

# A Two-Oscillator Model for the Photon: Toward a Dynamical Explanation of Electromagnetic Attraction and Repulsion

Furne-Gouveia

Independent Researcher, France  
furnegouveia@gmail.com

July 11, 2025

## Abstract

We propose a two-component internal structure for the photon composed of coupled oscillating fields with transverse and longitudinal components. These oscillations interact rotationally, leading to helical propagation. The coupling mechanism explains not only the photon's ability to propagate but also sheds light on the dual attractive/repulsive nature of electromagnetic forces. This model offers a novel framework for interpreting fluctuations in photon energy and may serve as a basis for future refinements of quantum electrodynamics.

**Keywords:** photon structure, coupled oscillators, helical propagation, electromagnetic force, longitudinal modes, soliton model, phase dynamics, light-matter interaction

## 1 Introduction

The photon is traditionally modeled as a massless, transverse quantum excitation of the electromagnetic field, with no internal structure. However, various experimental hints and theoretical considerations suggest the need for a richer picture. In this paper, we propose a model in which the photon consists of two coupled oscillating components, each with transverse and longitudinal elements, separated by a small distance  $\delta x$  proportional to the wavelength. Their mutual interaction enables the propagation of the photon in space.

## 2 Physical Motivation

Several observations motivate the development of a structured photon model:

- Explain the motion of the photon.
- Apparent fluctuations in photon energy observed in emission or scattering experiments.
- Optical forces can be attractive or repulsive depending on context.
- Directional interactions influenced by phase alignment.
- Measurement limitations suggest we may only observe certain projections (e.g., transverse or longitudinal).

These phenomena justify considering a model with two interdependent oscillatory subcomponents.

### 3 Model Description: Two Coupled Oscillators

#### 3.1 Central Hypothesis

The photon comprises two vectorial structures  $\vec{S}_1(\vec{r}, t)$  and  $\vec{S}_2(\vec{r}, t)$ , separated by a small spatial offset  $\delta x = \eta\lambda$ , with  $0 < \eta < 1$ . Each component is a local oscillation, and propagation emerges only from their dynamic coupling. This coupling is rotational, similar to classical spin precession or soliton interaction.

#### 3.2 Coupled Evolution Equations

We propose the following local dynamical system:

$$\partial_t \vec{S}_1 = \vec{S}_2 \times \vec{k} \quad \partial_t \vec{S}_2 = -\vec{S}_1 \times \vec{k} \quad (1)$$

Here,  $\vec{k}$  is the photon's propagation vector. The cross-product coupling results in mutual rotation around  $\vec{k}$ , forming a helical structure in the transverse plane.

#### 3.3 Helical Solution

A general solution is given by:

$$\vec{S}_1(\vec{r}, t) = A (\cos(kz - \omega t) \sin(kz - \omega t) 0), \quad (2)$$

$$\vec{S}_2(\vec{r}, t) = A (-\sin(kz - \omega t) \cos(kz - \omega t) 0) \quad (3)$$

The combined effect is a circularly polarized wave with intrinsic rotation, whose propagation arises from the dynamic interplay between  $\vec{S}_1$  and  $\vec{S}_2$ .

#### 3.4 Energy Conservation

We define the local energy density as:

$$\mathcal{E} = \frac{1}{2}(|\vec{S}_1|^2 + |\vec{S}_2|^2) = A^2$$

This energy remains constant over time, indicating internal redistribution without dissipation. This may explain observed photon energy fluctuations as mere projection effects.

#### 3.5 Mechanism of Propagation

The propagation of the photon in this model is not an imposed axiom but a consequence of the mutual coupling between the two oscillatory structures. Assuming space is the propagation medium [5], each oscillator induces local compressions and extensions of the medium, and the transfer of these deformations between the two components leads to their mutual displacement. Depending on their phase alignment, this displacement can be either symmetric (resulting in local vibration without net translation) or asymmetric (yielding coherent displacement in a preferred direction). When the phases are properly matched, the mutual deformation propagates helically along a shared axis, leading to a rotational translation of the photon in space. The direction of propagation thus emerges from the internal dynamics of the oscillators, and the motion follows a helical trajectory rather than a purely linear one.

### 3.6 Mechanism of Electromagnetic Attraction and Repulsion

In this model, electromagnetic attraction and repulsion arise from the phase-dependent momentum transfer between the photon's internal oscillatory components and external charged fields. When a photon interacts with a particle, the phase alignment between the photon's coupled oscillators and the oscillating charges or fields of the target determines the direction and magnitude of the effective impulse. If the transverse and longitudinal components of the photon arrive in phase with the local oscillations of the target field, constructive interference occurs, resulting in a net impulse that pulls the particle (attraction). Conversely, if the components arrive out of phase, destructive interference leads to a repelling impulse. This phase-sensitive coupling resembles the behavior of driven oscillators, where energy transfer depends critically on the synchronization between the driver and the receiver. The photon's internal structure, with its coupled helical oscillations, provides both the directional selectivity and temporal coherence required to generate either attractive or repulsive interactions, without the need to invoke separate field types or signs of charge. This framework suggests that force directionality is an emergent property of phase dynamics within a unified photonic structure.

## 4 Physical Interpretations

- **Spin:** angular momentum from helical motion of  $\vec{S}_1$  and  $\vec{S}_2$ .
- **Polarization:** determined by relative phase and rotation plane.
- **Propagation:** results from mutual rotation.
- **Attraction/Repulsion:** depends on phase alignment with target fields, producing net impulse transfer.

## 5 Outlook and Future Work

Several research avenues emerge from this model:

- Generalization to stationary and pseudo-stationary wave patterns as manifestations of electromagnetic forces [5].
- Quantifying  $\eta$  as a function of photon energy.
- Relativistic generalization (e.g., Dirac formalism, spinor fields).
- Exploring links with topological soliton models.

## 6 Conclusion

The standard transverse-only view of the photon may be a special case of a more complex oscillatory structure. The two-oscillator model offers qualitative insight into photon propagation and electromagnetic force duality. While speculative, this framework may serve as a springboard toward a richer understanding of quantum light-matter interaction.

## References

- [1] . Mihalache et al., "Solitons in nonlinear optics," *Reports on Progress in Physics*, 73, 076401 (2010).
- [2] . Einstein, "On a heuristic viewpoint concerning the production and transformation of light," *Annalen der Physik* (1905).
- [3] . E. Sipe, "Photon wave functions," *Phys. Rev. A*, 52, 1875 (1995).
- [4] . Dauxois and M. Peyrard, *Physics of Solitons*, Cambridge University Press (2006).
- [5] Furne-Gouveia (2025). "A Unified Wave-Based Model of Matter, Light, and Space: Stationary Waves in an Elastic, Non-Dispersive Medium". *Preprints.org*, [DOI]. Available at: <https://doi.org/10.20944/preprints202506.0121.v1>.