ABOUT THE NATURE OF THE PHOTON

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The light wins more and more in meaning and attractiveness as energy and information carrying medium. It is already today foreseeable, how rapidly the optical technologies of the future will develop. Precise control of the nanostructures processes, which taken place, may be not achieved without the deepened and more exact knowledge of the thereby applied physics. In past centuries the physics of the light as well as the electromagnetic radiation was intensively and successfully investigated. The outstanding scientists such as Newton, Einstein, Wien, Planck and Brouglie shaped the development of the theory as well as their practical application strongly. According to Newton, we know today that the light consists of the different energetic levels and behaves like particles. The experiments showed further that light could be itself regarded as an electromagnetic wave under certain circumstances. The investigations from Wien and Planck, in particular of the photoelectric effect determined new procedures, which could be explained only with difficulty. The behaviour of the light could not be explained by the dominant laws at that time. The introduction of the light particle as photon, the explanation of the photoelectric effect and the ingenious formula for the computation of the photon energy was the achievement of Einstein. It became clear that the light possesses both - particle and wave characteristics. This phenomenon - dualism of the light was called wave - particle dualism.

The law derived from Planck

$$E = hf \tag{1}$$

led to the birth of the quantum mechanics. The formula introduced by Einstein later

$$E = mc^2 \tag{2}$$

had astonishing similarity with Newton's formula for the computation of the kinetic energy. In this case, we should write, however $E = mc^2/2$

The difference between both results is exactly 100 %. What does it mean? Is the similarity between both historical formulas coincidental? Could the Newton laws, which were accepted nearly in all areas of physics, afterwards in the fluid mechanics and thermodynamics, prove also their validity in the quantum world? Are not the quanta world and the world of the Newton mechanics any parallel worlds, but the world in their other, us well unknown yet, harmonious form? What happens with the mass of a light particle? Do the photons have a mass and if the answer could be positive, how does this mass change with the increasing energy of the photon?

The photon model

On the conference [1] was the model of the light particle presented, which made possible to understand and to explain the dualistic characteristics of the light. This model and the in [1] imported postulates should be explained in more detail now. Figure 1 shows a moving photon schematically.

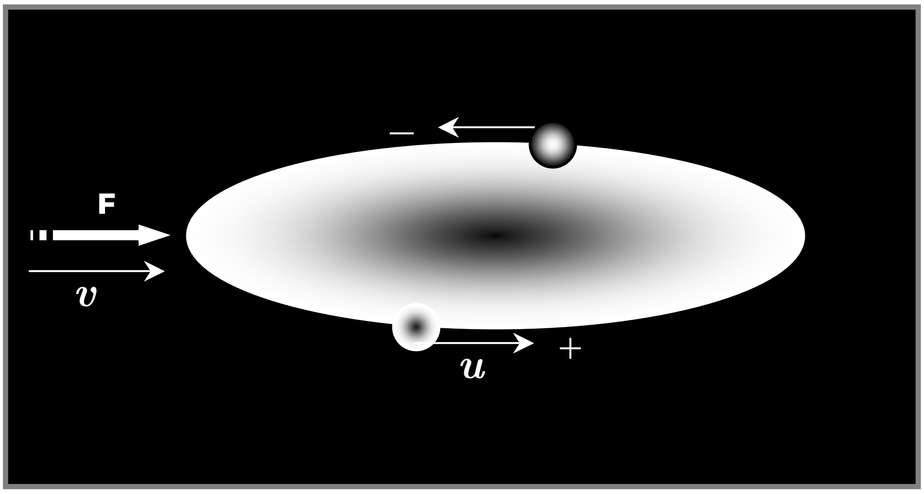

Fig. 1 The Model of the photon

It can be recognized hereby that the photon rotates around an axis. The propagation velocity v is well known, however which value the rotation speed u has, is now our task to find out. In fact, it can be accepted, that the rotation does not take place from itself, but requires energy. In connection to [1] was postulated, that the entire energy of the photon could be represented in the following way:

$$E_P = E_V + E_R \quad (3),$$

whereby E_V is energy portion of progressive movement, and E_R is energy portion of the rotation. The entire energy E_P of the photon could be on the basis the Einstein's formula (2) defined. The energy E_V has to be printed out in the following form:

