation in a dispersed medium in the case of interference of two intersecting beams. Alternating minima of light intensity in space indicate the absence of an interference pattern of a source of scattered photons, i.e. moving photons, scattered in the region of nodes in the medium. The absence of scattered photons is explained by the transition of laser radiation photons into axions and vice versa with a period equal to the period of the interference pattern. The propagation of axions in the medium occurs without scattering. In fact, at the intensity minima of the intersecting beam - nodes, the axions represent dark matter that does not interact with the environment.

Keywords: Interference, Scattering of Light, Photon, Axion, Dark Matter

Introduction
In this paper, we will try to link the non-participation of dark matter in electromagnetic interaction in experimental physics with the processes of light scattering and interference, using the idea of light as a beam of light quanta propagating in a dispersed medium. As a rule, the propagation of light in such an environment is accompanied by scattering processes, which we will discuss separately.

The process of light interference in classical physics is defined as follows: Light interference is the redistribution of light intensity as a result of superposition of several beams of light. This phenomenon is usually characterized by alternating maxima and minima of light intensity in space. A specific type of such light intensity distribution in a dispersed medium or on a screen where the light falls is called an interference pattern.

The process of propagation of a light beam through a dispersed medium is accompanied by light scattering. When a light beam is scattered, photons appear, the direction of propagation of which changes. This effect is called opalescence. Due to this effect, it is possible to observe a ray of light passing through a dispersed medium from the outside.

The aim of the work is to explain how the interference pattern formed by photons propagating in the medium of two intersecting beams, stationary in space, with alternating maxima and minima of light intensity in space, is related to the process of light scattering.

Scattering of Laser Radiation in the Medium Under Study
Light scattering is a phenomenon that has been of great interest to physicists since the very beginning of studying the properties of light. The reason is not so complicated: phenomena related to light scattering create certain visual effects that are usually easy to notice.Scattering of laser radiation in the studied medium is one of the main methods of using a laser in scientific research [1]. In the laboratory, when the laser is turned on, the path of the laser beam can be traced by scattering light in the air.

The study of light scattering processes began after Lord Rayleigh's discovery of the law of light scattering by objects whose dimensions are comparable to the wavelength of the radiation applied to the medium. Individual atoms and molecules are those particles on which elastic scattering occurs according to Rayleigh's law.From a quantum point of view, Rayleigh scattering occurs in two stages: first, an atomic electron absorbs an incoming quantum of light, a photon, and briefly switches to a temporary, intermediate energy level (in quantum mechanics it is called virtual, from the Latin word virtualis – capable, worthy), and then returns back, emitting a photon with the same energy - frequency, but with a different – random, probabilistic – direction of propagation. However, the discovery of the Raman effect in 1928 showed that the scattering process is more complex than Rayleigh's law. In addition, the process of light scattering in the case of a solid, liquid, or even gas is influenced by the collective movements of atoms or molecules. The scattering of light by extraneous particles or small impurities placed in the medium under study deserves mention. Such impurity scattering is called Tyndall scattering. The paper presents the results of a study of these types of scattering [2]. Let's name a few more cases of laser radiation scattering. This is molecular scattering, which was studied by Fabelinsky the Mandelstam—Brillouin effect, associated with the scattering of optical radiation by condensed media (solids and liquids) as a result of its interaction with the intrinsic elastic vibrations of these media) and scattering directed along conical guides is Vavilov-Cherenkov radiation caused by the movement of photons at a speed exceeding the speed of light in the medium under study [3-4].

In this paper, we will limit ourselves to considering the process of Rayleigh scattering of light in air during the interference of two beams of light quanta received from a single laser and intersecting with each other. Optical properties of the medium under study (in our case, air) They are associated with vibrations of elementary dipoles (identical, indistinguishable negatively charged electrons) associated with positively charged atomic nuclei entering the molecules of the air environment. In other words, air is an ensemble of oscillators with a wide range of frequencies called the Bohr frequencies [5]. The natural frequencies of these oscillators are determined by elastic forces and do not depend on the frequency of the external field [6]. As a rule, the frequency of laser radiation does not coincide with the natural frequencies of electrons, and in our case we have forced oscillations of electrons with the frequency of laser radiation. Rayleigh's scattered radiation has the same frequency.

