The NUVO Photon

Part 18 of the NUVO Theory Series

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Abstract

In this work, we develop a scalar-topological formulation of the photon within the NUVO framework, modeling it as a dynamically closed sinertia loop—a finite, coherent structure that carries quantized energy without sourcing curvature or interacting with the scalar field $\lambda(x)$. Unlike traditional approaches that treat photons as quantized excitations of vector fields, the NUVO photon arises from the closure of scalar flux during charge transitions, forming a self-contained loop that propagates along null geodesics in scalar-conformal space.

We derive the quantization relation $E = h\nu$ as a geometric constraint on scalar phase coherence, and show that classical electromagnetic waves emerge in the macroscopic limit from ensembles of phase-aligned photon loops. Photon absorption and emission are modeled as topological reconnection events with open-loop sinertia structures, governed by scalar compatibility and phase alignment. Polarization, redshift, interference, and entanglement are shown to follow directly from the internal geometry and phase constraints of the sinertia loop, without invoking external fields or probabilistic interpretations.

This model unifies quantum optical phenomena and classical wave behavior under a single scalar-geometric principle, providing a physically grounded explanation for light as a topological transport of scalar flux within the coherent scalar field architecture of NUVO space.

1 Introduction

In the scalar-conformal framework of NUVO theory, all physical phenomena arise from the topology and coherence of sinertia—conserved scalar flux that shapes and navigates the geometry of space. Sinertia flowing in closed loops gives rise to mass and gravitational effects by modulating the scalar field $\lambda(x)$ [1], which determines the conformal structure of spacetime. When a sinertia loop is broken, its open ends manifest as electric charge: inflow and outflow endpoints that generate directional scalar imbalance and induce acceleration in other charged systems. These topological configurations form the basis for the unified treatment of mass and charge in NUVO space.

A key question that follows from this foundation is how energy is transmitted between separated charge configurations while preserving scalar coherence. Specifically, what is the nature of the entity that carries quantized energy through space when no sinertia source or sink is present along the path?

In this work, we define the photon as a dynamically closed configuration of sinertia: a coherent, self-contained loop of scalar flux that propagates through space without coupling to or sourcing the scalar field $\lambda(x)$. Unlike open-loop sinertia, which induces acceleration via scalar imbalance, or closed-loop sinertia, which defines geometry via curvature, the photon represents a topologically sealed object—carrying energy and phase information without modifying the underlying geometry. It exists entirely within the scalar-conformal structure but is dynamically distinct from both mass and charge.

We show that such a photon arises naturally from the closure of open sinertia flows—such as those generated during charge acceleration or recombination—and that its stability is maintained by scalar coherence. The photon propagates along null geodesics defined by $\lambda(x)$, and interacts only through reconnection with compatible open-loop sinertia endpoints, i.e., charged particles. It does not couple to gravitational curvature and does not alter the scalar field, explaining its non-gravitating, light-speed propagation.

This topological formulation of the photon allows us to derive its key properties—including quantization, redshift, and polarization—from scalar structure alone, without invoking vector fields or gauge symmetries. In this sense, the photon in NUVO theory is not a field excitation but a topological solution: a stable, finite, coherent object embedded in scalar space.

The treatment presented here preserves compatibility with all prior results in the NUVO series. Scalar geometry remains governed by closed-loop sinertia; acceleration between charges continues to arise from open-loop sinertia flows; and all observable interactions follow from the topology of sinertia and its coupling to matter via the particle's pinertia. The photon, as introduced in this work, represents a new but consistent configuration in the unified scalar framework—a self-propagating, non-curving, quantized loop that transmits energy without altering the geometric field.

2 Scalar-Coherent Framework Recap

NUVO theory describes all physical systems as embedded within a scalar-conformal geometric space, where the scalar field $\lambda(x)$ determines the mapping between proper and coordinate measurements. This scalar field is sourced and shaped by the flow of sinertia, a conserved scalar quantity representing coherent energy flux. The physical behavior of matter arises not from distinct fields, but from the topological configuration of sinertia within space.

2.1 Topological Modes of Sinertia

The core innovation of NUVO theory is the recognition that sinertia exists in multiple topological states, each corresponding to a different physical role:

- **Closed-loop sinertia:** Forms the geometric structure of space by modulating the scalar field $\lambda(x)$. This corresponds to mass and gravity; the resulting curvature defines geodesic motion and gravitational time dilation.
- **Open-loop sinertia:** Occurs when a sinertia loop is broken, resulting in endpoint structures that act as charge. These endpoints generate directional scalar imbalance and induce acceleration in other open-loop systems, explaining classical electric interactions.
- **Dynamically closed sinertia:** Forms coherent, self-contained scalar loops that propagate without sourcing or responding to $\lambda(x)$. These configurations correspond to photons—entities that transmit energy while remaining topologically and geometrically neutral.

Each of these sinertia modes respects scalar coherence and conservation, but they differ in how they couple to geometry and how they interact with other systems.

2.2 Pinertia and Particle Coupling

Particles interact with the scalar structure of NUVO space via their *pinertia* $\pi = (\pi_m, \pi_q)$, which determines how they couple to different sinertia configurations:

- π_m couples the particle to closed-loop sinertia and governs motion through scalar-curved geometry (i.e., gravity).
- π_q couples the particle to open-loop sinertia and governs charge-based acceleration due to scalar imbalance.

These couplings explain both gravitational and electric dynamics within the same scalar-conformal framework, requiring no additional field structures.

2.3 Continuous Presence and Conditional Photonic Visibility

A subtle but essential point in NUVO theory is the distinction between the continuous presence of a particle and the conditions under which it becomes visible through photon-mediated interactions. All particles remain continuously embedded in scalar space, and their sinertial and charge-based effects persist independently of observation. Their mass continuously contributes to $\lambda(x)$, and their charge continuously acts on other open-loop systems via scalar imbalance.

However, photon-based interaction requires specific topological conditions: the emission or absorption of a photon corresponds to a loop closure or reconnection event in the sinertia network. These events occur only when scalar phase coherence is satisfied between the particle and the surrounding space. When this condition is not met, the particle cannot interact photonicly, though it remains fully present and active in all other scalar respects.

This explains why macroscopic systems such as Mercury are always visible—due to the continuous incoherent photon interactions of their many charged constituents—while isolated quantum particles like electrons may appear "invisible" until coherence conditions are met.

In such cases, the particle does not disappear; rather, the scalar configuration does not permit loop-compatible photonic exchange at that moment.

This framework preserves ontological continuity while providing a geometric explanation for discreteness, quantum visibility thresholds, and conditional measurement in scalar-coherent terms.

3 Definition of the Photon as a Dynamically Closed Sinertia Loop

Within the NUVO framework, sinertia serves as the sole conserved scalar flux underlying all physical interaction and structure. Its behavior is determined not by changes in substance, but by changes in topology. While closed-loop sinertia defines the scalar field $\lambda(x)$ and modulates geometry, and open-loop sinertia induces acceleration between charged particles, we now introduce a third topological configuration: the *dynamically closed sinertia loop*, corresponding to the photon.

