Compton effect as a Doppler effect

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Abstract

An electromagnetic wave with the wavelength λ, which has some energy, descends on an electron and makes it move in the same direction of propagation of the wave. The wave makes the moving electron oscillate with a lower frequency. A simple analysis shows that this moving oscillating electron radiates, in the direction making angle θ with the direction of the incident wave, an electromagnetic wave which its wavelength is bigger by a factor proportional to $\lambda(1 - \cos\theta)$.

1 Introduction

When an electromagnetic wave descends on a target, bound electrons of the target are made to oscillate with the same frequency of the incident wave. These oscillating electrons radiate electromagnetic waves in every direction with the same frequency of their oscillation.

Further to these radiations, it is observed in practice that there is another electromagnetic wave with a wavelength longer than the wavelength of the incident wave. Difference between the wavelengths of this wave and the incident wave is different in different directions being proportional to the factor $1 - \cos\theta$ in which θ is the scattering angle (ie the angle relative to the line of propagation of the incident wave in which the detector sees the target).

The empirical linear proportion of the above difference of the wavelengths to the factor $1-\cos\theta$ is justified by Compton's reasoning [1-5] in the form of

$$\Delta\lambda = \lambda' - \lambda = \frac{h}{m_0 c}(1-\cos\theta) \tag{1}$$

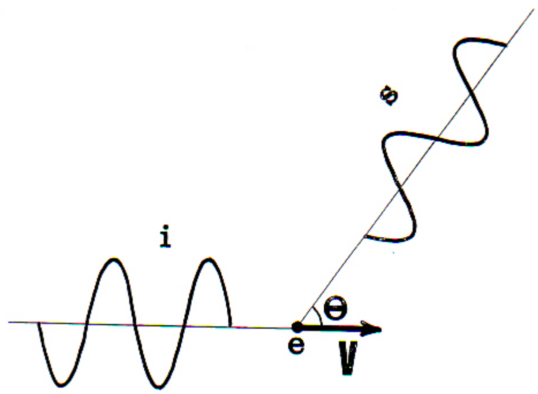
in which it is assumed that the electromagnetic wave in the form of photon hits the electron and causes its recoiling.

What is intended by this article is obtaining the above-mentioned empirical linear proportion in a simple classical manner. The use of this act is that firstly no longer we can consider the Compton effect as an entire quantum (and relativistic) phenomenon and recognize it among the phenomena which only the quantum (or relativistic) physics is able to justify them, and secondly the proportion of $\Delta\lambda$ to λ will appear absence of which in Compton's reasoning has been always surprising [6-8].

2 The reasoning

Since an electromagnetic beam incident on a target has energy, it causes that the relatively free valence electrons of the target start moving into the target in the direction of propagation of the wave. In fact, motion of the electrons in this manner produces a kind of local closed electric current which is not concerned here. (We must also believe in such a current in Compton's reasoning produced by the recoiling electrons moving inwards.) Verification about the cause and exerting mechanism of such an energy or force pushing the electron into the target is an important matter to which we pay in the next section. But until then we accept existence of the mentioned motion for the (being pushed) free electrons of the target.

The wave incident on the target not only makes the bound electrons of the target oscillate making scattered waves with the same wavelength of the beam, but also makes the free electrons moving towards the inside of the target oscillate. We are to study the mechanism of the oscillation of the free electrons and the wavelengths produced by them in different directions.



The wave i with the wavelength λ descends on the electron e which is moving in the same direction of the wave i with the speed v. We want to obtain the oscillation frequency that the electron gains from the wave i incident on it. The speed of propagation of the wave i is c. Then, for obtaining the above mentioned oscillation frequency, we can suppose that the electron is stationary but the wave i descends on it with the speed $c - v$. Therefore, the frequency received by the electron will be $(c - v)/\lambda$.

Now we have an electron moving with the velocity $\mathbf{v}$ and oscillating with the frequency $(c-v)/\lambda$. It is obvious that such an oscillating electron radiates electromagnetic wave. We want to obtain the wavelength of this radiated wave in the direction related to the angle θ.

