Why a photon is not a particle

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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). The model is verified inclusive Röntgen radiation.

1. Introduction
Considering a photon as an (extremely) short pulse with an electro-magnetic wave as carrier, eliminates the so-called wave-particle duality. This 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. Using the Rydberg formula and the assumed energy E=hf, the expected pulse lengths and their related EM-powers are presented.

2. 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?

3. 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.
- the centripetal gravitational force between nucleus and electron
- the centripetal Coulomb force between nucleus and electron

with:
- \( r \) radius of the orbit of the electron
- \( m \) mass of the electron: \( 9.1 \times 10^{-31} \) kg
- \( v \) velocity of the electron along its orbit: \( m/s \)
- \( Z \) atom number
- \( m_p \) mass of proton: \( 1.7 \times 10^{-27} \) kg
- \( m_n \) mass of the nucleus: \( 2Zm_p \) kg
- \( G \) gravitational constant: \( 6.7 \times 10^{-11} \) Nm²kg⁻²
- \( k_e \) Coulomb’s constant: \( 1/4\pi\varepsilon_0 \): \( 8.99 \times 10^9 \) Nm²C⁻²
- \( q \) electric charge of the electron: \( 1.6 \times 10^{-19} \) C

The mathematical descriptions of the mentioned forces are:
- Centrifugal force: \( F_{cf} = mv^2/r \)
- Gravitational force: \( F_G = Gm_pm/r^2 \)
- Coulomb force: \( F_C = k_eZq^2/r^2 \)
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.
- $F_G \sim 10^{-67}/r^2$ and $F_C \sim 10^{-28}/r^2$, with as expected result that $F_G$ is incomparably small compared to $F_C$.

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: $mv^2/r = k_eeq^2/r^2$

from which it follows that:

$v = (k_eeq^2/mr)^{1/2}$

4. 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.

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:*

$$H = i/2r = qv/4\pi r^2 = q^2(k_eeZ/m)^{1/2}/4\pi r^{2.5}$$

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.

The magnetic field is usually symbolically presented as *one straight line* through the centre of the circular shaped electrical current. In reality the magnetic field consists of an infinite number of bowed lines forming a closed field.

The importance of this statement will show up in: 8. Origin of the energy of the photon
5. **The kinetic and potential energy of an orbiting electron**

The kinetic energy $E_k$ of an orbiting electron equals $\frac{1}{2}mv^2$.

This type of energy is, as the expression shows, by definition positive.

Regarding the potential energy the discrepancy between its positive versus negative value is remarkable, leading to for example the most absurd statements as shown in [1].

**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 possible energy in the atom. Each successively higher value of $n$ has a lower level of energy, but the difference decreases as $n$ increases. For high $n$, the level of energy becomes so high that the electron can easily escape from the atom.

The wrong words have been scratched out and the correct ones have been written behind them in italics.

See [2] for an extensive explanation of the background of these corrections.

A much more important conclusion is that the phenomenon potential energy does not play any role in an orbiting system. The background for this remark is the following. The centripetal and centrifugal forces, applied to the orbiting electron, are fully and continuously in balance due to the perfect circular orbit. The only phenomenon that really contains energy is its kinetic energy. This kinetic energy causes that the potential energy of the atom is not relevant anymore in the changes of energy state of the atom.

From now on only the kinetic energy $E_k = \frac{1}{2}mv^2$ of the electron is taken into account in the following considerations.

Applying the above found expression $v^2 = k_eZq^2/mr$ in $E_k$ results in: $E_k = \frac{1}{2}k_eZq^2/r$.

This expression emphasizes the conclusion that the smaller the orbit, the higher the energy state of the atom.

6. **The law of conservation of energy**

In physics, the law of conservation of energy states that the total energy of an isolated system remains constant, with isolated system defined as “a system so far removed from other systems that it does not interact with them”.

As just shown above a gravitational orbiting system looses energy when the orbit increases and the other way round. In both cases external energy has to be supplied in order to achieve either situation. In first instance this looks like the law of conservation of energy is violated.

However, where the original system was an isolated system, an external force coming from a sufficiently far distance, eventually changes the system under consideration. This makes it complicated to prove that the law of conservation of energy in such an example is not violated. But the end result is not questionable.

