Why a photon is not a particle

Sjaak Uitterdijk
sjaakenlutske@hetnet.nl

Abstract – The variables and parameters of the presented model for the generation of an arbitrary photon fit like the pieces of a jigsaw puzzle and therefore justify the conclusion that the model eliminates the wave-particle duality of the photon by explicitly excluding the possibility that it can be a (massless) particle too. On top of that it has been proven that the energy of the photon is directly delivered by the magnetic energy of the atom, as created by the orbiting electron(s).

Introduction

Considering a photon as an (extremely) short pulse with an electro-magnetic wave as carrier, this eliminates the so-called wave-particle duality. The article shows how the origin of such a pulse can be explained by applying Ampère's and Faraday's law in Bohr's atomic model. The Rydberg formula shows that E=hf is a correct relation between energy and frequency of photons, but also that it is only valid for photons. The pulse lengths of the photons have been calculated by equating that energy with their electromagnetic energy.

I Bohr's atomic model

In Bohr's atomic model, in case of a stable atom, an equal number of electrons revolve around the nucleus, as there are protons in this nucleus. These electrons can rotate in orbits with different distances with respect to the nucleus. These distances are discreet. In other words: an electron will never orbit in between the determined circles.
The generally accepted concept is that a photon is emitted if an electron jumps out of an inner orbit into a more outer orbit. The question is: how is such a photon fundamentally and precisely generated?

II Forces holding the electron in its orbit

An electron is held in its orbit by three forces:

- the centrifugal force trying to jump the electron out of its orbit. F_{cf}
- the centripetal Coulomb force between nucleus and electron F_C
- the centripetal gravitational force between nucleus and electron F_G

with:

r	radius of the orbit of the electron		m
v	velocity of the electron along its orbit		m/s
Z	atom number		
m	mass of the electron	$9.1 \cdot 10^{-31}$	kg
m_p	mass of proton	$1.7 \cdot 10^{-27}$	kg
m_n	mass of the nucleus	$2\,Z\,m_p$	kg
G	gravitational constant	$6.7 \cdot 10^{-11}$	Nm^2kg^{-2}
κ	Coulomb's constant $(1/4\pi\varepsilon_0)$	$9.0 \cdot 10^9$	Nm^2C^{-2}
q	electric charge of the electron/proton	$1.6 \cdot 10^{-19}$	C

The mathematical descriptions of the three mentioned forces are respectively:

$F_{cf} = mv^2/r$ $\quad F_C = \kappa q^2/r^2$ $\quad F_G = Gm_nm/r^2$

Remarks:

-r has the discreet values n^2a_0/Z, with a_0 the so called Bohr radius (n=1, 2, 3……)
-The mass of a proton is about equal to the mass of a neutron.
-The number of neutrons is taken equal to the number of protons.
- $F_G \sim 10^{-67}Z/r^2$ and $F_C \sim 10^{-28}Z/r^2$, with the result that F_G is completely negligible.

So, the real number of neutrons does not play any role in this article, neither does F_G anymore.

As a result, the electron is held in its orbit by $F_{cf} = F_C$.

So: $mv^2/r = \kappa Zq^2/r^2$

from which it follows that:

$$v = (\kappa Zq^2/mr)^{½}$$

III The basic idea behind the generation of a photon

The fundamental part of the investigated model is the assumption that the orbit of an electron around the nucleus of an atom is equivalent to a circular shaped electric current, creating a magnetic field.

Suppose the "round trip" of an electron is t seconds and its electric charge is represented by the symbol q. Then the first approximation of the meant electric current is $q/t = i$ [A]. The mentioned "round trip" is equal to $2\pi r/v$, with r the radius of the orbit of the electron and v the velocity along that orbit. So $i = qv/2\pi r$.
Such an electric current causes a static magnetic field H, perpendicular to the plane of the orbit. *Only in the centre of the orbit this field yields:*

$$H = i/2r = qv/4\pi r^2 = q^2(\kappa Z/m)^{½}/4\pi r^{2.5}$$

As soon as the electron jumps out of its orbit, r changes, so the strength of this magnetic field changes. And a change of a magnetic field causes a change of an electric field.