3.1 Topological Closure Without Geometric Coupling

A photon is defined in NUVO theory as a closed loop of sinertia that carries no net divergence and does not couple to the scalar field $\lambda(x)$. Unlike closed-loop sinertia associated with mass, the photon's loop structure is dynamically self-contained and does not source or modulate geometry. It exists entirely within the scalar-conformal space as a coherent object, but is geometrically passive:

$$\nabla_\mu J^\mu = 0, \quad \text{with} \quad \delta\lambda(x) = 0.$$

The photon arises through a loop closure event—typically from charge acceleration or annihilation—where open-loop sinertia reconnects into a self-contained path. Once formed, the photon propagates without altering the scalar field, and without contributing to spacetime curvature.

3.2 Null Geodesic Propagation

Because it is massless and does not couple to $\lambda(x)$, the photon moves along null geodesics defined by the scalar-conformal metric [2]. Its propagation speed is fixed at c, the characteristic speed of scalar-coherent information transfer in NUVO space. Since the photon does not deform the geometry through which it travels, it remains purely a passenger of the scalar curvature generated by massive systems.

This explains why photons are deflected in gravitational fields (via $\lambda(x)$) but do not themselves curve space or experience time dilation. Their closed sinertia configuration is preserved along the propagation path, and their observed energy may vary due to changes in $\lambda(x)$ (e.g., gravitational redshift), but their internal structure remains intact.

3.3 Scalar Coherence and Stability

The stability of the photon derives from scalar coherence: the loop remains closed and phase-aligned throughout its propagation. No scalar flux is gained or lost, and the absence of endpoints means there is no mechanism for dissipation. The photon remains conserved until it encounters a compatible open-loop system—typically a charged particle—capable of reconnecting with the closed sinertia path.

The photon carries not only energy, but scalar phase information from the point of emission. This includes polarization state, coherence structure, and frequency, all embedded in the loop's internal geometry. These properties are preserved across propagation, except insofar as they are modulated by the scalar field $\lambda(x)$ along the photon's path.

3.4 Interaction Conditions

A dynamically closed sinertia loop does not interact with sinertia of other configurations unless topological conditions allow for reconnection. Specifically:

- It does not couple to closed-loop sinertia (i.e., gravity).
- It does not interact with uncharged particles lacking open-loop connectors.
- It may be absorbed or emitted only by charged particles through open-loop reconnection events.

This framework explains why neutral, massive systems can be invisible to photons, and why photons interact selectively with certain quantum transitions—those with compatible scalar topology and phase alignment.

3.5 Summary

The photon in NUVO theory is a dynamically closed loop of sinertia: conserved, finite, scalar-coherent, and topologically sealed. It does not curve space, is guided by the scalar geometry, and carries quantized energy and scalar phase without divergence. It is neither a field excitation nor a massless particle in the traditional sense, but a geometric-topological object that propagates scalar information and energy through space via coherent loop transport.

4 Quantization and Scalar Closure Conditions

The photon in NUVO theory is modeled as a dynamically closed loop of sinertia—a coherent, self-contained structure that propagates without interacting with the scalar field $\lambda(x)$. Because it is topologically closed, its internal scalar flux must satisfy specific phase continuity and coherence conditions. These conditions naturally lead to the quantization of photon energy, not through imposed postulates, but as a consequence of scalar-topological constraints.

4.1 Scalar Loop Closure and Phase Coherence

To maintain stability during propagation, the sinertia loop that constitutes a photon must close not only topologically, but also in scalar phase. That is, the internal oscillatory structure of scalar flow around the loop must complete an integer number of full phase cycles. If the scalar flux within the loop has an intrinsic frequency ν, then the loop length L must satisfy:

$$L = n\lambda_\nu = n\frac{c}{\nu}, \quad n \in \mathbb{Z}^+,$$

where λ_ν is the scalar coherence wavelength associated with the frequency ν, and n is the integer winding number or mode count. This ensures constructive phase alignment throughout the loop, allowing it to maintain coherence across propagation.

The simplest, lowest-energy photon corresponds to $n = 1$: a loop whose scalar flux completes exactly one phase cycle in one traversal. Higher-energy photons correspond to higher n, representing tighter scalar curvature within the loop and higher internal frequency.

4.2 Quantized Energy from Coherent Sinertia

Since sinertia is conserved and scalar flux must remain coherent throughout the closed loop, the energy E of a photon is directly proportional to its internal frequency ν:

$$E = h\nu,$$

where h is the scalar action constant—interpreted in NUVO theory as the minimal scalar flux circulation required for a stable dynamically closed loop. This relationship emerges naturally from the scalar phase closure condition and reflects the loop's internal flux frequency rather than any probabilistic or external field structure.

In this interpretation, Planck's constant h [5] [4] does not arise from quantization postulates or operator algebra, but from the requirement that scalar flux within a photon loop be phase-stable and topologically self-compatible. Quantization is thus a *topological constraint* imposed by scalar coherence.

4.3 Scalar Redshift and Wavelength Stretching

Because the scalar field $\lambda(x)$ defines the metric of coordinate space, a photon propagating through varying scalar curvature will experience a redshift or blueshift [3] in its observed frequency:

$$\nu_{\text{obs}} = \frac{\nu_{\text{emit}}}{\lambda(x)},$$

where $\lambda(x)$ is the scalar field value along the photon's path. This redshift arises not from energy loss, but from the geometric stretching of the scalar frame in which the photon propagates.

Despite these apparent frequency changes, the loop itself remains phase-closed and energy-conserved in its own proper frame. Observers embedded in scalar-modulated coordinate space experience the change as a shift in frequency and wavelength, consistent with gravitational redshift and cosmic expansion.

4.4 Implications for Emission and Absorption

Photons may only be emitted or absorbed through loop-compatible scalar transitions—namely, when a charged particle's open-loop sinertia configuration matches the coherence conditions of the photon. This requirement imposes selection rules based on scalar topology and phase continuity, which in the quantum regime manifest as transition constraints between atomic or molecular states.

These constraints explain why only discrete photon energies are observed in spectroscopic processes, and why only certain transitions are permitted. The photon's quantization is thus a geometric consequence of scalar loop formation, not a statistical outcome.

4.5 Summary

Photon quantization in NUVO theory arises from the scalar phase closure condition required for dynamically closed sinertia loops. The quantized energy $E = h\nu$ is a direct consequence of topological coherence, not a postulate. Redshift and emission constraints are understood as geometric effects of scalar modulation and phase compatibility. This framework provides a scalar-geometric origin for quantized electromagnetic radiation without invoking external field operators or abstract Hilbert spaces.

5 Propagation in Scalar Geometry

The photon in NUVO theory propagates as a dynamically closed loop of sinertia—topologically stable, scalar-coherent, and geometrically passive. Unlike closed-loop sinertia associated with mass, which sources the scalar field $\lambda(x)$, the photon carries no curvature and moves freely along null geodesics defined by the surrounding scalar geometry. Its behavior is therefore governed entirely by the scalar-conformal metric shaped by distant sinertia sources.

5.1 Geodesic Motion Without Scalar Coupling

Once emitted, the photon follows a path determined by the local scalar field $\lambda(x)$, experiencing no internal evolution or dissipation. Its sinertia loop remains phase-closed and conserved. Because it is massless and divergence-free, the photon propagates at the fixed scalar-modulated speed of light c, traversing paths of vanishing scalar interval:

$$ds^2 = \lambda(x)^2(-c^2 dt^2 + d\vec{x}^2) = 0.$$

These null geodesics allow the photon to respond to curvature induced by massive bodies without itself contributing to the scalar field. Thus, light deflection in gravitational fields arises naturally in NUVO theory as a geometric effect, requiring no coupling between the photon and $\lambda(x)$.

