A Rotating Dipole Model of the Photon

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Abstract

Feynman's diagrams suggest that photons can temporarily transform into a pair of charged particles, specifically an electron and a positron. This paper explores the possibility that a photon can be modeled as a rotating dipole composed of these opposite charges. The dipole radius is calculated by balancing the electrostatic attraction with centripetal acceleration. Initial calculations, assuming only electrostatic forces, yielded values for Planck's constant that were close to the known value of $\mathbf{6.626 \times 10^{-34}}$, with slight variations between $\mathbf{10^{-32}}$ **and** $\mathbf{10^{-36}}$. These small deviations suggested the need for additional force contributions. By identifying an equilibrium frequency within the electromagnetic spectrum and incorporating magnetic interactions, the model fully reconciles with Planck's constant across all frequencies.

A full mathematical derivation supporting these conclusions is provided in the **Appendix**.

Polarization states may bear relation to the direction of motion in relation to rotation and the model may suggest that photon-photon interactions contribute to diffraction. Further experimental correlations will be explored in future work, and a forthcoming paper will further justify the inclusion of magnetic forces and perhaps self-propelling effects due to the rotating motion of the charges.

1. Background

Light exhibits both wave and particle properties, interacting strongly with matter, particularly electrons. To better understand photon behavior, a diffraction experiment was conducted in a vacuum. A Poisson's spot was generated using an externally placed HeNe laser, passing through a focusing hole in a copper gasket inside a vacuum chamber. The diffraction pattern remained unchanged at 10^{-9} torr, suggesting that diffraction occurs independent of a medium.

This led to a hypothesis that photon wave characteristics arise from interacting rotating dipoles of opposite charge. It is possible but unlikely that polarization effects arise solely from dipole orientation in relation to movement. Further analysis is needed to determine whether such effects conflict with the self-propelling hypothesis proposed in this model. If the dipole's rotational axis is perpendicular to its direction of motion, linear movements appear. If parallel, circular polarization emerges, while intermediate angles result in elliptical polarization.

2. Theoretical Model and Mathematical Formulation

(Note: The equations presented in this paper remain valid for different values of mass and charge, provided the mass-to-charge ratio remains the same. This flexibility allows for the exact values of these parameters to be determined experimentally without altering the fundamental balance of forces in the model.)

For a complete step-by-step derivation of these equations, including the force balance calculations and the role of magnetic interactions, see the **Appendix**.

- 2.1 Dipole Radius Calculation

The dipole radius **R** is derived by balancing electrostatic and centripetal forces:

$F_e = k q^2 / R^2$
$F_c = m v^2 / R$

Setting these forces equal:

$k q^2 / R^2 = m v^2 / R$

Solving for **R**:

$R = k q^2 / (m v^2)$

The total rotational energy is then calculated as:

$E_{rot} = (1/2) I \omega^2$

where **I** is the moment of inertia and $\boldsymbol{\omega}$ is the angular velocity.

The photon energy equation:

$E = h \nu$

is compared with the above results. Although approximate values of **h** are obtained, deviations occur at extreme frequencies, suggesting the necessity of incorporating magnetic effects.

- 2.2 Magnetic Force Considerations

(Further theoretical analysis is required to fully justify the square root dependence on frequency using tensor-based derivations. This will be addressed in a follow-up study.)

At equilibrium frequency f_{eq}, magnetic forces are assumed to be negligible. However, for frequencies above or below f_{eq}, the electron and positron spins contribute additional forces, modifying the dipole radius. The corrected radius R_m is derived by including these magnetic interactions, leading to:

$$F_e + F_m = F_c$$

where $\mathbf{F_m}$ represents the magnetic contribution. The magnetic force initially estimated was:

$$F_m = \alpha (f/f_{eq} - 1)$$

However, to mathematically balance the equation, the required force is found to be:

$$F_m = \alpha \sqrt{(f/f_{eq})} - 1$$

where $\boldsymbol{\alpha}$ is a proportionality factor dependent on charge spin dynamics. This discrepancy suggests that the initial estimation did not fully account for the interaction of the dipole rotation with the magnetic moment.