Since the electron has the speed v in the direction of propagation of the wave i, the situation is as if it has the speed $v\cos\theta$ in the direction related to the angle θ. Now it is sufficient to see which wavelength will be radiated in the direction of motion (ie θ direction) by an electron moving with the speed $v\cos\theta$ and oscillating with the frequency $(c-v)/\lambda$. Since the speed of this radiated wave is also c, the situation is as if the electron is stationary and while it is oscillating with the frequency $(c-v)/\lambda$, radiates a wave with the speed $c-v\cos\theta$ in the θ direction. It is obvious that the wavelength of such a wave is

$$\lambda' = \frac{c - v\cos\theta}{\frac{c-v}{\lambda}} = \frac{c - v\cos\theta}{c - v} \cdot \lambda.$$

Now we can calculate $\Delta\lambda = \lambda' - \lambda$. The result will be

$$\Delta\lambda = \frac{v\lambda}{c - v}(1 - \cos\theta). \tag{2}$$

As we see $\Delta\lambda$ is directly proportional to the wavelength of the incident wave (λ) too. If accurate experiments indicates dependence of $\Delta\lambda$ to λ, the only acceptable reasoning will be the one presented in this article not Compton's one. But, to verify this, we must note that we have also another variable, v, in the coefficient of Eq. (2). So, the coefficient of Eq. (2) depends on two variables (λ and v), while the coefficient of Eq (1) is independent of any variable. It is probable that shorter wavelengths are able to create more thermal fluctuation due to their more penetrability. So, probably we should expect that for shorter wavelengths, the effect of increasing of v to be much more than the effect of decreasing of λ in modification of the coefficient of Eq. (2). And this means that probably this coefficient is increased by decreasing of λ. Now, for our verification, we need some published data presented for fractional wavelength shift, $\Delta\lambda/\lambda$, for various λ's. For example for $\theta = 45^\circ$ we can find in a published report [10], $\Delta\lambda/\lambda = 1.2 \times 10^{-6}$ for $\lambda = 550nm$ (green light) which results in $\Delta\lambda = 6.6 \times 10^{-13}m$, and also $\Delta\lambda/\lambda = 0.67$ for $\lambda = 1.06pm$ (gamma rays such as those emitted from a radioactive cobalt source) which results in $\Delta\lambda = 7.102 \times 10^{-13}m$. As we can easily calculate, the difference between these two $\Delta\lambda$'s is more than 7 percent. And this is not so negligible, and clearly shows the dependence of $\Delta\lambda$ on λ (and of course on v).

It is noticeable that to the trying for justifying this phenomenon as a Doppler effect has been pointed in some texts [9] but in this incomplete form that because of the Doppler effect the moving electron accepts some wavelength longer than the incident wavelength and then radiates just this wavelength in all the directions, but, (according to the current opinion of the physicists) since the electron is accepting continuously the incident wavelength from a stationary state to its final speed we must expect a continuous distribution of scattered wavelengths from the incident wavelength to the Dopplery lengthened wavelength (and since this is not the case, the classical reasoning is not acceptable and the interaction between the wave and the electron is impulsive not continuous). It was only sufficient that, as in fact has been done in this article, researchers in this phenomenon would take one other step forwards and, as they accept that the moving electron accepts lower frequency, they would accept that this electron (accepting the lower frequency) would radiate just this lower frequency only if it was motionless, but now that it is in motion, again, Doppler effect would be effective and it radiates different wavelengths in different directions (according to what has come in this paper).

3 Mechanism of exerting force

If Eq. (2) is to be right, the mentioned mechanism for giving initial speed to electron should also be correct. But this mechanism is like the mechanism causing the revolution of the vanes in the Crooks radiometer in which radiation energy causes fluctuation of the molecules in vanes. Through this fluctuation, molecules of the vanes strike the adjacent air molecules and as reaction cause recoil of the vanes. This is the case because in high vacuum the rotation of the vanes will cease because there will be such leaned air molecules no longer [11].

In Compton's experiment too, such a thermal fluctuation is created on the target surface due to the attraction of the electromagnetic wave, and in a similar manner these fluctuations strike the adjacent air molecules and as reaction cause recoil of the lighter and freer particles of the target ie its electrons. In this manner. electrons are made to move toward inside of the target.

Now, if the experiment is performed in high vacuum we expect (like the case of performance of Crooks experiment in high vacuum) to have no such recoil practically and we expect v in the coefficient of Eq. (2) (ie $\lambda/((c/v) - 1)$)) to approach to zero while λ is not zero. Thus, we expect to have $\Delta\lambda$ equal to zero in this state.

EXPERIMENTAL NOTE: As far as I know, Compton's experiment generally is not performed in vacuum. Certainly, the most straightforward solution is preparing for doing this experiment in a high vacuum. This can be done by inserting the setup of the experiment (fixed for a constant angle) in a sealed chamber, and starting the evacuation of the chamber, and observing that whether or not the separated (Compton-shifted) wavelength will begin to close to the main scattered wavelength as the vacuum gets better.

In the case of experimental establishment of this theory, Eq. (2) will be a good formula by which we can measure drift velocity (v) in electric currents, through experiment, since the only unknown parameter in this equation will be v.

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