Light Without Waves: A Pulse-Based Field Framework and the Forge Equation

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Abstract

This paper introduces a pulse-based theoretical framework for modeling light propagation, based on discrete spacetime events rather than continuous electromagnetic waves. We propose the **Forge Equation**, a relativistically covariant field law that governs the emission and propagation of energy pulses via a local pulse density field. This model reproduces core predictions of special relativity, general relativity, and quantum optics—including Doppler shift, cosmological redshift, photon anti-bunching, and statistical double-slit patterns—without invoking wavefunctions, field amplitudes, or continuous oscillations. We outline the foundational components of the theory and present a variational formulation of the Forge Equation.

1 Introduction

Traditional treatments of light rely on Maxwell's equations or wavefunctions—smooth, continuous fields that stretch and interfere. However, all empirical measurements of light consist of *discrete detection events*: photons arrive one by one. This motivates a theory in which the wave picture is not fundamental but emergent. Here we present such a model, grounded in pulse emission, geometry, and detection statistics.

2 Pulse Density Field

Let $\rho(x^\mu)$ denote the *pulse emission density field*, representing the expected number of pulses emitted per unit spacetime volume. Let $u^\mu(x^\nu)$ be the pulse 4-velocity field, constrained to null propagation:

$$g_{\mu\nu}u^\mu u^\nu = 0. \tag{1}$$

3 The Forge Equation

We define the **Forge Equation** as:

$$\boxed{\partial_\mu \left(\rho(x^\mu)u^\mu(x^\nu)\right) = \sigma(x^\mu)} \tag{2}$$

Here $\sigma(x^\mu)$ is a source term representing physical systems (atoms, transitions, etc.) capable of emitting light pulses. This equation governs the flow of discrete energy pulses through spacetime and replaces traditional wave-based field equations.

4 Energy-Timing Duality

From the quantization condition:

$$E = \frac{h}{T_P} \tag{3}$$

we obtain a link between local pulse timing and energy, establishing:

$$\rho(x^\mu) \propto \frac{1}{T_P(x^\mu)}. \tag{4}$$

5 Propagation and Detection

Each pulse travels along a null geodesic. Upon arrival at a detector, it is observed probabilistically:

$$P_{\text{detect}} = \eta \cdot \min\left(1, \frac{E}{E_0}\right) \tag{5}$$

where η is detector efficiency and E_0 is a threshold energy.

6 Variational Formulation

We now present a variational principle from which the Forge Equation and its constraints can be derived.

Let $(M, g_{\mu\nu})$ be a 4D Lorentzian spacetime with metric signature $(-,+,+,+)$. Define the action:

$$S[\rho, u^\mu, \lambda] = \int d^4x \sqrt{-g}\,(-u^\mu \nabla_\mu \rho + \sigma \ln \rho - \lambda\, g_{\mu\nu} u^\mu u^\nu) \tag{6}$$

Here $\lambda(x)$ is a Lagrange multiplier enforcing the null propagation condition.

Euler–Lagrange Equations

The variation of the action yields:

1. **Variation w.r.t. ρ:**

$$\delta S \Rightarrow \nabla_\mu(\rho u^\mu) = \sigma(x) \tag{7}$$

2. **Variation w.r.t. u^μ:**

$$\delta S \Rightarrow \nabla_\mu \rho + 2\lambda g_{\mu\nu} u^\nu = 0 \tag{8}$$

3. **Variation w.r.t. λ:**

$$\delta S \Rightarrow g_{\mu\nu} u^\mu u^\nu = 0 \tag{9}$$

These three equations form a complete system for the pulse density field, null propagation, and source-emission dynamics in spacetime.

7 Conclusion

The Forge Equation provides a simple but powerful tool for modeling light without waves. Its derivation from a covariant action principle reinforces its role as a fundamental equation governing discrete light propagation. This framework matches known physical phenomena and lays the groundwork for a new class of optics and spacetime models based entirely on pulse dynamics.