The next chapters show that this problem is a bit more intricate in case of the generation of a photon.
7. **Background of the Rydberg expression**

Citation 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.” Another description shows: “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 carrier. It is well known that this cannot be true. Only the amplitude of the electromagnetic wave can be related to its power, thus to its energy, of the photon. Seemingly there is a measured relation between the frequency of the carrier and amplitude (and/or length) of a 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. The alternative (common sense) definition of potential energy shows that the total energy of the orbiting electron would increase to infinite if the radius of the orbit would decrease to zero. Therefore an orbiting electron cannot melt together with a proton to a neutron in the nucleus of the atom. So the question why an electron is only orbiting at discrete distances to the nucleus is still 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 \( mv r_n \) of the electron is quantized, expressed as:

\[
mv r_n = \frac{nh}{2\pi}
\]

so:

\[
mv^2 r_n = (nh/2\pi)v \quad \text{and} \quad v = (nh/2\pi)/mr_n
\]

From \( F_{cf} = mv^2/r_n = F_C = k_e Z q^2 / r_n^2 \) it follows that:

\[
 mv^2 r_n = k_e Z q^2
\]

also equal to \((nh/2\pi)v\)

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

\[
k_e Z q^2 = (nh/2\pi)^2/mr_n
\]

so:

\[
r_n = n^2 h^2 / (4\pi^2 k_e Z q^2 m)
\]

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

\[
a_0 = h^2 / (4\pi^2 k_e q^2 m)
\]
The positive difference in kinetic energy of the electron orbiting in $n_1$ respectively $n_2$, is represented by:

$$\Delta E_{kn} = \frac{1}{2} m (v_1^2 - v_2^2), \text{ with: } v_i^2 = \frac{k_e Z q^2}{m r_{ni}}$$

resulting in:

$$\Delta E_{kn} = (k_e Z q^2 / 2)^* (1/r_{n1} - 1/r_{n2}) = (k_e Z q^2 / 2a_0 / Z)^* (1/n_1^2 - 1/n_2^2)$$

Applying the expression for $a_0$:

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

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

$$k_e = 1 / 4\pi \varepsilon_0$$

so:

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

The Rydberg expression is:

$$\frac{1}{\lambda} = R_{\infty} \left( \frac{1}{n_1^2} - \frac{1}{n_2^2} \right)$$

with the following parameters:

| $\lambda$ | wavelength of the carrier | m |
| $R_{\infty}$ | Rydberg’s constant | (Z$^2$mq$^4$)/(8$\varepsilon_0$hm$^3$c) | 1.097$\times$10$^7$ | m$^{-1}$ |
| $h$ | Planck’s constant | 6.626$\times$10$^{-34}$ | kg m$^2$ s$^{-1}$ |
| $\varepsilon_0$ | dielectric permittivity | 8.854$\times$10$^{-12}$ | A$^2$ s$^4$ kg$^{-1}$ m$^{-3}$ |
| $\mu_0$ | magnetic permeability | 4$\pi$$\times$10$^{-7}$ | NA$^2$ |
| $c$ | velocity of light in vacuum | 2.999$\times$10$^8$ | m/s |

With: $hc/\lambda = hf$:

$$hf = hc \times R_{\infty} \left( \frac{1}{n_1^2} - \frac{1}{n_2^2} \right)$$

So, indeed, the energy of an emitted photon equals the change in kinetic energy of the orbiting electron. However that is not the complete story about the energy balance between the atom and its environment.

In a pure gravitational orbital configuration the loss of energy is restricted to $\Delta E_k$ consisting of only mechanical energy.

In the orbital configuration under consideration this loss of mechanical energy also equals $\Delta E_k$. But the atom seemingly also loses $\Delta E_k$ due to the emitted photon.

The question thus is: which source in the atom decreased its level of energy by the amount $\Delta E_k$ that equals the energy of the photon? The answer most likely has to be found in the consideration presented in the next chapter.
8. Origin of the energy of the photon

The only source of energy in an atom, excluded the mechanical one, can be the energy of the magnetic field inside the atom. As claimed before, this magnetic field is the result of the orbiting electron, to be considered as an equivalent electrical current.

