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Occlusion Interferometry: Inferring Hidden Objects via Quantum Path Elimination in Interference Patterns

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Abstract
We propose a new paradigm, Occlusion Interferometry, in which the presence of hidden or eclipsed objects is inferred by analyzing modifications in optical interference patterns caused by the elimination of certain quantum or classical light paths. Unlike conventional imaging systems that rely on direct photon-object interaction, this method leverages the path integral formulation of quantum mechanics, wherein every possible light path contributes to the observed pattern. By introducing a controlled interference system and analyzing the statistical perturbations introduced by occlusions, we aim to reconstruct occluded geometry through negative information—i.e., the absence of contributing paths. We outline a theoretical framework, propose experimental configurations, and discuss potential applications in non-line-of-sight imaging, quantum sensing, and covert detection systems.

Keywords: Fine Structure Constant, Einstein's Mass-Energy Relation, Dirac Equation, Hyper complex Gauge Theory, Octonion, Sedenion and Pythagorean Prime

Introduction
The ability to infer the presence and shape of an object without direct visual access has been the subject of study by physicists, from the classical shadows of occlusion to quantum interaction-free measurement. Building on concepts from Feynman's path integral formulation and modern computational imaging, we propose a method of inferring hidden objects not from their reflection or scattering, but from their capacity to exclude certain light paths from contributing to an interference pattern. We refer to this method as Occlusion Interferometry, opens a new avenue in quantum and wave-based imaging. It allows for reconstruction based not on what is seen, but on what could have been seen had a path not been blocked. This is, in essence, a form of imaging via subtraction from a superposition.

We position this approach at the intersection of interaction-free measurement, weak-value detection, and computational wavefront analysis. Our goal is to propose a formal framework for how occluded path elimination alters interference statistics, and to show how this change can be inverted to yield spatial information about the hidden object.

At the heart of our proposed method lies the interpretation of quantum mechanics where photons—treated as quantum particles or as wavefronts in classical optics—traverse all paths between a source and a detector. This idea, famously formalized by Richard Feynman in his path integral formulation, asserts that the behavior of light at a detector results from the interference of contributions from all possible paths a photon could have taken. These paths are not limited to straight lines; they include curved, scattered, and indirect routes.

In the absence of occlusion, the sum of these paths produces a predictable interference pattern. However, when a physical object partially or fully blocks certain regions of path space, it selectively eliminates specific contributions from the ensemble of all paths. Importantly, this can occur even when the object is not in the direct line of sight of the detector. The resulting interference pattern is no longer the same—it carries subtle but detectable distortions that encode the absence of those blocked paths. In our experimental design, we deliberately do not image the hidden object directly. Rather than direct detection, we utilize how the hidden object alters the ensemble of light paths, thereby modifying the resulting interference. By comparing interference patterns obtained with and without the hidden object—while modulating the optical response using a rotating diffraction grating—we amplify these differences and make them measurable.

This concept—Occlusion Interferometry—thus leverages the idea that physical occlusion alters the informational landscape of interference, not by addition, but by subtraction. The absence of paths becomes a signal in itself. This inversion of the usual imaging approach forms the core novelty of this proposal.

Coherent Illumination

A laser provides high spatial and temporal coherence for interference-based detection. This ensures even subtle occlusion effects can modulate the resulting interference patterns.

Hidden Object Behind Foreground Occluder

The setup replicates the condition where certain light paths (especially indirect or angled ones) would have reached the detector if not blocked. The hidden object's shadow doesn't appear directly, but its presence alters the statistical landscape of paths.

Diffraction Grating Film (Half Aperture + Rotation)

Applying the grating to half the detector face and rotating it gives you:

- A scanning Fourier component of the incoming field
- A way to pick up angular-dependence or path-based exclusion signatures as the grating modulates part of the interference
- An effectively multi-angle interference analyzer without moving the source or camera

Detection via Differential Interference

By comparing the with-object and without-object cases across grating rotations, will capture the perturbations caused by occluded paths—even if no light hits the hidden object directly.

Early Goal

For a first proof of concept for this novel detection system will seek to show that the presence of the hidden object causes a statistically or visually detectable shift in interference patterns—especially as the grating rotates.

Our objective is to develop a physically and computationally tractable framework that models how an occluded object modifies interference patterns as a function of both spatial position x and grating rotation angle θ.

Specifically, We Would Seek to:

- Define a measurable interference intensity $I_{free}(x, \theta)$ when no occlusion is present.
- Define a modified intensity $I_{occ}(x, \theta)$ when a subset of photon paths is blocked.
- Formulate a residual signal: $\Delta I(x, \theta) = I_{occ}(x, \theta) - I_{free}(x, \theta)$

This residual signal encodes the shadow or footprint of the occluded object.