5.2 Redshift as Scalar Differential

Although the photon's internal sinertia loop remains fixed, the scalar field through which it propagates may vary over space or time. As the photon travels from a region of scalar field

$\lambda(x_0)$ to a region $\lambda(x_1)$, the frequency observed by an embedded observer is modulated by the scalar field ratio:

$$\nu_{\text{obs}} = \frac{\nu_{\text{emit}}}{\lambda(x_1)}.$$

This phenomenon corresponds to redshift if $\lambda(x_1) > \lambda(x_0)$, or blueshift if $\lambda(x_1) < \lambda(x_0)$. The photon itself does not change, but the observer's coordinate measurement does, as it is scaled by the local scalar geometry.

5.3 Scalar Frame Analogy: The Ocean Depth Model

This behavior may be intuitively understood by analogy to a sealed pressure vessel moving through an ocean of varying depth. The photon, like a pressure-sealed container, preserves its internal scalar configuration as it moves. Its internal scalar phase and energy content remain fixed relative to its point of emission. However, the scalar field outside the photon varies with location, analogous to changing ocean pressure with depth.

An observer embedded in the scalar "ocean" perceives a mismatch between the photon's internal structure and the surrounding scalar field. This scalar differential manifests as a redshift or blueshift in frequency. The shift does not imply energy loss or gain, but a reinterpretation of the photon's internal structure through a differently scaled geometric frame.

5.4 No Energy Dissipation or Backreaction

Because the photon is topologically closed and does not couple to $\lambda(x)$, it neither gains nor loses energy during propagation. It does not radiate or scatter unless it encounters an open-loop sinertia configuration (e.g., a charged particle) capable of scalar reconnection. There is no backreaction on the scalar field, and no energy is transferred to the geometry through which it travels.

This explains the photon's extreme stability and lack of interaction with neutral or uncharged matter. It is not absorbed or deflected unless a topologically compatible scalar structure is present to support reconnection.

5.5 Summary

Photons propagate in NUVO space as scalar-coherent, dynamically closed sinertia loops. Their internal structure is fixed at emission, while their observed frequency is modulated by the scalar field $\lambda(x)$ along the propagation path. This scalar differential gives rise to redshift and blueshift without altering the photon's energy in its own frame. The photon is not a field excitation but a topological object whose motion is fully guided by scalar-conformal geometry.

6 Interaction with Charged Particles

Photons in NUVO theory are dynamically closed sinertia loops that propagate without coupling to the scalar field $\lambda(x)$. Their internal structure is scalar-coherent and topologically sealed. However, under appropriate geometric and topological conditions, these loops may interact with matter by reconnecting with open-loop sinertia structures—specifically, the endpoints associated with electric charge.

6.1 Charged Particles as Open Sinertia Structures

Electric charge is understood in NUVO theory as the presence of an open-loop sinertia configuration. A positive charge corresponds to an unbalanced inflow of scalar flux; a negative charge corresponds to an unbalanced outflow. These endpoints act as connectors to the scalar flux network and are responsible for inducing acceleration through local scalar imbalance.

Because photons carry scalar flux in a closed-loop configuration, interaction with a charged particle requires that the loop be opened and attached to a compatible endpoint. This process is fundamentally topological: the loop must be broken in a way that satisfies scalar coherence and phase compatibility with the open structure of the absorbing or emitting particle.

6.2 Photon Absorption as Loop Reconnection

When a photon encounters a compatible open-loop sinertia structure—such as that of a charged particle—it may be absorbed via loop reconnection. This process involves attaching one segment of the photon's scalar loop to the charge's endpoint and integrating the photon's scalar flux into the particle's existing sinertia configuration.

This absorption event occurs only if the following conditions are satisfied:

- The charge possesses an open-loop sinertia endpoint with appropriate phase alignment.
- The scalar flux of the photon matches the particle's internal flux configuration within allowable coherence margins.
- The combined structure remains consistent with scalar conservation and topological closure.

When these criteria are met, the photon loop becomes part of the particle's sinertia structure, typically resulting in a transition to an excited state in a bound system.

6.3 Photon Emission as Loop Formation

Conversely, when a charged particle undergoes a transition that releases scalar flux—such as during deceleration, state relaxation, or recombination with an oppositely charged particle—the particle may emit a photon. This occurs when a portion of the particle's open-loop sinertia flow self-connects into a dynamically closed loop, forming a photon.

This process of scalar loop closure produces a stable, quantized, phase-coherent sinertia structure that detaches from the emitting particle and propagates freely. As in absorption, the process is governed by coherence and conservation:

- The emitted scalar flux must form a closed loop with quantized phase winding.

- The emission must preserve total sinertia flux and scalar phase continuity.
- The resulting loop must be dynamically sealed and divergence-free.

Photon emission is thus not random, but a topological event governed by the scalar geometry and coherence of the emitting charge configuration.

6.4 Selective Interaction and Quantum Conditions

The topological criteria for photon emission and absorption impose natural selection rules on scalar interactions. Only configurations that permit scalar phase matching and topological compatibility will lead to photon exchange. This explains, from first principles, the discrete nature of atomic transitions and the wavelength-specific nature of photon-matter interaction.

In traditional quantum mechanics, these effects are modeled using operator-based selection rules. In NUVO theory, the same constraints arise directly from scalar geometry: only certain transitions are allowed because only certain loop reconnections are topologically and phase-coherently possible.

6.5 Note on Transient Scalar Reconnection

It is worth noting that during photon absorption or emission, the dynamically closed sinertia loop of the photon momentarily reconnects with an open-loop sinertia structure. Although the photon does not normally couple to the scalar field $\lambda(x)$, such a transient reconnection mimics a closed-loop configuration and may, in principle, produce an infinitesimal and non-persistent local curvature. This effect is addressed in Appendix A, where we also clarify the distinction between energy-carrying and power-sourcing sinertia modes.

6.6 Summary

Photons interact with charged particles through topological reconnection of scalar flux. Absorption corresponds to the incorporation of a closed sinertia loop into an open-loop structure; emission corresponds to the closure and detachment of scalar flux from a charged system. These interactions are governed by scalar coherence, phase alignment, and conservation. The photon is not absorbed or emitted by neutral systems, nor by geometric curvature, but exclusively by open-loop sinertia configurations capable of topological engagement.

7 Polarization and Loop Structure

In NUVO theory, the photon is modeled as a dynamically closed loop of sinertia: a coherent, finite structure of scalar flux that propagates without coupling to the scalar field $\lambda(x)$. While its frequency and energy are determined by internal phase winding, the photon's polarization emerges from the geometric and rotational characteristics of its closed loop structure.

7.1 Loop Geometry and Directionality

Because the photon is a closed sinertia loop, it possesses an internal circulation path that defines a preferred direction around the loop. This circulation is preserved under propagation and forms the geometric basis for polarization. Two primary characteristics emerge from this structure:

- **Loop plane orientation:** The orientation of the loop's geometric plane defines the polarization axis.
- **Circulation sense:** The handedness or twist of scalar flow around the loop corresponds to circular or elliptical polarization states.