A source of an electro-magnetic wave has been created!

The purpose of this analysis is to investigate whether this idea makes sense or not in relation to the available information about photons.

IV The kinetic and potential energy of an orbiting electron

The phenomenon potential energy is fully eliminated in an orbiting system by the fact that the centripetal and centrifugal forces, resulting from a perfect circular orbiting electron, are continuously in balance with each other. The only phenomenon that really contains energy therefore is its kinetic energy.
The kinetic energy E_k of an orbiting electron equals $½mv^2$. This type of energy is, as the expression shows, by definition positive. Incorporating potential energy leads to the most absurd statements regarding the energy levels in an atom, as shown in [1].
The wrong words have been scratched out and the correct ones have been written behind them in italics.

> **Orbital energy**
> In atoms with a single electron (hydrogen-like atoms), the energy of an orbital (and, consequently, of any electrons in the orbital) is determined exclusively by n. The n=1 orbital has the ~~lowest~~ *highest* possible energy in the atom. Each successively higher value of n has a ~~higher~~ *lower* level of energy, but the difference decreases as n increases. For high n, the level of energy becomes so ~~high~~ *low* that the electron can easily escape from the atom.

From $E_k = ½mv^2$, with $v^2 = \kappa Zq^2/mr$, it follows that $E_k = ½\kappa Zq^2/r$, emphasizing the conclusion that the smaller the orbit, the higher the energy state of the atom.

V Background of the Rydberg expression

Citations from Wikipedia:

> *"The Planck constant h has been introduced to express the relation between frequency f and energy E for a light quantum (photon) as: E=hf."*
>
> *"The Planck constant was first described as the proportionality constant between the energy (E) of a photon and the frequency (f) of its associated electromagnetic wave."*

The formula E=hf is a non-physical equation, because it suggests that the energy of a photon is proportional to the frequency of its "associated electromagnetic wave". It is well known that this can, physically speaking, not be true. Only the amplitude of the electro-magnetic wave can be related to its power, thus to its energy. Apparently *measurements* have shown this relation between the frequency and the amplitude of its associated electro-magnetic wave, including the duration of the photon.

It is generally accepted that the orbits of an electron are discrete. However, up to now nothing in Bohr's model forces us to such a hypothesis. For whatever radius r, the balance between the Coulomb and the centrifugal force is, by definition, perfect. That would also mean that in principle an arbitrary small orbit radius would be possible. Chapter IV shows that the total energy of the orbiting electron would increase to infinite if the radius of the orbit would decrease to zero. This will not happen because an external source with an infinite energy would be necessary to reach such a situation.
But still the question why an electron is only orbiting at discrete distances to the nucleus is not answered.

The discrete radii are mathematically represented by $r_n = n^2 a_0/Z$, with n is an integer.
The radius a_0 is the so-called Bohr's radius, the smallest in the neutral hydrogen atom.

The mathematical expression for a_0 is found as follows.

The idea behind the quantitative presentation of the discrete radii is based on the assumption, for whatever reason, that the angular momentum mvr_n of the electron is quantized, expressed as:

$mvr_n = nh/2\pi$ so: $mv^2r_n = (nh/2\pi)v$ and $v = (nh/2\pi)/mr_n$

From $F_{cf} = mv^2/r_n = F_C = \kappa Zq^2/r_n^2$ it follows that:

$mv^2r_n = \kappa Zq^2$ also equal to $(nh/2\pi)v$

Given $v = (nh/2\pi)/mr_n$ it follows that :

$\kappa Zq^2 = (nh/2\pi)^2/mr_n$ so:

$r_n = n^2h^2/(4\pi^2\kappa Zq^2m)$

r_n is defined as a_0 for n=1 and Z=1, so:

$a_0 = h^2/(4\pi^2\kappa q^2m)$

The *positive* difference in kinetic energy of the electron orbiting in n_1 respectively n_2, is represented by:

$\Delta E_{kn} = ½m(v_1^2 - v_2^2)$, with: $v_i^2 = \kappa Zq^2/mr_{ni}$ resulting in:

$\Delta E_{kn} = (\kappa Zq^2/2) \cdot (1/r_{n1} - 1/r_{n2}) = (\kappa Zq^2/2a_0/Z) \cdot (1/n_1^2 - 1/n_2^2)$

Applying the expression for a_0:

$\Delta E_{kn} = \{\kappa Z^2q^2/(2h^2/(4\pi^2\kappa q^2m))\} \cdot (1/n_1^2 - 1/n_2^2)$

$\Delta E_{kn} = h^{-2}\, \kappa^2Z^2q^4 2\pi^2m \cdot (1/n_1^2 - 1/n_2^2)$ $\kappa = 1/4\pi\varepsilon_0$ so:

$\Delta E_{kn} = Z^2mq^4\, 2\pi^2/(h^2 \cdot 4\pi\varepsilon_0 \cdot 4\pi\varepsilon_0) \cdot (1/n_1^2 - 1/n_2^2)$

$\Delta E_{kn} = h \cdot c \cdot Z^2mq^4/(8\varepsilon_0^2h^3c) \cdot (1/n_1^2 - 1/n_2^2)$

$\Delta E_{kn} = h \cdot c \cdot Z^2mq^4/(8\varepsilon_0^2h^3c) \cdot (1/n_1^2 - 1/n_2^2) = h \cdot c \cdot Z^2 \cdot R(1/n_1^2 - 1/n_2^2)$

With $R = mq^4/8\varepsilon_0^2h^3c$, being the so called Rydberg constant, with the following values:

m	mass of the electron	$9.1 \cdot 10^{-31}$	kg
q	electric charge of the electron	$1.6 \cdot 10^{-19}$	C
ε_0	dielectric permittivity	$8.854 \cdot 10^{-12}$	As/Vm
h	Planck's constant	$6.626 \cdot 10^{-34}$	VAs^2
c	velocity of light in vacuum	$2.999 \cdot 10^8$	m/s
R	Rydberg's constant	$1.097 \cdot 10^7$	m^{-1}

For Z=1 the result is the well known expression:

$1/\lambda = R(1/n_1^2 - 1/n_2^2)$

Because

$c/\lambda = f$ it follows that for Z =1:

$f = c \cdot R(1/n_1^2 - 1/n_2^2) = \Delta E_{kn}/h$ leading to the expression for arbitrary Z:

$\Delta E_{kn} = hf = h \cdot c \cdot Z^2 \cdot R(1/n_1^2 - 1/n_2^2)$

N.B. The restriction of this equation is that it is only valid for orbits with radius $r_n = n^2 a_0/Z$!

This loss of *mechanical* energy cannot directly be converted into the energy of the EM-wave of the photon. This is solved by the fact that the orbiting electron creates a magnetic field. The change of this field directly causes the generation of this EM-wave. So a decrease of the kinetic energy is converted directly into a decrease of the magnetic energy, representative for the power of the EM-wave, multiplied by the time during which this wave is emitted, called the pulse width of the photon.

VI Calculation of the pulse width of the photon

Given the basic idea behind the generation of a photon as described in the previous chapter, the magnetic and electric fields A_H and A_E of the emitted EM-field will be described by a sinusoidal shaped function: $A_H(t) = A_H\cos(\omega t)$ resp. $A_E(t) = A_E\cos(\omega t)$, with $A_E = Z_v A_H$ and Z_v the so called characteristic impedance for vacuum. $Z_v = (\mu_0/\varepsilon_0)^{½} = 377\ \Omega$.