In the Feynman path integral formulation of quantum mechanics, the probability amplitude for a photon to travel from a source point S to a detection point D is given by a sum over all possible paths γ between the two points:

$$A(S \to D) = \int_{\gamma\in\Gamma} \exp(i\, S[\gamma]/\hbar)\, D\gamma$$

Here, $S[\gamma]$ is the classical action along the path γ, and Γ represents the full ensemble of allowed trajectories. When no objects block the paths, the integral includes all possible paths (straight, curved, scattered) that constructively or destructively interfere based on their accumulated phase.

Introducing an object into the field—especially one that is not directly imaged—has the effect of removing a subset $\Gamma_{occ} \subset \Gamma$ of blocked paths from the integral:

$$A_{obs}(S \to D) = \int_{\gamma\in\Gamma \setminus \Gamma_{occ}} \exp(i\, S[\gamma]/\hbar)\, D\gamma$$

To formalize this, we consider a 2D model with path angle α. The electric field at position x on the detector with grating rotation θ is:

$$E(x, \theta) = \int_{-\alpha_{max}}^{\alpha_{max}} A(\alpha) \exp(i\, k\, x \sin \alpha)\, G(\alpha, \theta)\, d\alpha$$

Occluding angles $\alpha \in [\alpha 1, \alpha 2]$ gives:

$$E_{occ}(x, \theta) = \int_{\alpha \notin [\alpha 1, \alpha 2]} A(\alpha) \exp(i\, k\, x \sin \alpha)\, G(\alpha, \theta)\, d\alpha$$

The measurable signal is: $\Delta I(x, \theta) = |E_{occ}(x, \theta)|^2 - |E(x, \theta)|^2$

This ΔI function is the measurable signature of occlusion.

Path Decomposition by Rotation Angle

When a diffraction grating is placed in front of part of the detector and rotated, it selectively modulates light arriving from different directions (i.e., path angles). At each rotation angle θ, the grating modulates incident light according to a transfer function $G(\alpha, \theta)$, where α is the incidence angle of the path $\gamma(\alpha)$.

As the Grating Rotates

- Different subsets of paths become enhanced or suppressed.
- This provides an angular sweep of contributions from different directions.
- Over a full 360° rotation, all angular classes of photon paths are sampled.
- Resolving Occlusion via Differential Rotational Sampling

We treat the interference field at the detector as a superposition of angular modes:

$$E(x, \theta) = \int_{-\alpha_{max}}^{\alpha_{max}} A(\alpha) \cdot e^{i k x \sin \alpha} \cdot G(\alpha, \theta)\, d\alpha$$

An occluder blocks a subset of angles $\alpha \in [\alpha_1, \alpha_2]$, modifying this field.

By recording $\Delta I(x, \theta)$ for multiple θ, we build up a 2D map $\Delta I \in \mathbb{R}^{X \times \Theta}$ that reveals:

- Which angular paths are missing or distorted
- Where in x these perturbations concentrate
- How occlusion effects rotate in and out of the grating's modulation window

Mathematical Tools for Inversion (Resolution) From $\Delta I(x, \theta)$, we propose to resolve the occlusion using:

- Fourier Transform in θ: Detect dominant angular loss signatures.
- Radon Transform or Backprojection: Reconstruct 2D occlusion profiles.
- Sparse Inversion / Compressed Sensing: Use prior sparsity of hidden objects.
- Machine Learning Models: Train a neural network to learn the inverse mapping from $\Delta I(x, \theta)$ to occlusion geometry.

Outcome

If a consistent, detectable $\Delta I(x, \theta)$ pattern emerges from the data with and without occlusion, then:

- Detection of hidden objects is possible.
- With enough angular and spatial sampling, even reconstruction is theoretically achievable.
- This could become a passive, interaction-free quantum imaging method in occluded or obstructed scenes.

Deriving the Pattern

To derive the interference pattern observed at a detector due to multiple possible light paths, we begin by considering the principle of superposition. In quantum mechanics—and classical wave optics—each possible path a photon could take contributes an amplitude to the total field observed at a point. The interference pattern arises from the coherent summation of these amplitudes.

Assume a coherent, monochromatic light source with wavelength λ illuminates a region that includes a foreground object and possibly a hidden occluder. The light propagates toward a detector positioned in the far field (Fraunhofer regime). Let us denote x as the position on the detector, and θ as the rotation angle of a diffraction grating positioned before the detector.