A photon with scalar flow circulating in a planar loop without torsion corresponds to linear polarization. If the loop exhibits a continuous twist or helicity, the photon exhibits circular or elliptical polarization, depending on the scalar phase relationship between loop segments.

7.2 Linear Polarization

Linear polarization arises when the scalar flux circulates in a planar loop with a fixed orientation. The scalar field's oscillation vector lies in a single plane, and the closed-loop sinertia structure maintains a stable polarization axis throughout propagation. The plane of the loop, projected onto coordinate space, defines the polarization direction observed by embedded scalar observers.

Because the loop is dynamically closed, this orientation is conserved unless the photon interacts with a boundary or medium capable of modifying the loop geometry through scalar reconnection or induced phase shift.

7.3 Circular and Elliptical Polarization

When the scalar flux circulates through a helical or twisted loop configuration, the photon exhibits circular or elliptical polarization. In such cases, the scalar phase does not oscillate in a fixed plane but traces out a rotating vector in space. This behavior corresponds to:

- **Circular polarization:** A symmetric twist in scalar phase around the loop, producing equal-amplitude phase rotation in orthogonal directions.
- **Elliptical polarization:** An asymmetric twist or phase imbalance across the loop, resulting in an unequal amplitude ellipse traced by the scalar oscillation vector.

These polarization states are encoded in the photon's internal loop structure and are preserved along its null geodesic trajectory. They may be altered only by interaction with topologically compatible systems, such as birefringent materials or polarizing boundaries capable of modifying loop geometry.

7.4 Geometric Origin Without Field Vectors

Importantly, polarization in NUVO theory does not arise from oscillating electric and magnetic field vectors, as in classical electrodynamics. Instead, it is a purely geometric property of the scalar-coherent sinertia loop. The scalar flux's path around and through the loop defines its polarization state, and changes in polarization arise from alterations in the loop's shape, twist, or internal phase geometry.

This framework accounts for all classical polarization phenomena without invoking field lines or vector superposition. Interference, birefringence, and filtering all correspond to geometric selection or modulation of scalar loop topology.

7.5 Summary

Polarization in NUVO theory is a geometric attribute of the photon's closed sinertia loop. Linear, circular, and elliptical polarizations correspond to different loop orientations and phase twist patterns. These configurations are preserved under propagation and may only be altered by coherent scalar interaction. The topological origin of polarization replaces field vector formalism with loop-based scalar geometry, consistent with the unified scalar-coherent framework of NUVO space.

8 Classical Limit: Electromagnetic Waves from Photon Flux

While NUVO theory models photons as discrete, dynamically closed sinertia loops, classical electromagnetic waves emerge in the macroscopic limit as coherent ensembles of such structures. In this regime, the collective behavior of many photons—each propagating as an individual scalar-coherent loop—produces interference, diffraction, and continuous wave phenomena familiar from classical electrodynamics.

8.1 Photon Ensembles and Scalar Flux Superposition

In the low-frequency, high-density limit, a large number of photons with nearly identical phase, polarization, and propagation direction can be treated as a coherent scalar flux ensemble. Although each photon remains a distinct topological object, their phase-coherent emission results in constructive interference along defined directions, and destructive interference in others.

This scalar superposition yields an effective continuous oscillatory scalar structure in coordinate space, analogous to the classical electric field:

$$\vec{E}_{\text{eff}}(x,t) \propto \sum_i \nabla \lambda_q^{(i)}(x,t),$$

where each $\lambda_q^{(i)}$ represents the scalar potential contribution associated with the i^{th} photon's internal flux alignment. In the far-field regime, this effective field forms a transverse wave whose direction, amplitude, and polarization are governed by the collective loop geometries of the photons involved.

8.2 Wavefronts and Propagation Direction

In a classical electromagnetic wave, energy propagates in a well-defined direction orthogonal to the polarization axis. In NUVO theory, this directionality arises from the alignment of photon loop orientations and the phase-synchronized emission of closed-loop sinertia structures. As a coherent packet of photons moves through space, the overlap of their scalar contributions defines effective wavefronts whose normal vector points along the propagation direction.

The transverse nature of these wavefronts is preserved because scalar flux within each photon loops in a direction orthogonal to its motion. In this way, the polarization and propagation direction of a classical electromagnetic wave emerge naturally from the loop geometry of its constituent photons.

8.3 Emergence of Maxwellian Behavior

While NUVO does not introduce electric and magnetic vector fields as fundamental objects, the classical behavior described by Maxwell's equations is effectively recovered in this limit. Specifically:

- The time evolution of coherent scalar flux patterns gives rise to wave-like energy propagation at speed c.
- The scalar gradients traced by many photons form transverse oscillating patterns consistent with $\vec{E}$ and $\vec{B}$ fields.
- The combined structure satisfies macroscopic wave equations in regions where sinertia sources and sinks are negligible.

In this sense, classical electrodynamics is recovered as a statistical and geometric limit of underlying scalar-topological photon dynamics. The fields of Maxwellian theory are not rejected but are reinterpreted as emergent, effective constructs derived from coherent sinertia loop ensembles.

8.4 Loss of Individuality in the Classical Limit

As the number of photons increases and coherence length extends, individual loop identities become statistically indistinct. The scalar flux structure approaches a continuum, and the discrete loop topology is no longer directly observable. This limit explains why classical wave optics does not exhibit quantum effects such as photon counting, polarization quantization, or spontaneous emission thresholds.

The continuous wave emerges not from a continuous medium, but from a densely packed scalar network of photon-like closed sinertia loops, whose individual identities blur in aggregate behavior.

8.5 Summary

Classical electromagnetic wave behavior emerges in NUVO theory as the macroscopic, coherent limit of ensembles of dynamically closed sinertia loops. Wavefronts, polarization, and directionality arise from collective geometric alignment of photon loops. Maxwellian wave equations are recovered as effective field approximations to coherent scalar loop interference patterns. In this way, the classical and quantum descriptions are unified under a single topological scalar framework.

9 Photon Coherence, Interference, and Entanglement

The NUVO framework describes photons as dynamically closed sinertia loops, each with a defined scalar phase structure and internal coherence. When multiple photons are emitted with correlated phase relationships, their interactions exhibit behaviors typically described as quantum coherence, interference, and entanglement. In NUVO theory, these effects are understood as consequences of geometric compatibility and scalar phase alignment across multiple sinertia loops.

9.1 Scalar Phase Coherence Between Photons

Each photon loop carries an internal scalar phase that is set at the time of emission. When multiple photons are emitted from a common source or coupled transition—such as an atomic decay or oscillator—they may share a well-defined relative phase. If their internal scalar flux structures are phase-aligned and topologically synchronized, they form a coherent ensemble.

This coherence allows overlapping scalar contributions to interfere constructively or destructively in space, producing well-defined interference patterns. In this picture, interference is not a field overlay but a result of geometric scalar flux compatibility between loop structures.

9.2 Double-Slit and Interference Patterns

In NUVO theory, the double-slit [5] experiment reveals the behavior of a single closed-loop sinertia structure propagating through multiple spatial extensions while preserving scalar coherence. As the photon traverses the slit apparatus, its loop temporarily spans multiple topologically admissible paths—each contributing a path-dependent scalar phase as it evolves through the local $\lambda(x)$ field geometry.