Let's focus on the case when the interaction process takes place in the laboratory. The scheme of the experiment on light scattering in the case of a single beam is shown in Figure 1. A beam of light photons emitted by a continuous laser falls on a homogeneous medium (in our case, air) - M. An optical receiver located at position P, remote by a distance of - R, registers the presence of a weak light signal propagating in a direction other than the direction of propagation of the laser beam. The presence of a weak light signal indicates that there is light scattering. Let us recall the mechanism responsible for the scattering process. Electrons of atoms and molecules of the illuminated medium - M experience forced oscillations under the influence of the electromagnetic field of radiation incident on the medium. These electrons are the source of scattered radiation. It is this radiation that is detected by a photodetector located at the point P, defined by the polar coordinates R,θ,ϒ. , where θ is the angle between the axis of the photon beam directed into the medium (k_0) and the direction of propagation of the scattered radiation (k), ϒ = 0° - 360°. As a rule, the structure of the scattered radiation field is symmetrical and the scattered radiation signal can be detected at any point in the space encompassing the medium M. An optical receiver located at position P, remote by a distance of - R, registers the presence of a weak light signal propagating in a direction other than the direction of propagation of the laser beam.

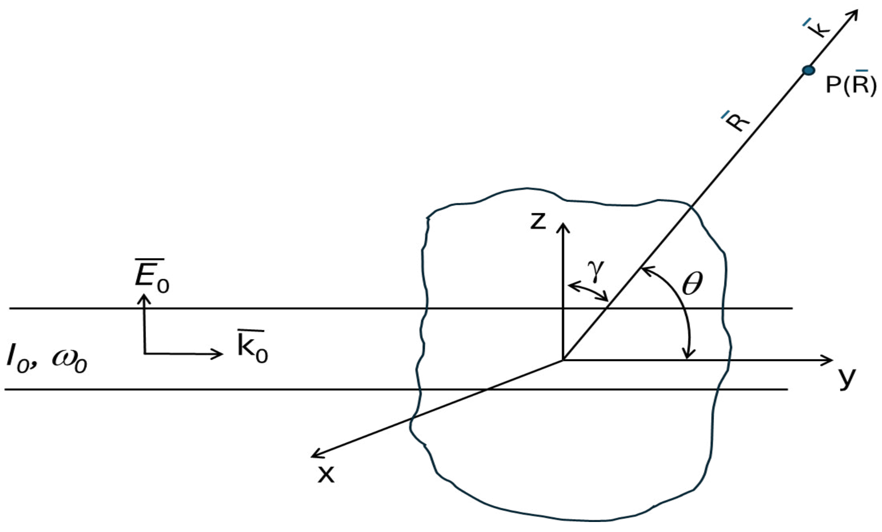

Figure 1: Is An Experimental Scheme for Detecting Scattered Radiation.The Laser Beam Propagates Along the Y axis and is Polarized along the Z axis; ω, I0 is the Angular Frequency and Intensity of the Laser Radiation. The Scattered Radiation is Recorded at the Point P, the Polar Coordinates of which are R,θ,ϒ. θ is the Angle Between the Direction of Propagation of the Light Beam and the Direction of Propagation of the Scattered Radiation. The Distance R is chosen in such a way as to Avoid Direct Laser Radiation Hitting the Photodetector

Interference of Laser Radiation in the Studied Medium
The phenomenon of interference is the addition of two or more coherent light beams (up to infinity), which, when combined after passing through the milky way in space, give one or another picture of the intensity distribution, usually in the form of maxima and minima of light.The scheme of adding two beams used in holography: the reference and the object is based on the scheme proposed by Fresnel for the implementation of two-beam interference using two mirrors [7].

Specialists in the field of holography use the interference process at the stage of obtaining holograms.

To obtain an interference pattern, it is better to perform the experiment on a holographic installation so that vibrations do not disrupt the interference pattern [8]. To obtain an interference pattern, the diameter of the laser beam can be increased using a telescopic system and divided into two beams using a beam-splitting cube, and then these two beams can be reduced at an angle θ to each other (Figure 2).