While the above equations describe the balance of forces maintaining the dipole structure, they do not yet explain how the photon acquires and maintains its motion. If the rotating dipole interacts with an external field or generates a reaction force within the vacuum, it could provide a means of continuous acceleration, distinct from external forces such as radiation pressure

A more detailed justification of the inclusion of these magnetic forces and self-propelling effects due to the rotating motion of the charges will be provided in a follow-up paper.

3. Experimental Validation

A vacuum diffraction experiment was conducted to investigate whether photon interactions require a medium. The Poisson's spot remained unchanged at 10^{-9} torr, supporting the intrinsic nature of diffraction. This result implies that photons exhibit mutual interactions independent of surrounding particles, consistent with the rotating dipole model.

Additionally, proposed experiments aim to use magnetic or electric fields that rapidly alternate at the frequency of the beam of light to investigate potential deviations.

4. Conclusion

A novel photon model as a rotating electron-positron dipole was proposed. This approach aligns with Feynman's interpretation of photon interactions while offering a potential mechanism for polarization and diffraction. Mathematical calculations suggest that electrostatic and magnetic forces govern dipole stability, and deviations from Planck's constant at extreme frequencies may be corrected by accounting for magnetic effects. A forthcoming paper will further explore the role of magnetic forces, refining these predictions and proposing additional experimental tests.

5. References

Note: A preliminary version of this work was copyrighted in 2021 under the title 'A Hypothetical Model of the Photon.'

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6. Appendix

This appendix contains two supplementary components to support the theoretical model presented in this paper:

1. **Mathematical Derivation** – This section provides a detailed step-by-step derivation of the equations used in the main text. It includes force balance calculations, energy considerations, and the role of magnetic interactions in stabilizing the rotating dipole structure.

2. **Diagram of Magnetic Forces and Equilibrium Frequency** – This diagram visually represents the relationships between the magnetic forces acting on the dipole as related to dipole frequency.

These supplementary materials are intended to clarify the theoretical foundation of the rotating dipole model and provide deeper insight into the force interactions that maintain the system's stability.

The Balanced Force Equation Pertaining to a Photon as a Rotating Dipole of Negative and Positive Charges

Definitions, formulas, and physical constants used in this paper:

Let R be the dipole radius of rotation. Thus $2 \cdot R$ is the dipole diameter.
Let f be the frequency of rotation about the center of the dipole axis and let s be the spin about the individual axis of the charged particles at the ends of the dipole.
Let w be the angular velocity which is equal to $(2 \cdot \pi \cdot f)$.

Rotational Inertia: $I = m \cdot R^2$ Where m is mass.
Rotational energy: $E_{rot} = \frac{1}{2} \cdot I \cdot w^2$ We can expand this to show: $E_{rot} = \frac{1}{2} \cdot m \cdot R^2 \cdot (2 \cdot \pi \cdot f)^2$

Charge of an electron. Note that the charge of a positron is of the same magnitude but opposite sign and hence there would be an attractive force between the two:
$q := 1.602 \cdot 10^{-19}\ \mathrm{C}$

Mass of an electron (and also mass of a positron):
$e_{mass} := 9.109 \cdot 10^{-31} \cdot \mathrm{kg}$

Speed of Light:
$2.998 \cdot 10^{8}\ \frac{\mathrm{m}}{\mathrm{s}}$

The Electrostatic Force (F_e) added to the Magnetic Force (F_m) must balance the Centripetal Force (F_m).

(1) $F_e + F_m = F_c$ This will be referred to as the **"Balanced Force Equation"**

The formulas for the Electrostatic Force and Centripetal Force are well known, however the Magnetic Force is more complicated. Plugging the known formulas into (1) gives:

(2) $\frac{K_e \cdot q^2}{(2 \cdot R)^2} + F_m = e_{mass} \cdot R \cdot (2 \cdot \pi \cdot f)^2$ *Where :* $K_e := 8.999 \cdot 10^{9} \cdot \mathrm{N} \cdot \mathrm{m}^2 \cdot \mathrm{C}^{-2}$ and frequency of rotation about the dipole axis is denoted by f.