Crucially, these scalar phases are not external wavefunctions but intrinsic to the loop's internal scalar circulation. Upon reaching the detection screen, the loop attempts reclosure in a way that preserves total scalar phase continuity. Constructive interference occurs where scalar phase contributions across all paths align to permit coherent reclosure. Destructive interference arises where no topologically valid reclosure is permitted under scalar continuity constraints.

This geometric interpretation avoids the need for wavefunction collapse or probabilistic interpretations. The interference pattern emerges not from delocalized wave interference, but from the scalar-geometric conditions required for a photon loop to close consistently across a multiply-extended path. The act of measurement or detection truncates the loop prematurely, collapsing its extended coherence and localizing the interaction.

This perspective provides a unified explanation for quantum interference: it is the natural consequence of scalar phase coherence across multiple geodesic paths within a single looped sinertia structure.

(See Appendix F for empirical examples across particle types.)

9.3 Entanglement as Global Scalar Loop Constraint

When two photons are emitted from a common quantum event—such as atomic decay or pair production—their sinertia loops may emerge as segments of a single, initially unified scalar loop. Although spatially separated, these loops remain linked by a global scalar phase constraint, such that measurements on one affect the topological compatibility of the other.

In NUVO theory, entanglement does not require non-local signaling or hidden variables. Instead, it reflects a topological dependency: the requirement that total scalar coherence be preserved across what were originally joint scalar structures. This explains why entangled particles exhibit correlated behavior when measured in matching bases, even when spatially distant.

9.4 Decoherence and Environmental Interaction

Decoherence occurs when the scalar phase integrity of a photon loop is disrupted through uncontrolled interaction with the environment. In NUVO terms, this corresponds to partial reconnection, scattering, or loop deformation caused by incoherent scalar structures. Once decoherence occurs, the photon no longer exhibits strict interference or entanglement behavior, as its scalar loop is no longer in a cleanly defined phase-closed state.

This framework provides a geometric explanation for the transition from coherent quantum behavior to classical statistical outcomes, without invoking wavefunction collapse. It also frames the measurement process as a physical act of scalar loop reconnection or destruction.

9.5 Summary

Quantum optical phenomena such as interference, coherence, and entanglement emerge in NUVO theory from scalar phase relationships and topological constraints between dynamically closed sinertia loops. Interference arises from path-dependent scalar flux reclosure, while entanglement reflects persistent global coherence between photon loops. Measurement and decoherence correspond to interactions that disrupt or reconfigure scalar loop structures. This view eliminates the need for abstract probabilistic formalism, replacing it with geometric coherence across scalar topology.

10 Summary and Principles

In this work, we have developed a scalar-topological model of the photon within the NUVO framework, grounded in the coherent dynamics of sinertia. Unlike traditional approaches that treat the photon as a point particle or a quantized excitation of a vector field, NUVO theory describes the photon as a dynamically closed loop of sinertia: a topologically sealed, scalar-coherent structure that propagates through scalar-conformal space without sourcing curvature or altering geometry.

10.1 Key Principles

1. **Photons are closed-loop sinertia structures.** Each photon is a finite, dynamically closed scalar flux loop, formed during charge transitions that reconnect or release open-loop sinertia. These loops are conserved, stable, and internally coherent.

2. **Photons do not couple to geometry.** Unlike closed-loop sinertia associated with mass, photons do not source or respond to the scalar field $\lambda(x)$. They propagate along null geodesics determined by the surrounding scalar geometry but do not contribute to scalar curvature.

3. **Energy quantization arises from scalar coherence.** Photon energy $E = h\nu$ results from the scalar phase closure condition required for loop stability. This quantization emerges naturally from the internal geometry of the sinertia loop, without invoking operator formalism.

4. **Redshift and blueshift reflect scalar differential.** As photons traverse varying scalar fields $\lambda(x)$, their frequency appears redshifted or blueshifted to embedded observers. This is interpreted as a scalar differential between the photon's internal structure and the external geometric field, not as energy loss or gain.

5. **Photon interaction occurs only through scalar reconnection.** Photons are emitted or absorbed by charged particles via topologically compatible scalar loop reconnection. Only open-loop sinertia structures—i.e., charge—can couple to photons, preserving the distinction between energy carriers and power sources.

6. **Polarization is a geometric feature of the loop.** Linear, circular, and elliptical polarizations correspond to loop plane orientation and internal twist. These are intrinsic properties of the sinertia loop structure and remain fixed under propagation.

7. **Classical wave behavior emerges from coherent photon ensembles.** In the limit of dense, phase-aligned photon emission, classical electromagnetic wave patterns emerge as effective scalar interference structures. Maxwellian behavior is recovered as a collective geometric approximation of underlying sinertia dynamics.

8. **Quantum optical effects arise from scalar topology.** Interference, coherence, and entanglement are consequences of scalar phase alignment and loop compatibility. These effects do not require abstract wavefunctions or probabilistic collapse, but follow from scalar flux continuity and topological constraints.

10.2 Conclusion

The photon in NUVO theory is not a particle in the conventional sense, nor a field excitation in quantized space. It is a geometric object: a coherent, closed-loop configuration of sinertia that transmits energy and scalar information through spacetime. Its interactions are discrete, its propagation is guided by geometry, and its quantization is topological.

This scalar-topological model unifies gravitational, electromagnetic, and quantum optical behavior within a single coherent framework. It eliminates the need for field dualism, replaces probabilistic postulates with geometric necessity, and offers a new conceptual foundation for understanding light as a natural consequence of scalar-coherent geometry.

A Transient Scalar Coupling and Curvature Considerations

In NUVO theory, photons are defined as dynamically closed sinertia loops that propagate without coupling to the scalar field $\lambda(x)$. However, during absorption or emission, the photon undergoes a brief topological reconnection with an open-loop sinertia structure. This process, while momentary, raises the question of whether the resulting intermediate configuration momentarily behaves like a closed-loop sinertia source, and thus might contribute to local curvature.

A.1 Local Curvature During Reconnection

During the reconnection event, the sinertia loop of the photon may become geometrically indistinguishable—briefly—from a closed-loop sinertia configuration. As such, it possesses the same topological prerequisites as a gravitationally active structure. This implies that, in principle, it could source a transient modification to the scalar field $\lambda(x)$ in the form of a localized, infinitesimal perturbation:

$$\delta\lambda(x) \propto \delta(t - t_0)\, f_{\text{reconn}}(x),$$

where t_0 is the moment of reconnection and $f_{\text{reconn}}(x)$ is a sharply localized scalar contribution. However, due to the vanishing duration and minuscule scalar flux involved, this curvature effect is negligible in all practical and observable scenarios:

$$\delta\lambda(x) \ll \epsilon_{\text{exp}},$$

where ϵ_{exp} denotes the experimental detection threshold.

A.2 Energy vs. Power in Scalar Topology

This momentary curvature interaction also highlights a deeper distinction between scalar structures that carry *energy* and those that deliver *power*:

- **Photons** (dynamically closed sinertia) are finite, encapsulated energy carriers. They transmit scalar flux in a sealed, conserved package with a defined coherence length and frequency.
- **Open-loop sinertia** (associated with electric charge) represents a continuous power conduit, capable of emitting or absorbing scalar flux indefinitely through sustained imbalance.
- **Closed-loop sinertia** (mass) defines spacetime curvature and may act as a persistent reservoir or sink of scalar power.

This distinction explains why photons can deposit discrete energy quanta without altering the underlying scalar field, and why charged particles can continue interacting indefinitely even in the absence of photonic exchange.

