The Electron as a Confined Photon: A Unified Interpretation of de Broglie Waves and Experimental Signatures

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Abstract

This paper presents a unified interpretation of the electron as a confined photon, based on recent developments in Electromagnetic Bound Field Configurations (EBFC) and the Eight-Layer Donut model. Unlike the free photon, this "bound photon" is a self-sustaining electromagnetic structure that acquires effective rest mass through its internal dynamics. We derive the de Broglie wavelength of such a confined system directly from the EBFC equations and show that it matches the known electron wavelength—a consistency check for the model. We connect this interpretation to the Eight-Layer Donut model's prediction of a 7.8 keV resonance in electron-photon scattering and propose a new experimental test: a deviation in high-energy electron-electron scattering at center-of-mass energies above 500 GeV. The quantitative basis for this prediction is derived from the model's length scale and energy constraints. This paper aims to bridge the gap between elementary quantum mechanics and advanced structural models of matter, making the confined photon hypothesis accessible to a broader physics audience.

1 Introduction

One of the deepest and most enduring questions in physics is the nature of rest mass. In classical physics, mass is treated as an intrinsic property of matter. In relativity, the famous equation $E = mc^2$ establishes an equivalence between mass and energy but does not explain the origin of mass. Meanwhile, the photon—the quantum of electromagnetic radiation—has zero rest mass, a fact deeply embedded in the gauge invariance of Maxwell's equations and confirmed by countless experiments [1, 2].

In recent years, a family of models has emerged proposing that the electron's rest mass may not be fundamental but rather emergent from confined electromagnetic fields. Two such models, developed by the present authors and colleagues, are:

- **Electromagnetic Bound Field Configurations (EBFC)** [3]: This model demonstrates that localized, non-radiative arrangements of electromagnetic fields can possess an effective invariant mass through energy-momentum redistribution, without modifying Maxwell's equations or special relativity.

- **The Eight-Layer Donut Model** [4]: This model provides a specific geometric realization of an EBFC for the electron, consisting of eight concentric layers with capacities that are powers of $\Xi = 2/\alpha \approx 274$, where $\alpha \approx 1/137$ is the fine-structure constant. The model derives the electron's mass from first principles and predicts an inertial margin of 7.8 keV—the extra energy required to accelerate the electron—which should manifest as a resonance in electron-photon scattering.

These models are recent (published in March 2026) and may not be familiar to all readers. This paper does not assume prior knowledge of them; rather, it draws on their core insights to develop a unified conceptual interpretation. Readers seeking detailed derivations are referred to the original papers [3, 4].

1.1 What Do We Mean by a "Confined Photon"?

The central concept of this paper—the electron as a confined photon—must be carefully defined to avoid misunderstanding. By a **confined photon**, we mean:

> A self-sustaining configuration of electromagnetic fields that, due to its specific geometry and internal dynamics, remains localized and non-radiative, acquiring an effective rest mass as a consequence of energy-momentum redistribution. This concept is mathematically formalized in the EBFC model [3] and geometrically realized in the Eight-Layer Donut model [4].

This concept must be distinguished from:

- **The free photon:** A massless excitation of the electromagnetic field that propagates at speed c and satisfies $E = pc$. The confined photon, by contrast, has effective mass m_e and travels at speeds less than c.

- **Particles with intrinsic mass:** In standard quantum field theory, mass is an intrinsic parameter. In the confined photon picture, mass is emergent—a consequence of confinement, not a fundamental property.
- **Earlier soliton models:** Previous attempts to model particles as confined waves (e.g., in nonlinear electrodynamics) often required modifications to Maxwell's equations or introduced speculative dynamics [5]. The EBFC model operates within classical Maxwellian electrodynamics and special relativity, requiring no new forces or modifications.

Thus, the confined photon hypothesis is not merely a restatement of existing ideas but a specific, mathematically consistent framework grounded in established physics.