Let Ω represent the full set of possible photon paths γ from the source to the detector. The field at position x for a given angle θ is:

$$E_{free}(x, \theta) = \int_{\Omega} A(\gamma) \cdot e^{i\phi(\gamma)} \cdot G(\gamma, x, \theta)\, d\gamma$$

Where:

- $A(\gamma)$ is the amplitude contribution of path γ, potentially weighted by its geometrical or scattering probability.
- $\phi(\gamma) = (2\pi/\lambda) \cdot L(\gamma)$, where $L(\gamma)$ is the optical path length associated with γ. This term determines the phase.
- $G(\gamma, x, \theta)$ is a grating modulation term that depends on the angular rotation θ and affects the effective transmission or phase shift imposed by the diffraction grating on that path.

Now suppose an occluder is introduced into the field, blocking a specific subset of paths $\Gamma_{occ} \subset \Omega$. The integral over all paths must now exclude these occluded paths:

$$E_{occ}(x, \theta) = \int_{\Omega \setminus \Gamma_{occ}} A(\gamma) \cdot e^{i\phi(\gamma)} \cdot G(\gamma, x, \theta)\, d\gamma$$

This exclusion alters the total field arriving at x, changing the interference pattern observed. The observable intensity is the square of the modulus of the electric field:

$$I_{free}(x, \theta) = |E_{free}(x, \theta)|^2$$

$$I_{occ}(x, \theta) = |E_{occ}(x, \theta)|^2$$

Hence, the measurable signal becomes: ΔI(x, θ) = I_occ(x, θ) - I_free(x, θ)

This ΔI(x, θ) captures the subtle but significant impact of occlusion. Paths removed from the ensemble due to the presence of the occluder shift the overall interference field. If this change can be recorded over several grating angles θ, then the variation ΔI(x, θ) across x and θ contains information about the geometry and angular extent of the occluded region.

In future work, ΔI(x, θ) may be subjected to inversion algorithms or machine learning models to infer the shape or location of the hidden object. Thus, this formulation not only defines the theoretical basis of Occlusion Interferometry, but also provides a measurable path toward object inference via quantum path subtraction.

If the grating rotation introduces angular modulation, we can sweep through path classes.
By collecting ΔI(x,θ)\Delta I(x, \theta)ΔI(x,θ) over several grating angles θ\thetaθ, we build a sort of "hologram" of missing paths. With sufficient angular diversity, and with assumptions about symmetry or prior geometry, it may be possible to invert the measured data using:

- Fourier or Radon transforms (common in tomographic imaging)
- Compressed sensing techniques
- Neural networks trained on forward simulations
- Practical Simplification for First Derivation

To make the problem analytically and computationally tractable, we can simplify the path integration by assuming:

- A planar 2D geometry
- Far-field conditions (Fraunhofer approximation)
- A grating that modulates only angular (incident) components

Let α be the angle of incidence (measured from the optical axis), and let the electric field at position x on the detector be defined as:
E(x, θ) = ∫_{-α_max}^{α_max} A(α) · exp(i k x sin α) · G(α, θ) dα

Here:

- A(α) is the amplitude of paths at angle α
- k = 2π / λ is the wavenumber
- G(α, θ) is the angular transmission or modulation function of the grating, dependent on rotation angle θ

This is effectively a coherent angular spectrum integral. If we introduce an occluder that blocks paths in a small angular region α ∈ [α1, α2], we define:
E_occ(x, θ) = ∫_{α ∉ [α1, α2]} A(α) · exp(i k x sin α) · G(α, θ) dα

The resulting interference patterns are:
I_free(x, θ) = |E(x, θ)|²
I_occ(x, θ) = |E_occ(x, θ)|²

And the measurable signal is: ΔI(x, θ) = I_occ(x, θ) - I_free(x, θ)

This formulation reduces the infinite-dimensional path integral into a 1D angular domain, where occlusion appears as a subtraction window in α-space.

As a further simplification, consider a 2D model:
Let path γ(α)\gamma(\alpha)γ(α) be parameterized by launch angle α\alphaα

Assume detector at distance zzz, grating modulates spatial frequency by f(θ)f(\theta)f(θ)

Then Compute:
E(x,θ)≈∫−αmaxαmaxA(α) eikxsinα·ei2πf(θ)x dαE(x, \theta) \approx \int_{\alpha_{\max}}^{\alpha_{\max}} A(\alpha) \, e^{i k x \sin \alpha} \cdot e^{i 2\pi f(\theta) x} \, d\alphaE(x,θ)≈∫−αmaxαmaxA(α)eikxsinα·ei2πf(θ)xdα

Block some angles to simulate occlusion, and recompute E(x,θ)E(x, \theta)E(x,θ), then simulate the difference.