A.3 Conclusion

The brief reconnection of a photon with a charged particle may transiently resemble a curvature-producing loop, but its effect on the scalar field $\lambda(x)$ is vanishingly small. Nonetheless, recognizing this interaction clarifies how photon-matter coupling sits at the interface between dynamical and geometric sinertia structures. It also underscores the conceptual importance of distinguishing scalar energy carriers (photons) from scalar power structures (mass and charge) in the broader architecture of NUVO theory.

B Loop Quantization Derivation

In NUVO theory, the photon is modeled as a dynamically closed sinertia loop—a coherent, finite scalar flux structure that propagates without coupling to the scalar field $\lambda(x)$. Its stability and quantized energy follow from the topological requirement that scalar phase within the loop completes a full integer winding upon closure. In this appendix, we derive the quantization condition for photon energy based on this scalar phase coherence constraint.

B.1 Scalar Phase and Loop Closure

Let the scalar flux circulating within the photon's loop have an intrinsic angular frequency $\omega = 2\pi\nu$. Define the total proper path length L around the loop (measured in the local scalar-conformal frame) and assume the scalar phase accumulates linearly along this path.

The total phase Φ accumulated over one complete circuit is given by:

$$\Phi = \int_0^L k\,ds = kL = \frac{2\pi}{\lambda_\nu} L,$$

where $k = 2\pi/\lambda_\nu$ is the scalar wavenumber associated with internal flux oscillation, and $\lambda_\nu = c/\nu$ is the scalar coherence wavelength.

For the loop to be stable and phase-closed, the scalar flux must complete an integer number of full phase cycles:

$$\Phi = 2\pi n, \quad n \in \mathbb{Z}^+.$$

Thus, the loop length is constrained by:

$$L = n\lambda_\nu = n\frac{c}{\nu}.$$

This condition ensures that scalar coherence is preserved as the loop circulates, allowing constructive interference of internal flux with itself and preventing destructive decoherence. It is a geometric-topological version of a standing wave constraint.

B.2 Quantized Energy from Loop Frequency

Since sinertia is conserved and the photon carries no open-loop endpoints, its total scalar flux energy must remain fixed across propagation. We postulate that the energy stored in the loop is proportional to the internal frequency of scalar phase rotation:

$$E = n\,h\nu,$$

where n is the number of phase windings around the loop and h is the scalar action constant—representing the minimal unit of coherent scalar phase flux in a stable loop configuration.

For the fundamental photon state with $n = 1$, this reduces to:

$$E = h\nu,$$

consistent with experimental observation. Higher-order scalar loop configurations (e.g., $n = 2, 3, \ldots$) correspond to higher-energy photon modes or coherent harmonic states.

B.3 Interpretation of h in Scalar Terms

Within this framework, Planck's constant h is interpreted not as an empirical quantum parameter, but as the scalar action associated with a single full cycle of phase-coherent sinertia loop closure. It defines the smallest amount of scalar flux that can maintain topological stability in a dynamical loop.

This reinterprets quantization as a geometric constraint, not a probabilistic rule. There are no imposed discrete energy levels; instead, scalar loops can only form in configurations that meet the conditions for internal phase closure.

B.4 Comparison to Classical Cavity Modes

This derivation closely parallels standing wave conditions in resonant cavities, where phase continuity at boundary points restricts allowed modes. However, in NUVO theory, the boundary is internal: the scalar loop must close upon itself in a globally phase-consistent way, rather than on an external container.

This distinction emphasizes that the photon is self-bounded: its internal structure defines the allowed frequencies, and its geometry enforces energy quantization through scalar coherence.

B.5 Conclusion

The photon energy relation $E = h\nu$ arises in NUVO theory from scalar phase closure constraints on dynamically closed sinertia loops. Quantization is not imposed, but emerges as a necessary condition for stability and coherence. This derivation supports the interpretation of photons as scalar-topological objects whose internal frequency, loop length, and energy are tightly coupled by geometric necessity.

C Comparison to Classical Electrodynamics

NUVO theory reformulates electromagnetic radiation as a scalar-topological phenomenon: photons are dynamically closed loops of sinertia, not excitations of a vector field. Nevertheless, classical electrodynamics has demonstrated remarkable empirical success, and any new framework must recover its predictions in the appropriate macroscopic limits.

In this appendix, we outline how NUVO theory recovers the functional behavior of classical electromagnetism, while offering a reinterpretation of its foundational constructs.

C.1 Maxwellian Fields as Emergent Scalar Structures

In classical electrodynamics, the electric field $\vec{E}$ and magnetic field $\vec{B}$ are treated as vector fields in space, governed by Maxwell's equations. These fields are continuous, differentiable, and defined everywhere, even in the absence of localized particles. The speed of propagation of field changes is set by the vacuum constants ε_0 and μ_0, with:

$$c = \frac{1}{\sqrt{\varepsilon_0 \mu_0}}.$$

In NUVO theory, photons are not excitations of a vector field. Instead, they are finite, quantized, scalar-coherent loops of sinertia. The observed electromagnetic fields $\vec{E}$ and $\vec{B}$ in classical systems emerge from the collective behavior of large ensembles of phase-coherent photon loops. That is:

- The effective $\vec{E}$ field corresponds to the scalar gradient structure generated by the loop orientations of many photons.
- The effective $\vec{B}$ field corresponds to the transverse circulation of scalar flux in space as loop ensembles propagate.

This reinterpretation resolves the ontological ambiguity of fields in vacuum: electromagnetic effects do not arise from structureless space but from scalar flux patterns embedded in a coherent topological network.

C.2 Wave Equation Recovery

Maxwell's equations predict that in the absence of sources, electric and magnetic fields satisfy wave equations:

$$\Box \vec{E} = 0, \quad \Box \vec{B} = 0.$$

In NUVO theory, the same wave behavior arises in the large-N, high-coherence limit of photon ensembles. When photons of similar frequency, polarization, and phase propagate together, their scalar fields superpose constructively, yielding smooth, continuous scalar structures. These scalar patterns satisfy wave-like evolution:

$$\Box \lambda_q(x) \approx 0,$$

where $\lambda_q(x)$ represents the effective scalar potential formed by overlapping photon loops. This scalar wave field plays the role of the classical electromagnetic wave, with group velocity and interference patterns consistent with classical optics.

C.3 Field Line Interpretation and Source Coupling

In classical theory, field lines emanate from charges and represent lines of force or flux. In NUVO theory, this picture is replaced by the topology of open-loop sinertia:

- Positive charges are inflow endpoints of open sinertia loops.
- Negative charges are outflow endpoints.
- Scalar flux travels along coherent paths between charges or into dynamically closed loops (photons).

There are no "field lines" per se, but rather real, structured scalar flux pathways governed by conservation, coherence, and topology. This removes the abstraction of virtual fields and replaces it with a more grounded scalar transport framework.

C.4 Energy Density and Radiation Pressure

The classical expressions for electromagnetic energy density and momentum flux:

$$u = \frac{1}{2}\left(\varepsilon_0 E^2 + \frac{1}{\mu_0} B^2\right), \quad \vec{S} = \vec{E} \times \vec{B}/\mu_0,$$

can be recovered as effective quantities in the scalar ensemble limit. In NUVO theory:

- The energy carried by a photon ensemble is the sum of individual loop energies: $\sum_i h\nu_i$.
- The energy density u arises from the spatial density of loop crossings and their internal flux.
- The Poynting vector $\vec{S}$ corresponds to the directional propagation of net scalar flux through space.