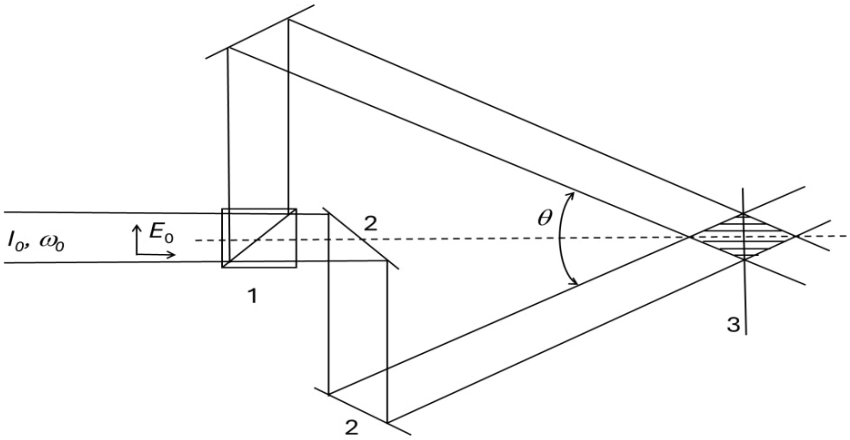

Figure: 2 Experimental Scheme for Detecting Radiation Interference.The Laser Beam is Divided into Two Equal Parts using a Beam-Splitting Cube -1. Using the Mirror - 2 System, the Two Beams Obtained Intersect with Each Other; ω, I0 is the Angular Frequency and Intensity of the Laser Radiation. θ is the Angle at which the Beams Intersect. The Interference Pattern in the Area of Beam Intersection is Recorded on a Photographic Plate – 3

Since laser beams propagate in the air, where the propagation of laser radiation is accompanied by light scattering, the scattered radiation will make a significant contribution to the interference pattern. It should be noted at once that this contribution is clearly present in bright light bands and absent in dark, unlit bands. If you place a photographic plate in the area of the intersection of the rays, expose and develop it, then an image of an interference pattern will appear on the photo layer.3 shows the result of the interference of two light rays, the wavefront of which has a flat shape. In this case, the scattered radiation is present in the light bands of the interference pattern and absent in the region of the dark bands. Note that there is no scattering, and the light emission in the area of the intersection of the rays is not modulated or mechanically interrupted. It is obvious that in the area of the intersection of light beams, the scattering process is influenced by interference occurring in the area of the intersection of the rays.

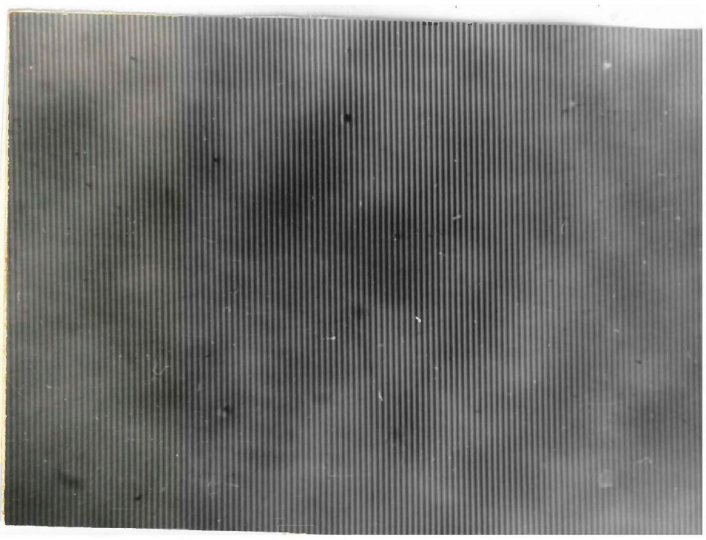

Figure 3: Is the Result of Interference of Two Flat Intersecting Laser Beams Recorded on a Photographic Plate

If we use the lens-4 in Figure 2 to make one of the beams diverge, then the interference pattern will change - we get curved interference fringes on the photographic plate (Figure 4).

