

A Mathematical Extension That Reveals Deeper Structure of Light Beyond Quantum Electrodynamics

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ABSTRACT

Quantum Electrodynamics (QED) currently provides the most accurate description of electromagnetic interactions, yet it treats photon energy quantization exclusively through frequency. Motivated by conceptual limitations in the photon hypothesis, the Einsmax Theory of Light Quanta and Massless Particles introduces a complementary quantization framework in which amplitude plays a primary mathematical role. In this paper, a unified theoretical and mathematical formulation is presented that fully preserves Maxwellian wave propagation, the Planck–Einstein relation, and relativistic momentum conservation. Discrete amplitude quantum levels at fixed frequency are derived and shown to provide deeper explanatory power for interference, black-body radiation, and image formation in darkness. This work establishes amplitude as an active quantum variable, offering a mathematically grounded extension to the foundations of optical physics.

INTRODUCTION

The theoretical understanding of light has evolved through major developments beginning with classical electrodynamics and extending into modern quantum field theory. Maxwell's formulation unified electricity and magnetism into a wave theory of light [6,41,45]. Planck's introduction of quantized energy exchange in black-body radiation marked the birth of quantum theory [4], which was further advanced by Einstein through the concept of light quanta [2,17].

Subsequent developments in quantum mechanics by Bohr, Heisenberg, and Schrödinger established the framework for microscopic physics [18–21], while Dirac and later Feynman, Schwinger, and Tomonaga formulated Quantum Electrodynamics (QED) as a relativistically consistent theory of light–matter interaction [1,3,9,12]. These developments culminated in a highly successful predictive theory, further refined through renormalization and field-theoretic approaches [10,34,36,37].

Despite this success, foundational questions remain regarding the interpretation of wave–particle duality, coherence, and intensity fluctuations in low-light regimes [26–28]. Experimental tests of quantum nonlocality and photon correlations [24,25] further emphasize the need for conceptual clarity. Einstein himself expressed reservations about the completeness of the photon description [15].

Motivated by these considerations, the Einsmax theory introduces amplitude as a complementary quantized variable, aiming to extend the interpretational framework of QED without altering its empirical validity.

Classical Electromagnetic Foundation

Maxwell's equations describe electromagnetic radiation as a propagating wave characterized by electric and magnetic fields [6,41]. The energy density of the electromagnetic field is given by:

$$u = \frac{1}{2} \epsilon_0 E^2 + \frac{1}{2} \mu_0 B^2$$

For plane waves in free space, this reduces to:

$$u = \epsilon_0 E^2$$

This formulation demonstrates that energy density depends quadratically on field amplitude, a result discussed extensively in classical electrodynamics and optics literature [7,8,44,45]. The propagation and interaction of electromagnetic waves are further governed by boundary conditions and wave equations derived from Maxwell’s framework [41,44].

Quantum Foundations and Photon Theory

The quantization of electromagnetic radiation was introduced through Planck’s relation:

$$u = \epsilon_0 E^2 \tag{4}$$

Einstein extended this concept to explain the photoelectric effect, establishing the particle-like nature of light [2,17]. Compton scattering experiments provided further evidence of photon momentum [16].

The development of quantum mechanics introduced probabilistic interpretations of physical systems [20,21], while de Broglie’s hypothesis established wave–particle duality [19]. The formal structure of quantum theory was further refined through operator mechanics and wave equations [18,20,21].

Quantum Electrodynamics emerged as a complete framework describing the interaction between light and matter using quantized fields [1,3,9,12,34]. The theory has been extensively validated through precision experiments such as the Lamb shift and anomalous magnetic moment [13,14].

Mathematical Framework of Einsmax Theory

Amplitude-Based Quantization

In classical theory, energy scales with amplitude squared:

$$u = \epsilon_0 E^2 \tag{7,8}$$

In quantum theory, energy is discretized as:

$$E_n = nhv \tag{4}$$

The Einsmax framework connects these relations by defining discrete amplitude levels:

$$A_n = \sqrt{n}A_1$$

This formulation preserves the Planck–Einstein relation while introducing amplitude as an explicit quantized parameter.

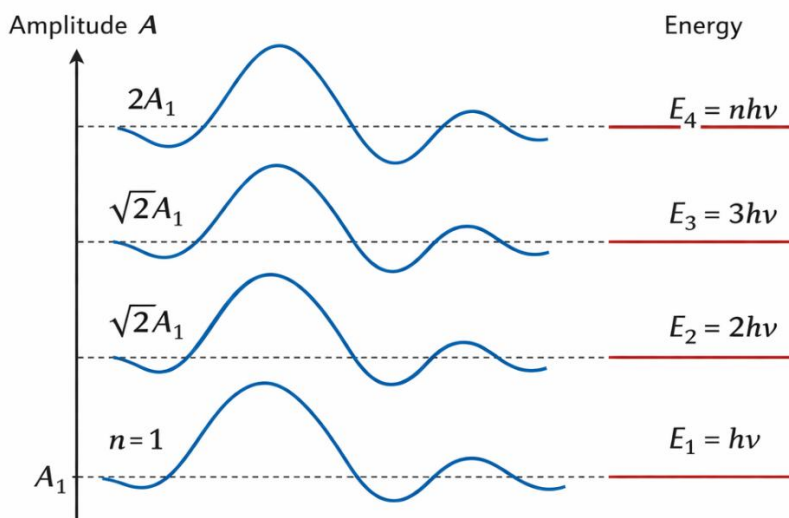


Fig. 1: Discrete amplitude levels corresponding to $A_n = \sqrt{n}A_1$, showing how energy quantization manifests as amplitude scaling at fixed frequency.