$$E_V = \frac{mc^2}{2} \quad (4)$$

Thus led to:

$$E_R = mc^2 - \frac{mc^2}{2} = \frac{mc^2}{2} \quad (5)$$

and to:

$$v = u = c \quad (6)$$

Wave characteristics

During the rotation different forces exert influence on the particle. If the photon turns against the direction of the spreading, the speed u is negative in this case. The photon is slowed down. However, if the photon is in a range where u is positive, the movement is accelerated by the force F. We can see that the rotation energy and due to of that, the total energy E_P changes, because the speed changes periodically (in fig. 1 this is with drawing with "+" and "-" indicated). The rotary motion and the changing energy accordingly will obviously lead to a typical wave course. In this case, we will see the typical waves, oscillation characteristics, or with another words, in sinusoidal mode swinging velocity or energy distribution.

Change of the mass

In [1,2] the photon mass was theoretically calculated for the sun radiation. It yielded that it is much "lighter" than the mass of an electron - $m_P = 4.406389 \cdot 10^{-36}$ [kg].

Now it is necessary to look at an important aspect of quantum mechanics, the topic of the mass, particularly the change of the mass by a changing speed. One assumes today is the photon possesses no mass. Here we have still with a phenomenon to do. It seems to be, that the photon represents something like a particularly singular object, which we can not understand with our logic and physics and what is still worse, we will not understand in the future. On the other hand, the statement – the photon does not have a mass leads to a set of questions. As it is well known, the light radiation has much energy. The Einstein formula (2) will be hardly who disputed. If however, the light particle would have a "0" mass, we should have it in conformity with the Equ. (2) and also the "0" value for the energy. However, either formula is not universal, or the mass does not equal zero? As such, head-breaking questions develop and those must be solved.

During the work on the theory of the relativity Einstein used the Lorenz formula for the determination of the changing particle mass:

$$m = \frac{m_0}{\sqrt{1 - \frac{v^2}{c_0^2}}} \tag{7}$$

It is evident, that the mass rises with the approximation of the particle speed to the speed of light in vacuum – $c_0 = 2.99792458 \cdot 10^8$ [m/s] rapidly. In case, where the particle speed resembles the speed of light, the denominator should go down to zero. From the latter follows inevitably that the particle velocity can never reach the speed of light.

In addition, the formula (7) can be regarded in another way, as was shown in [2]. By the mathematical shaping of the Eqv. (7) one comes to the following expression:

$$c_0^2\left(m^2 - m_0^2\right) = m^2 v^2 \tag{8}$$

If one divides the Eqv. (8) with c_0^2, then one receives with consideration $\frac{v_0^2}{c_0^2} \to 1$

$$m^2 - m_0^2 = m^2 \tag{9}$$

It can to be seen that the Equation (9) is fulfilled if the mass m_0 takes the value "0" only. This conclusion contradicts the Einstein view on the change of the particle mass, as well as today's views of theoretical physics, however it is mathematically completely correct. How could it be interpreted that the formula delivers different results? Does the mass increase at increasing speed, or does it decrease? What does really apply to the photon nature?

We will try to follow this question now and turn for these purposes to the fundamental and in nearly all physic areas implemented equations of Newton:

$$\frac{d\,(mv)}{dt} = \vec{F} \tag{10}$$

The time interval dt can be expressed with the following transformation:

$$v = \frac{dx}{dt} \Rightarrow dt = \frac{dx}{v} \tag{11}$$

By using the transformation (11), the following formula can be derived [2]:

$$\frac{dm}{m} + \frac{dv}{v} = \frac{dE}{E} \tag{12}$$

It is easy to see that the received equation (12) represents the balance of the total energy. In relativity theory [5] the photon speed does never resemble the speed of light in vacuum and it is always constant. Viewing the energy increase at constant velocity leads according to equation (12) inevitably to

$$\frac{dm}{m} = \frac{dE}{E} \tag{13}$$

the mass increase and in reverse. Here, in my opinion, is the matter of the problem. The electrons, for examples, which are radiated by a cathode, have as it is well known a substantially lower speed, which is proportional to the voltage applied. According to (12) the lower speed would mean a larger mass. This agrees, in my judgement, with the stated view.