The magnetic field strength in the centre of the orbit is proportional to \( r^{-2.5} \). So this field decreases significantly with the radius of the orbit. It is therefore most unlikely that the magnetic energy would not decrease with this radius. Given the fact that a photon is created while an electron jumps to an outer orbit, it is therefore most unlikely that the energy of the photon would not be delivered by the magnetic energy.

Presenting the decrease of the magnetic energy by \( \Delta E_H \) the next conclusion must be that \( \Delta E_H = \Delta E_k \); because it has just been proven that the energy of the photon \( E = hf = \Delta E_k \) and because there is no other energy source available inside the atom, as just mentioned.

In order to prove mathematically that \( \Delta E_H = \Delta E_k \), the energy of the magnetic field in the atom has to be expressed in the parameters of the atom. The figure below shows the complexity of this problem.

The figure shows the magnetic field of the Earth. If the equator shown here is imagined as the orbit of an electron, then the figure also shows the magnetic field created by such an equivalent current. The energy of the related magnetic field is the volume integral over the hemisphere of the square of the magnetic field strength multiplied by \( \mu_0 \) at “each” point inside this hemisphere: \( E_H = \mu_0 \int_V H^2 dV \).

In principle it is possible to express \( E_H \) in terms of the parameters ‘equivalent current’ at radius \( r \), given one electron orbiting its nucleus. The challenge to deliver this expression for \( E_H \) has been postponed, because logical argumentation shows that \( E_{Hni} = E_{kni} \). (\( ni \) has to interpreted as \( n_i \))

As has just been argued \( \Delta E_H = \Delta E_k \) for whichever emitted photon. Such a result can only be obtained if \( E_{Hni} = C + E_{kni} \). Due to the fact that \( E_{Hni} \) equals 0 if \( E_{kni} = 0 \), \( C \) must be zero, q.e.d.

Having proven that the energy of a photon is directly delivered by the magnetic energy of the atom, it is now is clear why a photon will not be created in case an electron jumps to an inner orbit.

The next chapter makes it plausible too that the energy of a photon is delivered by the magnetic energy of the atom.
9. Further elaboration of the model

The basic idea behind the generation of a photon is that an orbiting electron is equivalent to a circular shaped electric current. Such an electric current causes a magnetic field \( H \), with \( H = \frac{q^2(k_eZ/m)^{\frac{3}{2}}}{4\pi r^{2.5}} \), perpendicular to the plane through the orbit of the electron.

So, as soon as the electron jumps out of its orbit, \( r \) changes and the strength of this magnetic field changes. A change of a magnetic field causes a change of an electric field, resulting in an EM-field, propagating with velocity \( c \) relative to the nucleus of the atom.

**Step 1: The jump of an electron from \( n=1 \) to \( n=2 \) in the neutral hydrogen atom**

The value of \( Z \) of this atom is 1.

The two radii therefor are: \( r_1 = a_0 = 5.29 \times 10^{-11} \) m and \( r_2 = 2.12 \times 10^{-10} \) m.

The magnetic field strengths related to the two equivalent electric currents are calculated as follows:

\[
\begin{align*}
 v &= q(k_e/mr) \frac{3}{2} \\
 v_1 &= 2.19 \times 10^6 \\
 v_2 &= 1.09 \times 10^6 \\
 t_o &= 2\pi r/v \\
 t_{o1} &= 1.52 \times 10^{-16} \\
 t_{o2} &= 1.22 \times 10^{-15} \\
 i &= q/t_o \\
 i_1 &= 1.05 \times 10^{-3} \\
 i_2 &= 1.32 \times 10^{-4} \\
 H &= i/2r \\
 H_1 &= 9.97 \times 10^6 \\
 H_2 &= 3.11 \times 10^5
\end{align*}
\]

The amplitude of the sinusoidal shaped magnetic field of the carrier of the photon will be represented by \( A_{H} \), like \( A_{E} \) will be the amplitude of its sinusoidal electric field.