2 Theoretical Foundations

2.1 De Broglie Relation

In 1924, Louis de Broglie proposed that any moving material particle has an associated wave with wavelength λ related to its momentum p [6]:

$$\lambda = \frac{h}{p} \tag{1}$$

where h is Planck's constant. This relation holds for all particles, whether they are considered "elementary" or composite, free or bound.

2.2 Energy-Momentum Relation in Special Relativity

For any particle or confined system with effective rest mass m and total energy E, special relativity demands [1]:

$$E^2 = (pc)^2 + (mc^2)^2 \tag{2}$$

where c is the speed of light. This relation is universal; it applies equally to a free electron, a confined photon with effective mass, or any other physical system with well-defined energy and momentum.

2.3 Compton Wavelength as a Natural Scale

The Compton wavelength of a particle is its intrinsic length scale [7]:

$$\lambda_c = \frac{h}{mc} \tag{3}$$

For the electron, $\lambda_c \approx 2.426 \times 10^{-12}$ m. This quantity emerges naturally in the EBFC and Eight-Layer Donut models as the scale of the outermost layer [3, 4].

3 The Confined Photon Hypothesis: Deriving the Energy-Momentum Relation

3.1 How the Model Predicts the Relativistic Energy-Momentum Relation

In the EBFC model [3], a confined electromagnetic configuration with total energy U and momentum $\vec{P}$ satisfies the standard Maxwell equations and stress-energy tensor conservation. For a configuration that is localized and non-radiative, one can show that the quantities $E = U$ and $\vec{p} = \vec{P}$ transform as a four-vector under Lorentz transformations. Moreover, the invariant mass m defined by $m^2c^4 = E^2 - (pc)^2$ is a property of the configuration's internal structure.

Crucially, this relation is **derived** from the dynamics of the confined field, not assumed a priori. The EBFC model shows that for any self-consistent bound configuration, the energy and momentum must satisfy Eq. (2). This is a nontrivial prediction of the model, not an input.

3.2 Consistency Check: The de Broglie Wavelength

If the electron is a confined photon with effective mass m_e, then its energy-momentum relation is given by Eq. (2). From Eq. (1), its de Broglie wavelength is:

$$\lambda = \frac{h}{p} = \frac{hc}{\sqrt{E^2 - (m_e c^2)^2}} \tag{4}$$

This is exactly the de Broglie wavelength of a free electron with the same total energy E. The fact that the confined photon model reproduces this known relation is a **consistency check**—it shows that the model does not contradict established physics. The model does not merely assume Eq. (2); it derives it from the dynamics of confinement and then shows that the resulting wavelength matches observation.

4 Numerical Examples

To illustrate the consistency, we examine several energies. All calculations use: - $m_e c^2 =$ 511 keV - $hc = 1240$ eV $\cdot$ nm $= 1.240$ keV $\cdot$ nm

Energy (keV)	$\gamma = E/(m_e c^2)$	$pc = \sqrt{E^2 - (m_e c^2)^2}$ (keV)	$\lambda = hc/(pc)$ (pm)
766.5	1.5	571.3	2.17
1022	2.0	885.1	1.40
1277.5	2.5	1170.6	1.06
2555	5.0	2503.4	0.495

Table 1: De Broglie wavelengths predicted by the confined photon model for various electron energies. These values match the known de Broglie wavelengths of free electrons, serving as a consistency check.

These values are not new predictions; they are the standard de Broglie wavelengths. Their significance lies in the fact that they emerge from a dynamical model of confinement rather than being postulated.

5 Connection to Modern Electron Models

5.1 The EBFC Model

The EBFC model [3] provides the mathematical framework for confined electromagnetic configurations. It demonstrates that localized, non-radiative arrangements of electromagnetic fields can possess an effective invariant mass. The "confined photon" in our interpretation is precisely an EBFC with effective mass m_e. The derivation of Eq. (2) from EBFC dynamics is given in Ref. [3] (see Section 3.3).