The power density of the related EM-field is: $P_d = A_E/\sqrt{2}\cdot A_H/\sqrt{2} = Z_vA_H^2/2$ VA/m²

The generation of this EM-field will stop at the moment the electron orbits at a larger radius with the related and required velocity. The time between the start and the end of this process will be called the pulse width, so in terms of seconds. This name originally comes from the radar technic, where such a pulse is generated with mutually independent power, pulse duration and frequency. The equation E = hf thus is certainly not applicable in such a situation. In order to get a first impression of the pulse width of the photon the situation will be considered that the orbiting electron jumps out of the smallest orbit r_1 in a ^1_1H atom to an orbit which a much larger radius, or out of the atom. In such a situation the amplitude A_H equals the static magnetic field strength as shown in chapter III: $H_{i(nitial)} = q^2(\kappa/m)^{½}/4\pi r_1^{2.5}$, because the only cause of this field is the only electron orbiting the proton in the atom's nucleus. So, after such a jump no static magnetic field at all is left in the atom. This approach has lead to the description of $A_H(t)$ as $A_H\cos(\omega t)$, instead of $A_H(t) = A_H\sin(\omega t)$, but is further not of any importance.
The final result is an EM-field that propagates with velocity ***c, relative to the atom***.

N.B. ***Not relative to whatever reference, as the Special Theory of Relativity claims!***

It is assumed that the surface, related to this power density, is constrained by the orbit of the electron from which it jumps, so, equating A_H with H_i, the power P of the photon is:

$$P = (Z_vq^4\kappa/32\pi m)\cdot r_1^{-3} \quad \text{W}$$

This power multiplied by the length of the photon in seconds, from now on called pulse width, abbreviated as plsw, also results in an expression for the EM energy of the photon.

$$E_{EM} = \text{plsw}\cdot(Z_vq^4\kappa/32\pi m)\cdot r_1^{-3} \quad \text{Joule}$$

This energy equals the kinetic energy $E_{kin} = ½mv_1^2$, with $v_1^2 = q^2\kappa/mr_1$

So the pulse width follows from $E_{EM} = E_{kin}$ $\quad \text{plsw} = 16\pi mq^{-2}Z_v^{-1}\cdot r^2$ s

In the general situation an electron jumps from orbit r_i to r_j in an atom with atomic number Z.
In such an atom holds: $v_i^2 = q^2\kappa Z/mr_i$.

The related power of the EM-field *decreases* from

$$(Z_vq^4\kappa/32\pi m)\cdot r_i^{-3}$$

to

$$(Z_vq^4\kappa/32\pi m)\cdot r_j^{-3}$$

so Δ power of the EM field is

$$\Delta P = (Z_vq^4\kappa Z/32\pi m)\cdot(r_i^{-3} - r_j^{-3})$$

$$\Delta P = (Z_vq^4\kappa Z^4/32\pi ma_0^3)\cdot(n_i^{-6} - n_j^{-6})$$

Δ energy of the photon is

$$\Delta E = \text{plsw}\cdot\Delta P$$

Δ energy equals the Δ kinetic energy $\Delta E = ½q^2\kappa Z\cdot(r_i^{-1}–r_j^{-1})$

$\Delta E = ½q^2\kappa Z^2/a_0\cdot(n_i^{-2}–n_j^{-2})$

As a result: $plsw = 16\pi mq^{-2}Z_v^{-1}\cdot(r_i^{-1}–r_j^{-1})/(r_i^{-3}–r_j^{-3})$ s

$plsw = 16\pi mq^{-2}Z_v^{-1}(a_0/Z)^2\cdot(n_i^{-2}–n_j^{-2})/(n_i^{-6}–n_j^{-6})$

An interesting variable is plsw/T, with T the period time of the frequency of the EM-field, so 1/f. The variable shows the number of periods in a photon. T can also be written as h/ΔE, given ΔE = hf, so the expression for T, following from ΔE, is:

$T = (2h/q^2\kappa Z)\cdot r_ir_j/(r_j–r_i)$

$T = (2ha_0/q^2\kappa Z^2)\cdot n^2_in^2_j/(n^2_j - n^2_i)$

$plsw/T = 8\pi m(hZ_v)^{-1}\kappa(r_j-r_i)^2/\{r_i^2r_j^2(r_i^{-3}-r_i^{-3})\}$

$plsw/T = 8\pi m(hZ_v)^{-1}\kappa a_0(n_i^{-2}-n_j^{-2})^2/(n_i^{-6}-n_j^{-6})$

The expressions in n_i and n_j are obtained by applying $r_n = n^2a_0/Z$.