Field-Theoretic Context

In standard quantum optics, the electromagnetic field is expressed using creation and annihilation operators [1,26,27,28]. The expectation values of field observables relate intensity to photon number, implicitly connecting amplitude and energy.

The Einsmax formulation reinterprets this structure by treating amplitude as a primary quantized variable while maintaining consistency with established operator formalism [34,36,37].

LIHGT Decomposition

The theory represents light as:

$$L(x, t) = W(x, t) \cdot C(x, t)$$

The wave component satisfies Maxwell's equations [6], while the corpuscular component accounts for discrete interactions consistent with photon-based descriptions [26–28]. Similar dual descriptions appear in absorber theory and advanced formulations of radiation fields [38].

Interference and Coherence

Interference arises from the superposition principle, a direct consequence of linear wave equations [8,44]. For two coherent waves:

$$A_{res} = 2A, u \propto 4A^2$$

Quantum optics explains interference through probability amplitudes and coherence functions [26,27,28].

The Einsmax interpretation associates this enhancement with transitions between amplitude quantum states, providing an alternative perspective consistent with both classical and quantum descriptions.

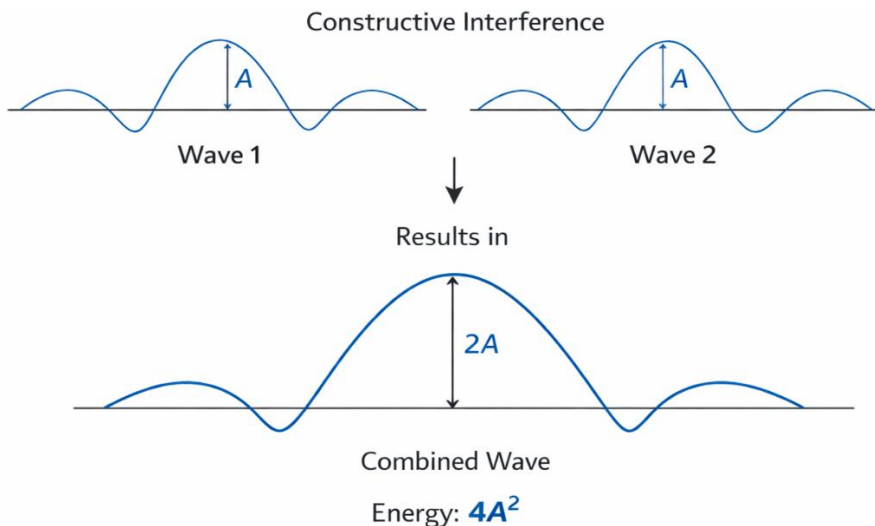


Fig 2. Constructive interference of two coherent waves of equal amplitude results in a combined wave with doubled amplitude and fourfold increase in energy, illustrating a transition between amplitude quantum levels.

Statistical and Thermal Radiation

Planck's radiation law describes the spectral distribution of black-body radiation [4]. Statistical mechanics and field theory further refine this understanding in cosmological and thermal contexts [42].

The Einsmax framework interprets this distribution in terms of amplitude stability and discrete energy levels, complementing conventional statistical interpretations.

Light–Matter Interaction

The photoelectric effect demonstrates the dependence of electron emission on frequency and intensity [2,17]. Quantum theory explains this through photon absorption, while intensity determines emission rate.

Quantum optics further describes light–matter interaction using coherent and incoherent states [26–28,29]. These frameworks are essential in modern applications such as lasers and spectroscopy.

The Einsmax model introduces a dual interpretation in which amplitude governs energy distribution while corpuscular components mediate interaction.

Broader Theoretical Context

The study of light extends beyond QED into broader areas of physics, including:

- Relativistic field theory [36,37]
- Gravitation and spacetime structure [43]
- Cosmological radiation processes [42]
- Quantum field theory frameworks [10,35]

These developments highlight the fundamental role of electromagnetic radiation across physical theories.

CONCLUSION

The Einsmax theory provides a mathematically consistent extension of classical and quantum descriptions of light by introducing amplitude as a quantized variable alongside frequency. Without modifying the predictive success of existing theories, the framework offers an alternative interpretational perspective on electromagnetic radiation and its interaction with matter. This approach opens potential avenues for deeper conceptual understanding while remaining compatible with established physical laws.

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