Thus, classical radiation pressure and energy transfer phenomena arise from the coherent transport of scalar flux by photon loops—not from abstract oscillating vectors.

C.5 Summary of Correspondence

Classical Quantity	**NUVO Interpretation**
$\vec{E}$ field	Scalar gradient from coherent photon loop orientation
$\vec{B}$ field	Transverse circulation of scalar flux in photon ensembles
ε_0, μ_0	Scalar coherence and transport constants (Appendix C, Charge Paper)
EM wave	Large-N coherent limit of scalar photon superposition
Radiation pressure	Net scalar momentum flux from photon loop transfer

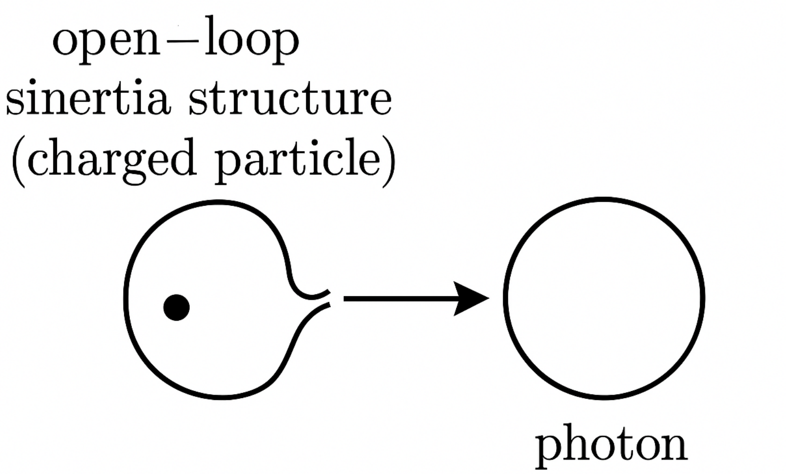
C.6 Conclusion

Classical electrodynamics is recovered in NUVO theory as the macroscopic, statistical limit of coherent scalar loop dynamics. The electric and magnetic fields are not fundamental but emergent from structured sinertia flow. This reinterpretation preserves all empirical predictions while eliminating the need for independent vector fields in vacuum, replacing them with a scalar-topological foundation grounded in geometry and coherence.

D Schematic Diagrams of Loop Closure and Photon Exchange

This appendix provides conceptual illustrations of photon-related sinertia dynamics in NUVO theory. Each diagram represents a simplified scalar-topological configuration that captures the essence of emission, absorption, and propagation of photons, modeled as dynamically closed loops of sinertia.

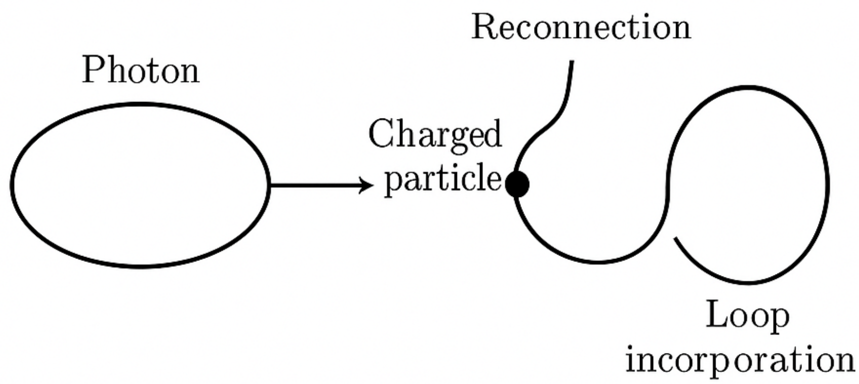
D.1 Figure D.1: Emission of a Photon via Loop Closure



Emission of a Photon via Loop Closure

Description: - A charged particle is depicted as an open-loop scalar flux line with an endpoint. - During a transition (e.g., energy level drop), a portion of this open loop self-reconnects to form a dynamically closed sinertia loop. - The resulting structure detaches and propagates away as a photon. - The charge retains an open-loop endpoint and continues to act as a scalar flux sink or source.

D.2 Figure D.2: Absorption of a Photon via Loop Reconnection



Absorption of a Photon via Loop Reconnection

Description: - A photon (closed sinertia loop) approaches a charged particle. - The loop partially opens and reconnects with the open-loop endpoint of the particle. - The scalar flux of the photon integrates into the particle's internal sinertia structure. - The photon ceases to exist as an independent loop, and the charge transitions to a new scalar state.

D.3 Figure D.3: Propagation of a Photon Through Scalar Geometry

Description: - A dynamically closed sinertia loop propagates along a null geodesic. - The curvature of the path is due to the gradient of the scalar field $\lambda(x)$, not due to any interaction with the photon. - The internal structure and phase of the loop remain intact throughout propagation. - Scalar redshift or blueshift can be inferred from the change in ambient $\lambda(x)$ along the path.

Figure D.3: Photon Propagation through Scalar Geometry

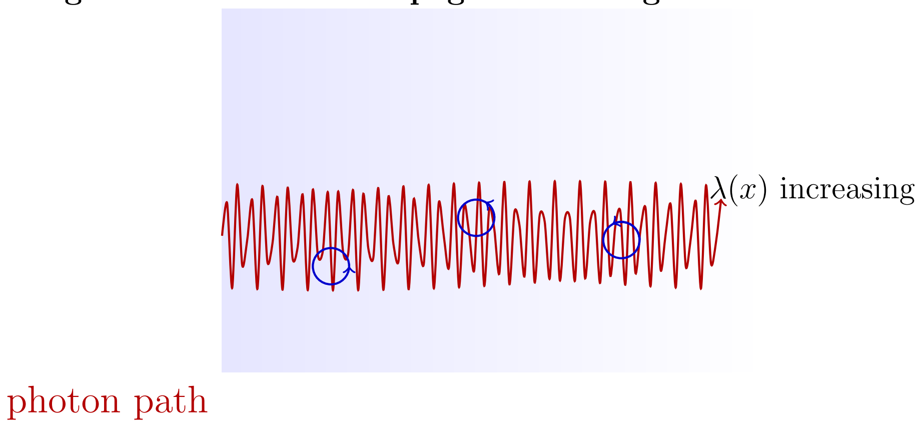
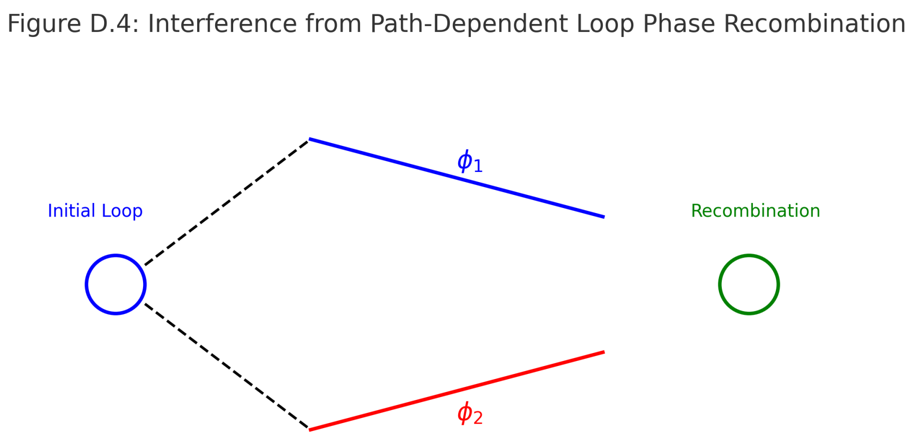


Figure 1: A closed sinertia loop (photon) propagating along a curved geodesic path in scalar-conformal space. The scalar background gradient, represented by horizontal shading, defines the modulation of $\lambda(x)$, which bends the photon's trajectory.