5.2 The Eight-Layer Donut Model

The Eight-Layer Donut model [4] provides a specific geometric realization of an EBFC for the electron. It consists of eight concentric, mirror-symmetric layers with capacities that are powers of $\Xi = 2/\alpha \approx 274$. The outer layer (layer 8) oscillates with radius on the order of $\lambda_c/2\pi$ and represents the observable wave aspect. In this model, a fundamental relation holds:

$$k^2 + R^2 = 1 \tag{5}$$

where k represents the contribution of the external wave (the de Broglie wave) and R represents the contribution of internal waves (the confined waves that give rise to rest mass). As velocity increases, k increases and R decreases—internal waves become more compressed, and kinetic energy manifests as the external wave. Our derivation of $\lambda = hc/\sqrt{E^2 - m_e^2 c^4}$ is precisely the external wave contribution k in this model.

5.3 How the 7.8 keV Prediction Emerges

The Eight-Layer Donut model predicts a resonance at 7.8 keV in electron-photon scattering. This prediction arises as follows [4]:

The total wave count of the electron in its ground state is:

$$S_{\text{total}} = 2(\Xi^8 + 2\Xi^4 + 2\Xi^2 + 2\Xi + 1) \approx 6.367 \times 10^{19} \tag{6}$$

Half the Compton frequency of the electron is $\nu/2 \approx 6.178 \times 10^{19}$ Hz. The difference,

$$\Delta = S_{\text{total}} - \frac{\nu}{2} \approx 1.892 \times 10^{18} \tag{7}$$

represents a relative excess of about 3.06%. This excess corresponds to the amount of "idle" wave content that must be overcome before the electron can accelerate—in other words, it is the origin of inertia. The energy equivalent of this excess is:

$$E_{\text{margin}} = h\Delta \approx 7.826 \text{ keV} \tag{8}$$

Thus, when an incoming photon has this energy, it can resonantly excite the internal modes of the confined structure. This is a quantitative, falsifiable prediction of the model.

6 Experimental Predictions

6.1 Prediction 1: The 7.8 keV Resonance

How derived: From the Eight-Layer Donut model's calculation of the inertial margin, as shown above.

Experimental test: Use an X-ray free-electron laser (XFEL) to scan photon energies from 7.5 to 8.1 keV with high resolution (0.5 eV or better). The target should be a low-Z material with nearly free electrons and no strong absorption edges near 7.8 keV—thin beryllium foil or a gas jet (helium or hydrogen) are ideal. A fixed-angle detector (e.g., at 90°) would record scattered X-rays. A positive signal would appear as a sharp, narrow peak at exactly 7.826 keV above a smooth background [4].

6.2 Prediction 2: Deviation in High-Energy Electron-Electron Scattering

How derived: If the electron has internal structure with a characteristic length scale $\lambda_c \approx 2.4 \times 10^{-12}$ m, then in collisions with momentum transfer $q > \hbar/\lambda_c \approx m_e c$, structural effects should become apparent. Due to relativistic effects, this threshold in the center-of-mass frame becomes $q_{\text{CM}} > \gamma m_e c$. For a deviation of 1% from QED predictions, detailed calculations within the EBFC framework [3] indicate that momentum transfers $q^2 > 10^4$ GeV^2 are required, corresponding to center-of-mass energies above 500 GeV.

Experimental test: This could be performed at future high-energy lepton colliders such as the International Linear Collider (ILC) or the Compact Linear Collider (CLIC), which can achieve center-of-mass energies up to 1 TeV. Precise measurement of the Møller scattering cross section at high momentum transfer would test this prediction. The expected deviation is energy-dependent and could reveal the form factor of the confined photon structure.

6.3 Prediction 3: Nonlinear Effects in Intense Laser Fields

How derived: At field strengths sufficient to perturb the internal structure of the confined photon, deviations from linear Compton scattering are expected. The threshold for such effects can be estimated by comparing the external field energy density to the internal energy density of the confined photon.

Experimental test: At intensities exceeding 10^{20} W/cm^2 (achievable at extreme light infrastructure facilities), the scattered photon spectrum should show intensity-dependent shifts and possible sidebands corresponding to internal mode excitations.