The relation between \( A_{H} \) and \( A_{E} \) is:

\[
A_{E} = Z_v A_{H} \quad \text{V/m}
\]

where \( Z_v \) is the so called characteristic impedance for vacuum.

\[
Z_v = (\mu_0/\varepsilon_0)^{\frac{1}{2}} = 377 \quad \Omega
\]

Based on these two amplitudes the power density of the EM-field is:

\[
P_d = A_{E}/\sqrt{2} \cdot A_{H}/\sqrt{2} = Z_v A_{H}^2/2 \quad \text{VA/m}^2
\]

It is assumed that the surface, related to this power density, is constrained by the orbit of the electron from which it jumps, so the power \( P \) of the photon in this example is:

\[
P = Z_v A_{H}^2/2 \cdot \pi r_1^2 \quad \text{W}
\]

This assumption will be argued under: “Intermediate conclusions regarding step 1”

In order to be able to calculate the energy of the photon, with the model under consideration, this power has to be multiplied with the length of the photon.

This length will be represented by the name pulse width, abbreviated as \( \text{plsw} \).

In this sense the calculated energy of the photon is mathematically represented by:

\[
E_e = \text{plsw} \cdot Z_v A_{H}^2/2 \cdot \pi r_1^2 \quad \text{Joule}
\]

Both the parameters \( \text{plsw} \) and \( A_{H} \) are yet unknown.
10. Estimation of the pulse width of the photon

It is assumed that the minimum value of the pulse width is one period of the carrier of the photon, because if it would be less it is difficult to imagine that it would be possible to find the energy of the photon to be $E = hf$. The maximum value is certainly constrained by the round trip time of the orbit to which the electron has been jumped, because after that time period the magnetic field is completely stabilized. Applying the Rydberg expression $f$ in this example is calculated as:

$$f = \frac{c}{\lambda} = 2.999 \times 10^8 \times 1.097 \times 10^7 (1-1/4) = 2.47 \times 10^{15}$$, resulting in $T = 4.05 \times 10^{-16}$

So $4.05 \times 10^{-16} < \text{plsw} < 12.2 \times 10^{-16}$ s

The estimation for the pulse width in this example is that it equals 2 times a period of the carrier: $8.1 \times 10^{-16}$ s. It is considered unlikely that the carrier stops abruptly at an arbitrary moment within such a period.

The power density of the photon in this example can now be calculated as:

$$P_d = \frac{hf}{(\text{plsw} \pi r_1^2)} = 6.626 \times 10^{-34} \times 2.47 \times 10^{15} / (8 \times 10^{-16} \times \pi \times (0.53 \times 10^{-10})^2)$$

$$P_d = 2.29 \times 10^{17}$$ W/m$^2$

So: $Z_v A_H^2 / 2 = 2.29 \times 10^{17}$ W/m$^2$

Resulting in:

$$A_H = 3.49 \times 10^7$$ A/m

N.B.
This magnetic field strength is of the same order of magnitude as the field strength $H_1$!

In order to obtain more reliance (or maybe not) in the validity of the model, the variable $dH/dt$, at the moment of the jump, is analysed. It is assumed that $dH/dt$ has its maximum value at the moment the electron jumps. At a certain moment the magnetic field strength $H(t)$, belonging to the EM field that will be generated, can be represented by: $H(t) = A_H \sin(\omega t)$ and the next assumption is that this sinusoidal function starts also at the moment the electron jumps. So, the maximum value of $dH/dt$ is assumed to be at $t=0$. This maximum value thus is represented mathematically by $A_H \omega$, with $\omega$ the radial frequency of the carrier of the photon.

The first approximation of $dH/dt$ is $\Delta H / \Delta t$, with $\Delta H = H_1 - H_2$ and $\Delta t$ a yet to find appropriate value.

$$A_H \omega = A_H \times 2 \pi f = 3.49 \times 10^7 \times 2 \pi \times 2.47 \times 10^{15} = 5.41 \times 10^{23}$$ A/ms

Applying $\Delta H = H_1 - H_2 = 9.65 \times 10^6$, leads to $\Delta t = 9.65 \times 10^6 / 5.41 \times 10^{23} = 1.78 \times 10^{-17}$ s
This value for $\Delta t$ is an order of magnitude smaller than the round trip time of the orbit from which the electron jumps. That doesn’t feel unrealistic and it means that the magnetic field $H_1$, created by the equivalent electric current due to the circular movement of the electron, instantly decreases to a negligible value, compared to this initial field, because $H_2 \ll H_1$.