D.4 Figure D.4: Interference from Path-Dependent Loop Phase Recombination



Description: - A single photon's loop follows two distinct paths around an obstacle (analogous to a double-slit). - Along each path, the loop accumulates a different scalar phase. - At recombination, the internal scalar coherence condition determines whether the loop can re-close constructively. - If phase alignment is satisfied, interference is constructive; if misaligned, the loop fails to reclose and yields destructive interference.

D.5 Use of Diagrams

These diagrams are intended to support conceptual understanding of NUVO photon dynamics. They do not depict literal geometric embedding, but rather the topological relations and scalar flux connectivity between charged systems and dynamically closed sinertia loops.

They serve as heuristic visualizations of scalar flow, loop reconnection, and coherence in a physically grounded geometric space.

E Mathematical Structure of Scalar Coherence and Entanglement

This appendix develops the scalar phase formalism underlying photon coherence and entanglement in NUVO theory. While the main text presents the conceptual topology of dynamically closed sinertia loops, this appendix describes how loop phase relationships constrain possible recombinations, interference outcomes, and entangled correlations.

E.1 Scalar Phase Representation of a Photon Loop

Each photon in NUVO theory is modeled as a closed sinertia loop with a scalar phase function $\phi(s)$, where s is the intrinsic loop coordinate (parameterized by arc length). To preserve coherence, the phase must complete an integer multiple of 2π over the full loop:

$$\phi(s + L) = \phi(s) + 2\pi n, \quad n \in \mathbb{Z}^+,$$

where L is the loop's scalar-modulated length and n is the winding number. The local scalar phase is defined modulo 2π, but the global structure enforces quantized winding.

E.2 Coherent Superposition and Interference Conditions

Two photon loops with scalar phases $\phi_1(s)$ and $\phi_2(s)$ can only interfere constructively if their phase difference remains constant or varies slowly over the region of overlap. Define the phase mismatch function:

$$\Delta\phi(s) = \phi_1(s) - \phi_2(s).$$

Constructive interference occurs if:

$$|\Delta\phi(s)| < \epsilon_{\text{coh}}, \quad \forall s \in \text{overlap domain},$$

where ϵ_{coh} is a scalar coherence threshold determined by environmental and geometric factors (e.g., path length difference, spectral width, curvature of $\lambda(x)$).

If this condition fails, the scalar flux structures of the two loops become incompatible, and the probability of successful scalar reconnection (or measurement) drops rapidly. This geometric scalar condition replaces probabilistic collapse with deterministic loop compatibility.

E.3 Entanglement as a Global Constraint on Scalar Phase

Consider two photon loops, $\phi_A(s)$ and $\phi_B(s)$, emitted as segments of a shared scalar-coherent event. These loops are not independent; they originate from a shared parent structure $\phi_{\text{total}}(s)$ such that:

$$\phi_{\text{total}}(s) = \phi_A(s) + \phi_B(s),$$

where scalar coherence requires that $\phi_{\text{total}}(s)$ satisfy global closure:

$$\phi_{\text{total}}(s + L_{\text{total}}) = \phi_{\text{total}}(s) + 2\pi n.$$

This imposes a constraint:

$$\Delta\phi_A(s) = -\Delta\phi_B(s),$$

meaning any scalar phase adjustment or measurement-induced realignment on one loop must be balanced by a corresponding shift in the other. This is the topological origin of entanglement correlations in NUVO theory.

There is no nonlocal signaling; rather, the loops share a global scalar phase structure. Observers detect correlated results because their measurements must conform to the same underlying phase constraint for scalar reconnection (i.e., measurement) to occur.

E.4 Measurement as Scalar Loop Reconnection

Measurement corresponds to an attempted topological engagement between a photon loop and a detector's internal sinertia structure. The scalar phase of the photon $\phi_\gamma(s)$ must match the internal phase of the detection interface $\phi_{\text{det}}(s)$ within coherence limits:

$$|\phi_\gamma(s) - \phi_{\text{det}}(s)| < \epsilon_{\text{meas}}.$$

When this condition is met, the photon loop is absorbed or otherwise topologically resolved. If not, the photon continues unmeasured. This condition naturally accounts for wavefunction-like behavior and interaction selectivity without invoking probabilistic collapse.

E.5 Summary

Scalar phase coherence in NUVO theory governs the conditions under which photon loops can interfere, recombine, or produce entangled correlations. Global scalar phase closure constrains entangled states, while local phase compatibility determines measurement and interference outcomes. This framework replaces probabilistic entanglement with geometric necessity, supporting a deterministic, topological interpretation of quantum optical effects.

F Scalar Coherence and Interference Across Particle Types

The scalar loop interpretation of quantum interference in NUVO theory requires that a particle exhibit sufficient internal coherence to preserve scalar topology during transit through multiple paths. This requirement is not limited to photons. Numerous experiments confirm that scalar coherence—manifested as interference—appears in a wide range of particle types, even those without net charge.

F.1 Electrons

Interference patterns with electrons were first demonstrated via diffraction (Davisson–Germer, 1927) and later by direct double-slit experiments using individual electrons (Tonomura et al., 1989). These support the interpretation of electron propagation as the evolution of a single closed-loop sinertia structure.

F.2 Neutrons

Neutrons, despite being electrically neutral, exhibit clear interference effects in interferometric setups. Experiments by Rauch et al. showed gravitationally induced phase shifts, magnetic field sensitivity, and coherence preservation, supporting the presence of a scalar loop structure even in neutral systems.

F.3 Protons

Direct double-slit experiments with protons are limited by technical constraints (small de Broglie wavelength, charge interaction), but proton diffraction through crystal lattices confirms wave-like behavior. Interference is expected in principle and would reinforce the NUVO model of scalar propagation if experimentally demonstrated.

F.4 Atoms

Atom interferometry has shown high-precision interference effects in systems ranging from hydrogen to cesium. These experiments detect gravitational and inertial phase shifts and are used for fundamental constant measurements, demonstrating that scalar coherence persists in composite particles.

F.5 Molecules

Interference has been observed in molecules as large as 25,000 amu, including buckyballs (C_{60}, C_{70}) and organic compounds. Experiments by Arndt et al. demonstrate that even highly complex systems can preserve scalar loop coherence over long propagation paths.

F.6 Implication in NUVO Theory

In NUVO, all of these phenomena support the view that sinertia-based scalar loops underlie the quantum behavior of particles. Interference arises not from delocalized probabilistic waves, but from the geometric and topological conditions required for scalar loop closure after multipath propagation. The widespread appearance of interference across charge-neutral and composite systems reinforces the scalar loop framework and suggests a universal coherence mechanism rooted in sinertia topology.

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