The objective of the following calulations is to determine what Magnetic Force is needed to balance the equation and see if this predicted force is reasonable. We expect it to be a function of the charges, the radius of rotation that creates a magnetic moment and also the distance between charges. We will also make an assumption that the charges spin about their own axis. This spin orientation and direction of spin make the direct calculation a difficult puzzle. But we can use the balanced force equation to make predictions about the Magnetic Force.

To do this, we start by considering the case where the Magnetic Force equals zero. In this case:

$$(3) \qquad \frac{K_e \cdot q^2}{(2\cdot R)^2} = e_{mass}\cdot R\cdot \left(2\cdot \pi \cdot f\right)^2$$

Solving for R, we get:

$$(4) \qquad R := \left(\frac{K_e}{e_{mass}} \cdot \left(\frac{q}{4\cdot \pi \cdot f} \right)^2 \right)^{\frac{1}{3}}$$

This is the Zero Magnetism equation for the Dipole Radius.

If we were to say that the rotational energy of the dipole system with equal mass on both ends ($e_{mass}\cdot R^2\cdot \left(2\cdot \pi \cdot f\right)^2$) equals the known energy of light based on frequency ($h\cdot f$) where h is planck's constant, so we could then say:

$$(5) \qquad e_{mass}\cdot R^2\cdot \left(2\cdot \pi \cdot f\right)^2 = h\cdot f$$

Lets examine this further by defining (ν_{eq}) as the constant **"Frequency of Equilibrium"** about the dipole axis, at which the magnetic force due to rotation about the ***dipole*** axis and the magnetic force due to spin about the ***charge*** axis cancel each other resulting in a **net zero magnetic force.**

$$(6) \qquad e_{mass}\cdot R^2\cdot \left(2\cdot \pi \cdot f_{eq}\right)^2 = h\cdot f_{eq}$$

Replacing f with f_{eq} into formula (4) for R and substituting the result into equation (6) we then are able to solve for the constant **"Dipole Frequency of Magnetic Equilibrium" (f_{eq}).** At Magnetic Equilibrium the net internal magnetic force is equal to zero.

$$(7) \qquad f_{eq} := \left(e_{mass}\cdot \left(\frac{K_e}{e_{mass}} \right)^{\frac{2}{3}} \cdot \left(\frac{q}{4\cdot \pi} \right)^{\frac{4}{3}} \cdot (2\cdot \pi)^2 \cdot \left(\frac{1}{h} \right) \right)^3 = \left(4.123\cdot 10^{14}\right)\cdot s^{-1}$$

Inserting the constant (f_{eq}) from (7) into our formula for Zero Magnetism equation for the Dipole Radius (4) we calculate the constant **"Dipole Radius of Magnetic Equilibrium" (*R_{eq}*)** to be:

$$(8) \qquad R_{eq} := \left(\left(\frac{K_e}{e_{mass}} \cdot \left(\frac{q}{4\cdot \pi \cdot \boldsymbol{f_{eq}}} \right)^2 \right)^{\frac{1}{3}} \right) = \left(2.114\cdot 10^{-10}\right)\cdot \mathrm{m}$$

Going back to our original equation (5) that asserts the rotational energy equals the energy of light given by Planck's formula ($h\cdot f$) and substituting the values obtained at rotational equilibrium we can define Plancks constant as a function of the equilibrium radius and the equilibrium rotational velocity as follows:

(9) $e_{mass} \cdot R_{eq}{}^{2} \cdot \left(2 \cdot \pi \cdot f_{eq}\right)^{2} = h \cdot f_{eq}$

Now we are able to obtain the value for Planck's constant h in terms of the constant R_{eq} and the constant f_{eq}