The expression for plsw/T shows that it is only dependent of the number of the orbit from where the electron jumps to the number of the orbit where it arrives *and independent of Z*!
See the Table below. A surprising result is that the higher the frequency, the fewer of these periods exist in the pulse.

	Z = 1		Z = 74		Z = 118		
n	f	plsw	f	plsw	f	plsw	plsw/T
1	3,3E+15	1,3E-14	1,8E+19	1,3E-14	4,6E+19	1,3E-14	44
2	2,5E+15	1,0E-14	1,4E+19	1,8E-18	3,4E+19	7,3E-19	25
3	4,6E+14	1,3E-13	2,5E+18	2,4E-17	6,4E+18	9,3E-18	59
4	1,6E+14	5,7E-13	8,8E+17	1,0E-16	2,2E+18	4,1E-17	91
5	7,4E+13	1,7E-12	4,1E+17	3,0E-16	1,0E+18	1,2E-16	123
6	4,0E+13	3,8E-12	2,2E+17	7,0E-16	5,6E+17	2,7E-16	153
7	2,4E+13	7,6E-12	1,3E+17	1,4E-15	3,4E+17	5,4E-16	183
8	1,6E+13	1,4E-11	8,6E+16	2,5E-15	2,2E+17	9,7E-16	213
9	1,1E+13	2,2E-11	5,9E+16	4,1E-15	1,5E+17	1,6E-15	243
10	7,7E+12	3,5E-11	4,2E+16	6,4E-15	1,1E+17	2,5E-15	272

Table 1: Frequencies and pulse widths as function of n and Z and plsw/T as function of n

Röntgen/X radiation, produced by Tungsten (Z =74), shows frequencies from 10^{16} to 10^{19} Hz. Copied from [4]: *" X-radiation is a penetrating form of high-energy electromagnetic radiation. ....Most X-rays show frequencies in the range 3×10^{16} Hz to 3×10^{19} Hz"*

If $n_j >> n_i$: $plsw/T = 8\pi m(hZ_v)^{-1}\kappa a_0n_i^2$

For all smallest radii $n_i = 1$, so $plsw/T = 8\pi m(hZ_v)^{-1}\kappa a_0$

The blue values in Table 1 are related to the last mentioned situation and play a crucial role in the alternative model of the neutron, emitting so-called nuclear photons, described in [5].

Conclusions

The study has proven that the generation of a photon can be explained by considering an orbiting electron in an atom as a circular electric current.
This current causes a magnetic field, perpendicular to the plane of the orbit and enclosed by the orbit of the electron.
As soon as the electron jumps to a more outer orbit, this magnetic field decreases rapidly and causes through this an electric field. A source of an EM filed has been created.

Calculations, carried out on this model, proved that this principle indeed works, but above all it also shows the mathematical expression for the length, expressed in seconds, of the photon.

The model confirms that the energy of the photon equals the kinetic energy of the electron in the orbit where it came from, minus this kinetic energy in the orbit where it jumped to, but this difference in kinetic energy is not the source of the energy of the photon.

The model shows that the source of the energy of the photon is the magnetic energy of the atom as created by the orbiting electron(s).

At the end of the day it has to be concluded that this model eliminates the wave-particle duality: no whatever (magic) particle plays whatever role in this model.

Einstein wrote about this duality the following;
"*It seems as though we must use sometimes the one theory and sometimes the other, while at times we may use either. We are faced with a new kind of difficulty. We have two contradictory pictures of reality; separately neither of them fully explains the phenomena of light, but together they do*".

My words:
Nature doesn't deal with dualities, paradoxes or contradictions.
Judgments like these are created by mankind, not understanding a certain phenomenon.
Physical science should not accept these kinds of judgements.

References

[1] http://en.wikipedia.org/wiki/Atomic_orbital
[2] Conventional Definition of Potential Energy is Controversial http://vixra.org/abs/1709.0440
[3] Einstein's and Galilei's Principle of Relativity http://vixra.org/abs/1611.0111
[4] https://en.wikipedia.org/wiki/X-ray
[5] Atomic Nuclei Modelled Without Exotic Particles and Magic Forces https://vixra.org/abs/1803.0036