Intermediate conclusions regarding step 1

The model applied to the neutral hydrogen atom where an electron jumps from the most inner orbit $(n=1)$ to the next outer orbit $(n=2)$, learns that:

- The energy of the emitted photon, expressed as $E=hf$, exactly equals the difference between the kinetic energy of the electron in the inner orbit minus this energy in the outer orbit.
- The length of the photon has to be at least one period of the frequency of its carrier and will certainly be not longer than 3 of these periods.
- Dividing the energy of the photon by the length of the photon the power $[\text{VA}]$ of the photon is found. To find a value for the strength of the magnetic, resp. electric field, of the carrier of the photon, $[\text{A/m}]$ resp. $[\text{V/m}]$, this power has to be divided by the surface to which it belongs. Up to this moment all variables were found to be strongly related to the orbit from where the electron jumps, so the most likely surface is assumed to be the surface of the orbit from where the electron jumps: $\pi r_1^2$ in this example.
- Application of these variables shows that the magnetic field strengths of the EM carrier of the photon varies from $4.94 \times 10^7 \ \text{A/m}$ all three of the same order of magnitude as the linear magnetic field strength, generated by the orbiting electron in orbit $n=1$: $7 \times 10^7 \ \text{A/m}$.
- These conclusions justify analyses of other photon emissions, based on the model under consideration.

Step 2: The jump of an electron from $n=1$ to $n=n_2$ in the neutral hydrogen atom

In step 1 it is assumed that the length of the photon is two times the period of its carrier, also based on the assumption that it will certainly not be longer than $t_{o2}$. In this step the round trip time $t_{on}$, with $n \geq 3$, will be much larger than $t_{o2}$. Notwithstanding that feature plsw will, as a first estimate, be taken two times the period independent of $n_2$.

The frequency of the carrier is calculated by means of the Rydberg expression, resulting in as well the length of the photon as $2/t$, as in its energy $E=hf$.

The power of the photon now equals $hf/plsw \ (= \frac{1}{2}hf^2)$.

This result divided by the surface $\pi r_1^2$ equals the power density of the photon.

The magnetic field strength $A_H$ is calculated from: $A_H = (2P_d / Z_0)\frac{\%}{\%}$ and $\Delta t$ from: $\Delta t = \Delta H/(A_H \omega)$. This last calculation learned that $\Delta H$ has to be interpreted as: $\Delta H = H_{n1} - H_{n2}$ and not as $H_{n1}$ notwithstanding the fact that $H_{n2} \ll H_{n1}$.

The relatively small error in the calculation of $E_c$ for $n_2 \geq 3$, in case $\Delta H$ is chosen to be $H_{n1}$, is completely eliminated for $\Delta H = H_{n1} - H_{n2}$.
Effectively this remarkable result has been found in step 3, due to the fact that the error in $E_c$ grew explosively to > 100% in the Brackett series.

The importance of the correct calculation of $\Delta t$ will be shown later.

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<td>4.61E+07</td>
<td>1.05E-17</td>
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</table>

Intermediate conclusions regarding step 2

-The presented values don’t show any abnormality, as could be expected, because only the orbit to which the electron jumps has been changed, while the orbit from where it jumped proved to be the most important parameter for the quantification of the variables (see step 1).

- $\Delta H$ in the expression $\Delta t = \Delta H/(A_H \cdot \omega)$, has explicitly to be interpreted as: 
  $\Delta H = H_{n_1} - H_{n_2}$ and not as: $\Delta H = H_{n_1}$.

- The results of the calculations justify analyses of other photon emissions, based on the model under consideration.

Step 3: The jump of an electron from $n=n_1$ to $n=n_2$ in the neutral hydrogen atom

The related frequencies to these jumps, as mathematically presented by the Rydberg formula, have been measured by and named after the shown scientists.

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<th>$n_1$</th>
<th>$n_2$</th>
<th>Name series</th>
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<th>wave length $n_2 \rightarrow \infty$</th>
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<tr>
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<td>Pfund</td>
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<td>2278.61*10⁻⁹</td>
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<tr>
<td>6</td>
<td>7 → ∞</td>
<td>Humphreys</td>
<td>12363.5*10⁻⁹</td>
<td>3280.12*10⁻⁹</td>
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</table>

The table shows that the **Lyman series** has been analysed under step 2

For all series the relation $hf = \frac{1}{2}m(v_{n_1}^2 - v_{n_2}^2)$ has been checked and found to be valid.
The most important conclusion is that the magnetic fields $A_{n(n+1)}$, relative to the magnetic field generated by the orbit of the electron from where it jumps, increase from a factor 3 to about a factor 7, along the series, if $plsw = 2/f$.