(10) $h := e_{mass} \cdot R_{eq}{}^{2} \cdot (2 \cdot \pi)^{2} \cdot f_{eq} \quad = \left(6.626 \cdot 10^{-34}\right) kg \cdot m^{2} \cdot s^{-1}$

Now substitute our value for h from (10) into equation (5):

(11) $e_{mass} \cdot R^{2} \cdot \left(2 \cdot \pi \cdot f\right)^{2} = e_{mass} \cdot R_{eq}{}^{2} \cdot (2 \cdot \pi)^{2} \cdot f_{eq} \cdot f$

This now enables us to calculate what the dipole radius R must be for any frequency after inclusion of magnetic forces as a function of frequency (υ), frequency of equilibrium (ν_{eq}), and radius of equilibrium (R_{eq}). We will call this the **"Dipole Radius with Magnetic Forces" (R_m)**. From (11) we solve for R_m.

(12) $R_m := \left(\frac{f_{eq}}{f}\right)^{\frac{1}{2}} \cdot R_{eq}$

To get rid of the R_{eq} term in equation (12), recall formula (8) and substitute the value for R_{eq}. This yields:

(13) $R_m := \left(\frac{f_{eq}}{f}\right)^{\frac{1}{2}} \cdot \left(\left(\frac{K_e}{e_{mass}} \cdot \left(\frac{q}{4 \cdot \pi \cdot f_{eq}}\right)^{2}\right)\right)^{\frac{1}{3}}$

Now we have all the values needed to complete the final calculations and predict the magnetic force between the dipoles:

We return to our Balanced Force Equation (2) but replace the second term (F_m) representing the Magnetic Force with the placeholder $\frac{A}{\left(2 \cdot R_m\right)^{2}}$. This is because we expect the force to be a function of the distance between the dipoles squared. The idea is to then solve for "A."
Notice I have replaced "R" with "R_m" in the final computations.

(14) $\frac{K_e \cdot q^{2}}{\left(2 \cdot R_m\right)^{2}} + \frac{A}{\left(2 \cdot R_m\right)^{2}} = e_{mass} \cdot R_m \cdot \left(2 \cdot \pi \cdot f\right)^{2} = \frac{4 \cdot e_{mass} \cdot R_m{}^{3} \cdot \left(2 \cdot \pi \cdot f\right)^{2}}{\left(2 \cdot R_m\right)^{2}}$ Here we set everything to a common denominator and the magnetic force is now given by:

(15) $$F_m := \frac{4 \cdot e_{mass} \cdot R_m^{\ 3} \cdot (2 \cdot \pi \cdot f)^2 - K_e \cdot q^2}{(2 \cdot R_m)^2}$$