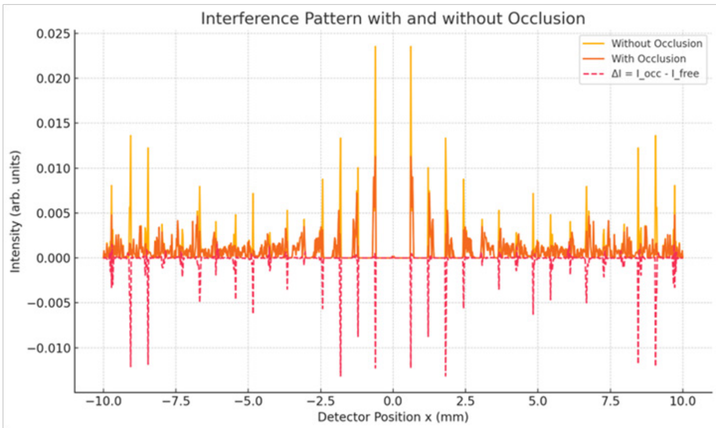

Figure 1: Simulated Interference Pattern with and Without Occlusion

Here Is A Plot Comparing The Interference Patterns

Yellow: Full interference pattern without occlusion
Orange: Interference with occluded angles (−10° to +5° blocked)
Dashed line: The measurable difference ΔI(x)\Delta I(x)ΔI(x)

You can see how even a partial angular occlusion noticeably alters the interference landscape—providing a viable signature for detecting hidden objects.

This visually communicates the premise of Occlusion Interferometry: detecting objects not from what light they reflect, but from the paths they prevent.

Experimental Proposal

We propose a tabletop optical experiment based on coherent illumination and differential interference analysis. A beam of coherent laser light illuminates a foreground object placed in the direct line of sight of a high-resolution detector. A smaller object is placed behind the first object, but offset asymmetrically so that its occlusion does not lie directly behind the first from all path perspectives.

A transparent diffraction grating film, with a line density of approximately 1000 lines per millimeter, is positioned over one-half of the detector surface. This film is slowly rotated through 360 degrees, introducing a scanning angular modulation to half the incoming wavefronts. Interference patterns are recorded continuously or at fine angular intervals throughout the rotation.

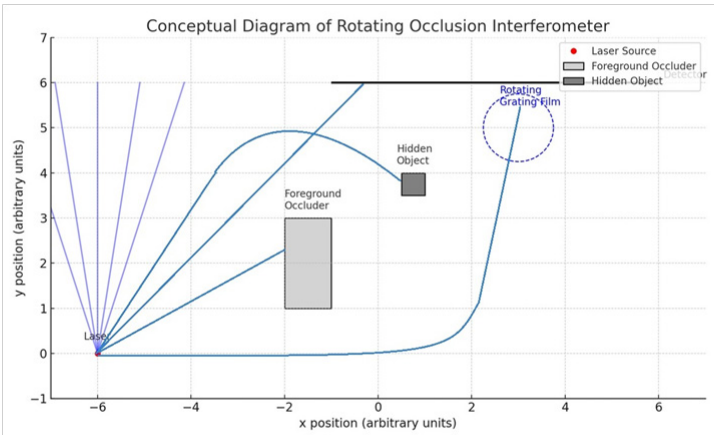

Figure 2: Conceptual Diagram of Occlusion Interferometry Setup with Coherent Source, Occluders, Rotating Grating Film and Path Tracing. Selected Photon Paths are Shown a Blue Traces

Two sets of data are collected: one with the hidden object in place, and one without. These datasets are then compared using an algorithm designed to extract differential features caused by occluded-path elimination. The immediate goal is not to reconstruct the object fully but to verify whether its presence introduces statistically or visually significant perturbations in the interference pattern as the grating rotates.

Applications and Future Work

Occlusion Interferometry opens several compelling directions for both applied and fundamental research:

- Non-line-of-sight imaging: Useful in navigation through obstructed environments.
- Quantum-enhanced sensing: Low-light detection and covert sensing.
- Autonomous navigation and collision avoidance.

- Military imaging: Target detection and battlefield awareness.
- Medical diagnostics: Inferring occluded biological structures.
- Foundational physics: Testing limits of path-based quantum measurement.

Future Directions Include

- Development of inverse reconstruction algorithms.
- Integration with adaptive optics and neural networks.
- Time-resolved extensions and multiplexed occlusion inference.
- Experimental validation of multi-object scenarios.

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