Impulse equation of the photons

On the basis of the above described photon model (Fig. 1) the forces, which develop during the motion and rotation of the photon, can be determined in the following way:

$$\frac{d(mv)}{dt} + \frac{d(mu)}{dt} = \vec{F} \tag{14}$$

If one introduces the transformation for the time interval (11), then one receives:

$$v\frac{d(mv)}{dx} + v\frac{d(mu)}{dx} = \vec{F} \tag{15}$$

Now we will regard a spectrum of the relatively small changing speeds. It can be assumed, that the mass changes slightly. This simplifies the equation (15):

$$vm\frac{dv}{dx} + vm\frac{du}{dx} = \vec{F} \tag{16}$$

In the cases, where the equation of Einstein is valid, the equality of the velocities $u = v$ is according to the equation (6) fulfilled and the formula (16) can be converted into the following expression:

$$2mvdv = dE \tag{17}$$

We turn now to Planck equation (1). The natural constant h can be expressed as,

$$h = mv\lambda \tag{18}$$

whereby – m - is mass of the photon [kg], v - the velocity [m/s], λ - the wavelength [m].

With equation (18) and the consideration, that the velocity v could be in such way - $v = \lambda f$ determined, the formula (17) can be brought to the following expression [6]:

$$2\frac{h}{\lambda}d(\lambda f) = dE \tag{19}$$

The differentiation of the formula (19) leads to the following relationship:

$$2\frac{h}{\lambda}fd\lambda + 2\frac{h}{\lambda}\lambda df = dE \tag{20}$$

If one divides the equation (20) on $E = hf$ and if one notices that $dE = hdf$, then arises:

$$\frac{dE}{E} = -2\frac{d\lambda}{\lambda} \tag{21}$$

After the integration Eqv. (21) in the interval between the conditions 1 and 2 finally follows:

$$\ln\frac{E_2}{E_1} = 2\ln\frac{\lambda_1}{\lambda_2} \tag{22}$$

or

$$\frac{E_2}{E_1} = \frac{\lambda_1^2}{\lambda_2^2} \tag{23}$$

Compton effect

In 1922, Arthur Compton discovered that the monochromatic x-ray causes an enlargement of the wavelength with the passage by subject. What takes place physically at the passage? How do the energetic conditions of the resulting waves change?

With the derived equations (23) these questions can be answered and processes occurred be illustrated. The subject, which should penetrate has a braking effect on the x-ray, which causes the reduction of the speed. This thought is based on the refraction laws, which became generally accepted in the optics and electrodynamics.

We assume now that the energy of an x-ray photon is E_1 before the impact and E_2 after the passage. Since we have to do with different speeds, the energetic conditions in 1 and 2 can be determined in such form:

$$\begin{aligned} E_1 &= mv_1^2 \\ E_2 &= mv_2^2 \end{aligned} \tag{24}$$

With the formula (24) the equation (23) will look as follows:

$$\frac{mv_2^2}{mv_1^2} = \left(\frac{\lambda_1}{\lambda_2}\right)^2 \tag{25}$$

or

$$\frac{\lambda_1}{\lambda_2} = \frac{v_2}{v_1} \qquad (26)$$
$$\lambda_1 v_1 = \lambda_2 v_2$$

From the equations (26) it follows clearly that the decrease of the velocity draws the enlargement of the wavelength, as well as in reverse – an acceleration should make the length of the waves smaller.

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References

1. About the dualism of the light. EPS-12 General Conference „Trends in Physics“, S. Reissig, S. 414, 2002
2. Presentation on the conference EPS-12 „Trends in Physics“, S. Reissig, //www.efbr.de/Publikationen, 2002
3. Änderung der Masse der Photonen bei großen Geschwindigkeiten. Teil I. S. Reissig, //www.efbr.de/Publikationen, 2002
4. Änderung der Masse der Photonen bei großen Geschwindigkeiten. Teil II. S. Reissig, //www.efbr.de/Publikationen, 2002
5. Über die spezielle und die allgemeine Relativitätstheorie. A. Einstein, Springer-Verlag, 2001, S.112
6. Bewegungsgleichung der Photonen. S. Reissig, //www.efbr.de/Publikationen, 2002