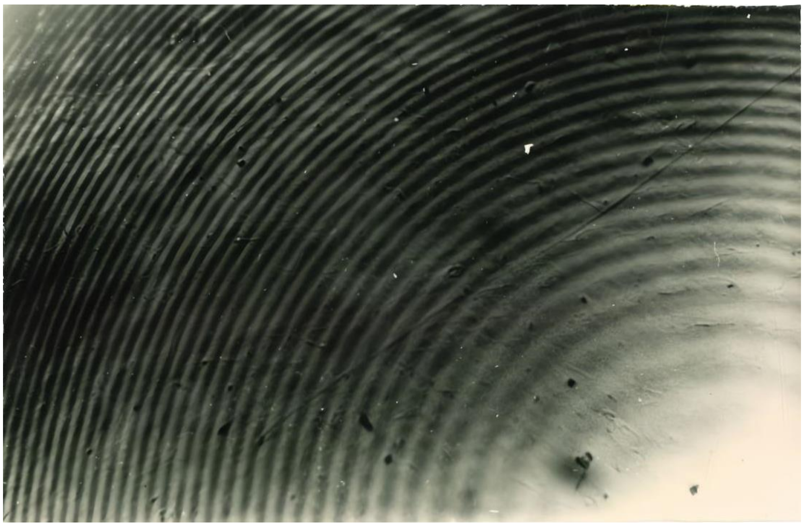

Figure 4: Is the Result of Interference of a Diverging Light Beam with a Light Beam with a Flat Wavefront

If one of the light beams is divided into several and these beams are brought together, the interference pattern will take on a complex patterned shape. Figure 5 shows the result of interference of a large number of intersecting laser beams, recorded on a photographic plate.

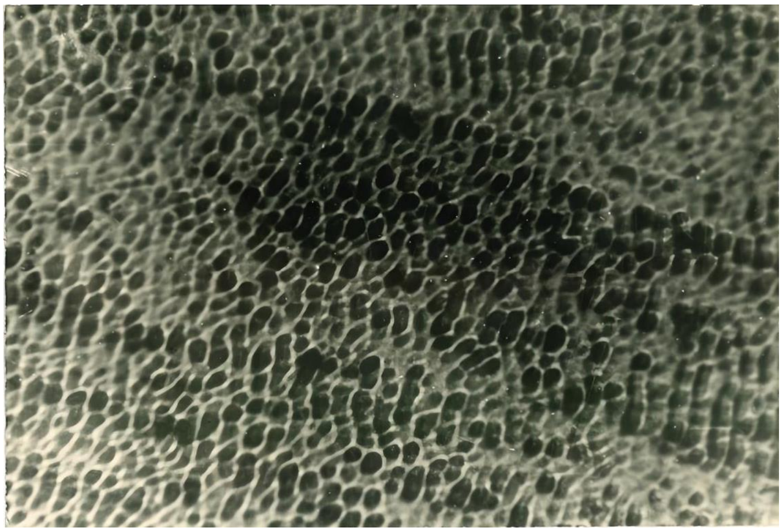

Figure 5: Is the Result of Interference of a Large Number of Intersecting Laser Beams with a Light Beam with a Flat Wavefront

In all three cases, the presence of areas on the photographic plate that are not affected by scattered radiation indicates that with the continuous propagation of light energy in light beams, a mechanism is activated in the interference region that eliminates the possibility of scattering in the medium under study.

Discussion

If the beams intersect in a vacuum (laboratory), there will be no interference in the area of beam intersection - the photons of one beam do not notice the photons of the other beam In vacuum conditions, the photons do not interact with each other [9].

We have shown above that when a single laser beam propagates in a dispersed medium, light scattering occurs. If a second beam appears in the medium, this statement needs additional consideration. If a second laser beam of the same laser intersects at an angle with the first, then interference occurs in the medium in the intersection area. In this case, the scattering process in the same medium undergoes changes, namely, alternating light and dark interference bands indicate that there are no scattered radiation photons in the gaps between the light bands occupied by the dark bands, despite the fact that the photon flux in each of the beams is continuous.

We have to figure out why there is no scattered radiation in the dark bands - the nodes of the interference pattern in the case of the intersection of two laser beams in a dispersed medium. As in the case of a single beam, the motion of photons in the case of two beams in the intersection region can be considered laminar, since the air density remains practically constant; the electromagnetic field of the atomic nuclei in the medium is evenly distributed in the volume of the medium.

In the case of interference, the situation changes - in the area of beam intersection, the electric field strength varies according to a sinusoidal law: nodes and antinodes. The intensity of the light field is minimal at the nodes, and maximum at the antinodes. In the latter case, the light beam, when propagating in a dispersed medium, interacts not only with electrons, but the interaction of photons with the electromagnetic field of the nuclei of atoms of the dispersed medium comes to the fore.

Let us turn to the model proposed by Primakov [10]. The Primakov effect (HENRY PRIMAKOFF) is the transformation of photons in a static electric or magnetic field (for example, in the field of the nucleus of an atom) into a neutral pseudoscalar particle, which can be an axion (direct Primakov effect).