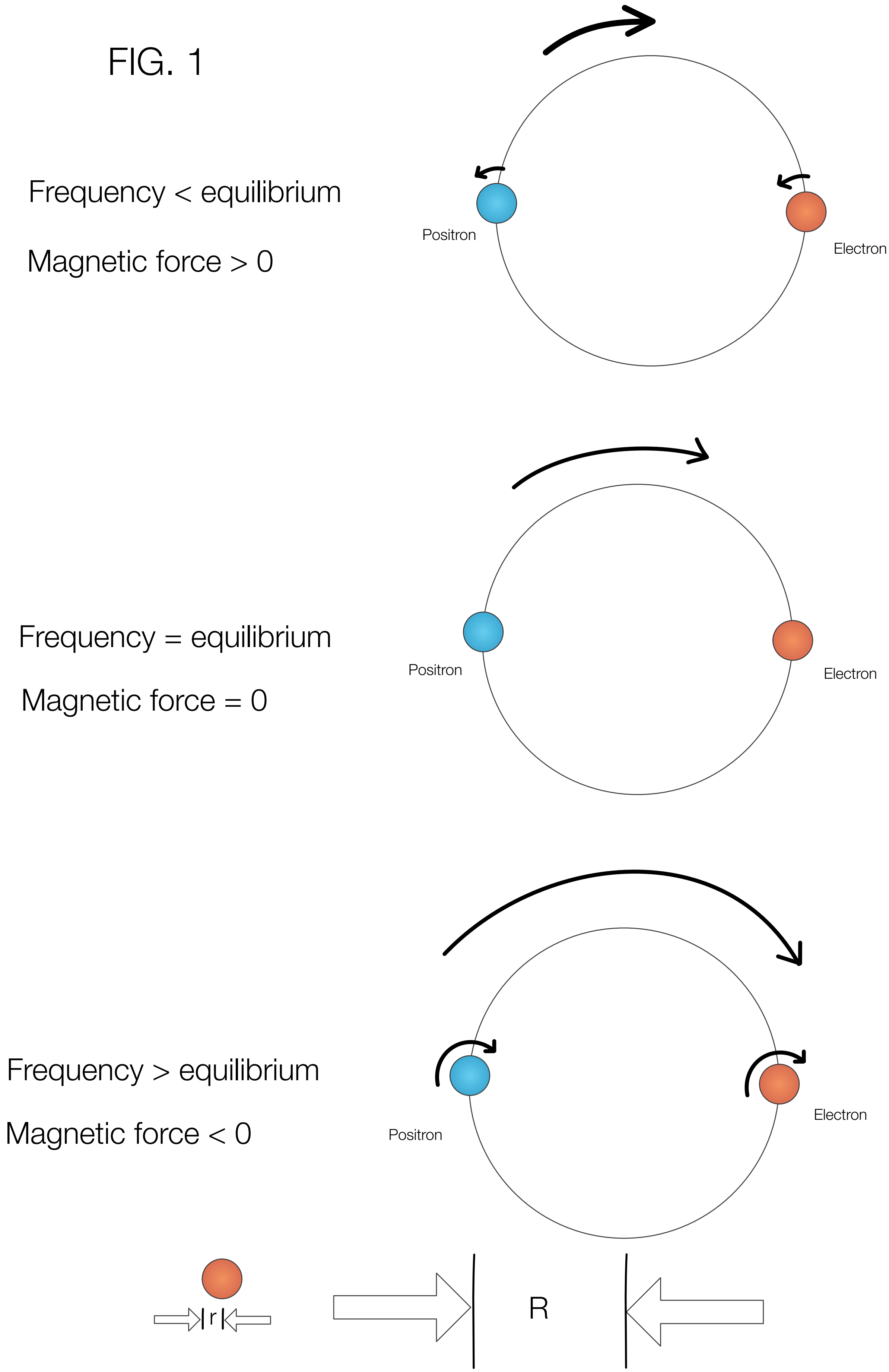
Finally, substitute the equation (12) for R_m into (14) and simplify. This gives a formula for the predicted Magnetic Force (F_m) as a function of frequency that fits the format of the Balanced Force Equation.

(16) $$F_m := \frac{K_e \cdot q^2 \left(\left(\frac{f}{f_{eq}} \right)^{\frac{1}{2}} - 1 \right)}{(2 \cdot R_m)^2}$$

The completed Balanced Force Equation (1) ($F_e + F_m = F_c$) now looks like this:

(**17**) $$\frac{\mathbf{K_e \cdot q^2}}{(\mathbf{2 \cdot R_m})^2} + \frac{\mathbf{K_e \cdot q^2} \left(\left(\frac{f}{f_{eq}} \right)^{\frac{1}{2}} - \mathbf{1} \right)}{(\mathbf{2 \cdot R_m})^2} = \mathbf{e_{mass}} \cdot \boldsymbol{R}_{\mathbf{m}} \cdot (\mathbf{2 \cdot \pi} \cdot \boldsymbol{f})^{\mathbf{2}}$$

FIG. 1



Frequency < equilibrium
Magnetic force > 0
Positron
Electron
Frequency = equilibrium
Magnetic force = 0
Positron
Electron
Frequency > equilibrium
Magnetic force < 0
Positron
Electron
r
R