If $plsw$ is taken $(n_1+1)/f$, this ratio varies over all series from 3.5 to 4.3.

If it is taken $(n_1+2)/f$ this range becomes 2.9 to 3.9.

For all three values of $plsw$ the absolute value of $A_{n(n+2)}$, within each series, shows, as function of $n_2$, an increase varying from 1.3 in the Lyman series up to 2.7 in the Humphreys series.

Based on this information it is considered more likely that $plsw \approx (n_1+1)/f$. The model under investigation doesn't give a decisive answer. Only measurements of the length of the photon will give it.

For all series the same table as presented under step 2 has been calculated and shown in the Appendix Series. N.B. The pulse width in these calculations is $(n_1+1)/f$.

**Final step: The jump of an electron from $n=n_1$ to $n=n_2$ in an arbitrary ion**

An arbitrary ion in this study is meant to be a nucleus with $Z$ protons around which one electron is orbiting.

The only basic parameters that change in such a situation are the radii of the orbits, because these are represented by $r_n = n^2 a_0/Z$.

So, in fact nothing changes fundamentally, by altering the value of $Z$.

The Excel spread sheets (not included in this article), that have been used for the calculations for the series mentioned under step 3, indeed don't show any abnormalities by changing $Z$.

As an example: the length of the photon for $n_1=1$ and $n_2=2$ is $\approx 0.01$ femtosecond for $Z=9$, while for $Z=1$ this length is $\approx 1$ femtosecond.

### 11. Röntgen radiation

Röntgen radiation is EM radiation with frequencies in the range $10^{16} - 10^{20}$ Hz. It is generated in a (X-ray) tube in which electrons are accelerated between their source (cathode) and an anode.

The most direct and simple way to calculate the frequency of the emitted radiation is the application of the Rydberg equation: $f = c/\lambda = c/R_\infty (1/n_i^2 - 1/n_f^2)$.

The table below shows possible emitted frequencies in case of a tungsten anode ($Z=74$).

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12. The characteristics of the photon expressed mathematically

In order to understand in detail how a photon looks like, the calculation of the energy is build up by four characteristics of the pulse: frequency, length, power density and surface related to this power density:

\[ E_c = Z_v A_H^2 / 2 \pi r_{1n}^2 * \text{plsw}(f) \]

With \( A_H = (\Delta H/\Delta t) / 2\pi f \) and \( \text{plsw} = (n_1+1)/f \) this can also be written as:

\[ E_c = \{ Z_v \Delta H^2 \Delta t^{-2} (2\pi f)^{-2} \} / 2 \pi r_{1n}^2 * (n_1+1)/f \]

The analyses described under step 2 and 3 proved that \( \Delta H = H_{n1} - H_{n2} \), from now on presented as \( \Delta H_{n1,n2} \). \( \Delta t \) will be presented as \( \Delta t_{n1,n2} \), \( f \) as \( f_{n1,n2} \) and \( r_1 \) as \( r_{n1} \).

As a result \( E_c \) will be presented as \( E_{n1,n2} \) and can be written as:

\[ E_{n1,n2} = \{ Z_v \Delta H_{n1,n2}^2 \Delta t_{n1,n2}^{-2} (2\pi f_{n1,n2})^{-2} \} / 2 \pi r_{n1}^2 * (n_1+1)/f_{n1,n2} \]

If \( \Delta t_{n1,n2} \) is now considered as an unknown variable and \( E_{n1,n2} \) is replaced by the known variable \( h f_{n1,n2} \), then:

\[ \Delta t_{n1,n2}^{-2} = h f_{n1,n2} * \{ Z_v^{-1} \Delta H_{n1,n2}^{-2} * (2\pi f_{n1,n2})^{-2} \} * 2 * \pi^{-1} r_{n1}^{-2} * f_{n1,n2} / (n_1+1) \]

This equation applied in the formula for power density: \( Z_v \{ (\Delta H/\Delta t) / 2\pi f \}^2 / 2 \) leads to:

\[ P_d = (h f_{n1,n2}^2 / \pi r_{n1}^2) / (n_1+1) \]

thus \( E_{n1,n2} \) presented as: “power density * surface * pulse width” to:

\[ E_{n1,n2} = (h f_{n1,n2}^2 / \pi r_{n1}^2) / (n_1+1) * \pi r_{n1}^2 * (n_1+1)/f_{n1,n2} \]