Particles that are born in this way are capable of splitting into two photons in the electromagnetic field (in the field of the nucleus) (the reverse Primakov effect). According to the annihilation of two quanta (photons) in the field of the atomic nucleus can lead to the birth of the axion -A0 and its decay outside the field of the atomic nucleus [10].

$$h\,v + hv = A^0 = hv + h\,v \qquad (1)$$

where:
h v is the energy of the quanta (photons) of the light radiation used to pump the dispersed medium, v is the frequency of this radiation.

In cases of photoluminescence, Raman scattering of light, the decay of an axion, as a rule, occurs into photons of different energies. The energy of one of the photons exactly corresponds to the energy of the electron transition from level to level, which leads to the transition of an atom or molecule into an excited state. The second photon of the decayed axion contributes to the Raman scattering or to the photoluminescent glow of the sample under study [11,12].

The resulting intensity pattern in the area of beam intersection will be modulated in space according to the periodic law. In places where the phase difference of the two beams is a multiple of 2 π, the amplitudes of the field strength of both beams add up, i.e. the light vibrations amplify each other and we will see bright bands of light - antinodes. In the same places where the phase difference is a multiple of an odd number of π, i.e. the waves are out of phase, the field strengths are subtracted, the waves cancel each other out, and we will see dark, unlit stripes - nodes. You can use a microscope to observe the interference pattern. Using a microscope, the axis of which is directed at an angle of θ/2 to the axes of the two laser beams strictly along the bisector of the angle - θ between the axes of these beams, it is possible to photograph the interference pattern.

Since laser beams propagate in the air, where the propagation of laser radiation is accompanied by light scattering, scattered radiation will make a significant contribution to the interference pattern. We should immediately note that this contribution is obviously present in bright bands of light and absent in dark, unlit bands.If we place a photographic plate in the area of the intersection of the beams, expose and develop it, then we will get an image of the interference pattern on the photo layer (Figure.3).

If we assume that in the antinode region, where the electromagnetic field strength of two intersecting laser beams is maximum, pairs of photons from the two beams annihilate into axions, then the absence of scattered photons can be explained by the ability of axions to propagate in a medium without scattering.Which explains the dark bands of the interference pattern. In the region of nodes, where the intensity of the electromagnetic field is minimal, axions break up into pairs of photons. In this case, the scattered radiation contributes to the light bands of the interference pattern.

In astronomy and cosmology, as well as in theoretical physics, a hypothetical form of matter that does not participate in electromagnetic interaction is discussed - dark matter. The main difficulty in searching for dark matter particles is that they do not participate in electromagnetic interaction, that is, the particles are invisible and have a non-baryonic nature. In it was proposed to give the role of dark matter to axions [13-18]. The authors believe that the main candidates for the role of dark matter are weakly interacting massive particles or ultralight bosons (axions) located at opposite ends of the mass scale, which were postulated by competing theories to eliminate the shortcomings of the Standard Model of Particle Physics [19]. The authors of the work note that dark matter - axions do not interact not only with the environment, but also do not interact with electromagnetic radiation and do not emit it [20]. The results presented in our article confirm this fact.

If we assume that in the antinode region, where the electromagnetic field strength of two intersecting laser beams is maximum, pairs of photons from the two beams annihilate into axions, then the absence of scattered photons can be explained by the ability of axions to propagate in a medium without scattering.Which explains the dark bands of the interference pattern. In the region of nodes, where the intensity of the electromagnetic field is minimal, axions

break up into pairs of photons. In this case, the scattered radiation contributes to the light bands of the interference pattern.

Conclusion

The purpose of the work: As a stationary interference pattern in space with alternating maxima and minima of light intensity, it is associated with the process of light scattering at the intersection of two light beams in a dispersed medium. The alternation of spatial minima of light intensity in the direction determined by the angle $\theta/2$ to the axes of the two laser beams indicates the absence of scattered photons in the minima of the interference pattern. In this work, the absence of scattered photons is explained by the transition of photons to Primakov axions and vice versa with a period equal to the period of the interference pattern. The propagation of axions in the medium occurs without scattering. In fact, in our case, the axions at the minima of the intensity of the interference pattern represent dark matter that does not interact with the environment and, therefore, light scattering does not occur in the region of minima.

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