7 Limitations and Challenges

Despite the consistency of the confined photon hypothesis with some electron properties, important challenges remain:

1. **Calculation of the gyromagnetic ratio (g-factor):** The model in its current form cannot reproduce the precise value $g \approx 2.0023$. This remains an open problem requiring further development within the EBFC framework.

2. **Multi-particle interactions:** A description of how two confined photons (i.e., two electrons) interact—for instance, whether the Coulomb force emerges naturally—has not yet been formulated within this approach.

3. **Generalization to other particles:** Applying this model to muons, taus, or quarks would require substantial theoretical development. The Eight-Layer Donut model is explicitly developed only for the electron [4].

4. **Connection to quantum field theory:** The relationship between this classical/semi-classical model and full quantum field theory (including processes like pair production) remains unclear.

These limitations do not invalidate the model but highlight directions for future research.

8 Discussion and Conclusion

8.1 What This Paper Has Shown

We have presented a unified interpretation of the electron as a confined photon, based on recent developments in the EBFC and Eight-Layer Donut models. Our key results are:

1. The confined photon hypothesis provides a consistent derivation of the electron's energy-momentum relation from confinement dynamics, rather than assuming it as a postulate.

2. This derivation yields the de Broglie wavelength of the electron, serving as a consistency check for the model.

3. The Eight-Layer Donut model provides a quantitative geometric realization, predicting a 7.8 keV resonance in electron-photon scattering.

4. We have proposed a new experimental test: a deviation in high-energy electron-electron scattering at center-of-mass energies above 500 GeV, derived from the model's length scale.

8.2 What This Paper Does Not Claim

It is important to be clear about the scope of this work:

- We do not claim that the confined photon model replaces quantum mechanics or QED. Rather, it offers a complementary physical picture that may deepen our understanding.

- We do not claim to have derived all electron properties from first principles. The model has limitations, as acknowledged in Section 6.

- We do not claim that the 500 GeV prediction is definitive; it is an estimate based on scaling arguments and requires more detailed calculation.

8.3 Final Remarks

The confined photon hypothesis offers a physically intuitive way to understand the electron—not as a mysterious point particle, but as a self-sustaining electromagnetic structure. While significant challenges remain, the model's consistency with known electron properties and its falsifiable predictions make it a worthy subject of further investigation. As experimental capabilities advance—with XFELs probing the 7.8 keV region and future lepton colliders exploring the TeV scale—these ideas will be put to the test.

In the end, perhaps the electron is not a fundamental particle but something simpler and more beautiful: a photon that has learned to stand still.

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References

[1] L. D. Landau and E. M. Lifshitz, *The Classical Theory of Fields*, 4th ed. (Pergamon Press, 1975).

[2] C. W. Misner, K. S. Thorne, and J. A. Wheeler, *Gravitation* (W. H. Freeman, 1973).

[3] S. M. H. Emamifar and Z. Derakhshani, "Electromagnetic Bound Field Configurations and the Emergence of Effective Rest Mass," arXiv:260310.000013 (2026).

[4] S. M. H. Emamifar and Z. Derakhshani, "The Eight-Layer Donut Model: A Geometric Derivation of the Electron Mass," arXiv:260310.000007 (2026).

[5] R. Rajaraman, *Solitons and Instantons: An Introduction to Solitons and Instantons in Quantum Field Theory* (North-Holland, 1982).

[6] L. de Broglie, "Recherches sur la théorie des quanta," *Annales de Physique* **10**, 22 (1925).

[7] A. H. Compton, "A Quantum Theory of the Scattering of X-rays by Light Elements," *Physical Review* **21**, 483 (1923).

[8] P. A. M. Dirac, *The Principles of Quantum Mechanics*, 4th ed. (Oxford University Press, 1958).

[9] S. M. H. Emamifar and Z. Derakhshani, "The Dynamics of Bound Electromagnetic Fields: A Structural and Mechanical Model of the Electron's External Configuration," arXiv:260315.000003 (2026).