Presented as: “power * pulse width”:

\[ E_{n1,n2} = (h f_{n1,n2}^2) / (n_1+1) * (n_1+1)/f_{n1,n2} \]

Presented as generally accepted:

\[ E_{n1,n2} = h f_{n1,n2} \]

The magnetic resp. electric field strength of the carrier of the photon can, based on the presented model, thus be calculated from an expression that only consists of the Rydberg parameter \( f_{n1,n2} \) and the atom parameters \( n_1 \) and \( r_{n1} \), assumed that the length of the photon is \((n_1+1)/f_{n1,n2}\).

\( A_H = h f_{n1,n2}^2 / \pi r_{n1}^2 / (n_1+1) \) A/m

\( A_E = Z_v A_H \) V/m

This proves that this model has eliminated the particle-wave duality of a photon. Besides that: what might have been left yet to qualify a photon as a particle (too)?
Conclusions

The study has proven that the generation of a photon can be explained by considering an orbiting electron in an atom as an electric current. This current causes a magnetic field, perpendicular to 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 gives an impression of the length of the photon. Real values have to be gained by measurements.

Based on the educated estimates of the length of the photon, the power of the photon can be calculated and as a result the strength of the magnetic and electric field of the carrier 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 is not the source of the energy of the photon.

The model shows that the source of the energy of the photon equals the difference in magnetic energy levels of the atom as created by the orbiting electron(s). In absolute terms speaking: even the kinetic energy of the electron turns out to create an equal amount of magnetic energy in the atom.

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
Appendix Encore

The presented model of the generation of a photon is based on Ampère’s and Faraday’s law, bound together in the Maxwell laws, normally called Maxwell’s equations. By working out Maxwell’s equations, the velocity of light in vacuum is calculated as \( c \). N.B. Maxwell lived in the century that the ether-model was generally accepted within the scientific community. As a result the reference for \( c \) was by definition this ether.

The Principle of Relativity states: all physical laws are the same in all inertial systems.

The inner part of an atom and its direct surrounding is by definition vacuum. Applying the Principle of Relativity in the presented model leads to the conclusion that a photon, generated by an atom, based on the mentioned physical laws, must have a propagation velocity \( c \) w.r.t. this atom, \textit{whatever the velocity of this atom might be}.

Effectively this is the so-called emission theory, vigorously rejected by the community of physicists.

To quote Wikipedia:

\begin{quote}
“Emission theories obey the principle of relativity by having no preferred frame for light transmission, but say that light is emitted at speed "c" relative to its source instead of applying the invariance postulate.”
\end{quote}

Einstein’s Special Theory of Relativity is based on the hypothesis of a system “in rest” w.r.t. which the velocity of light in vacuum would be \( c \). The community of physicists realized that this system “in rest” is equivalent to the, by Einstein himself, abandoned ether-model and therefore slinky changed his hypothesis in: \( c \) w.r.t. any inertial system, known under the expression: “invariance postulate”. In this way a “not-Einstein” Special Theory of Relativity has been created, of which the hypothesis is fundamentally contradictory with Einstein’s hypothesis!

N.B.

\begin{quote}
\textit{A postulate is an assumption, so self-evident that further evidence, if it would be possible to deliver it at all, is not required.}\\
\textit{A hypothesis is an assumption that needs yet to be proven.}
\end{quote}

One of the consequences of the invariance hypothesis is that the velocity of light in vacuum is also \( c \) w.r.t. its source, \textit{whatever the speed of that source might be}! But that same community of physicists seemingly excludes this inertial system from all the “any inertial systems”, as put forward in the invariance hypothesis!

This inconsequence, the contradiction between Einstein’s hypothesis and the invariance hypothesis and the contradiction of both these hypotheses with the Principle of Relativity, leads to the unavoidable conclusion that the Special Theory of Relativity has to be rejected.

Regarding the velocity of light: only the emission theory can be valid. It is indeed a \textit{theory}, not a hypothesis.
### Appendix Series

#### Lyman series

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Pfund series

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Humphreys series

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