

OPTICAL VORTICES AS A GATEWAY TO TACHYON DETECTION AND FASTER-THAN-LIGHT TRAVEL

A Speculative Theoretical Exposé

Exploring Phase Singularities, Superluminal Phenomena & Exotic Physics

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Speculative Theoretical Physics | Exploratory Research

NOTICE: This document is a speculative theoretical exploration. It synthesizes established physics with frontier hypotheses. Claims marked with [H] are hypothetical. Claims marked with [E] are experimentally established.

1. Introduction: The Case for a New Detection Framework

Modern physics stands at an intriguing crossroads. On one side, quantum optics has produced structured light phenomena — most notably optical vortices — that exhibit measurable superluminal phase behavior. On the other, theoretical particle physics has long entertained the possibility of tachyons: hypothetical particles constrained to travel faster than light. This document proposes a theoretical framework for how these two domains might intersect, outlining experimental approaches, detection methodologies, and the long-range implications for faster-than-light (FTL) travel.

The central insight driving this framework is deceptively simple: if a physical structure — the dark phase singularity at the core of an optical vortex — demonstrably exhibits superluminal phase motion, then this structure may represent a unique interface between classical electromagnetic physics and exotic physics operating beyond the lightspeed barrier. Whether that interface is passive (merely a detector) or active (a mechanism for inducing FTL phenomena) is precisely what this framework seeks to investigate.

2. Background: Optical Vortices and Phase Singularities

2.1 What Is an Optical Vortex? [E]

An optical vortex is a topological feature of a light beam in which the phase of the electromagnetic wave winds helically around a central axis. At the exact center of this helical structure — the phase singularity — the phase is undefined and the amplitude of the field collapses to precisely zero. This produces a dark core: a region of complete darkness embedded within an otherwise bright beam of light. This is not an artifact or imperfection; it is a topologically protected feature of the field.

Optical vortices carry orbital angular momentum (OAM) quantified by the topological charge l , an integer describing how many times the phase completes a full 2π rotation around the axis per wavelength of propagation. Beams with higher topological charges carry proportionally greater OAM and exhibit more complex phase structures. These beams are routinely generated using spatial light modulators, spiral phase plates, and Q-plates in modern laboratory settings.

2.2 The Superluminal Phase Velocity [E]

The phase of an optical vortex rotates around the beam axis at a rate that, when projected onto the transverse plane, can substantially exceed the speed of light. This is a measurable, experimentally confirmed phenomenon and does not violate special relativity because phase velocity is not a carrier of information or energy in the classical sense. The group velocity — which governs signal propagation — remains subluminal.

However, this distinction raises an underexplored question: is the superluminal phase a purely abstract mathematical quantity, or does it correspond to a physical degree of freedom in the vacuum that might couple to exotic phenomena? Standard quantum electrodynamics treats it as the former. The framework proposed here challenges whether this is complete.

2.3 The Dark Core as a Structured Vacuum State [H]

The zero-intensity core of an optical vortex is not truly empty. Quantum field theory tells us that the vacuum is never truly empty — it seethes with virtual particle-antiparticle pairs, zero-point fluctuations, and vacuum polarization effects. What makes the vortex core distinctive is that the electromagnetic field is structured to produce destructive interference of photons at that point, creating a region where the expectation value of

the photon number is zero but the vacuum fluctuations of the field are not suppressed in the same way.

This structured vacuum state is the theoretical fulcrum of the proposed framework. If the vacuum inside the dark core has anomalous properties — modified Casimir-like energy density, altered dispersion relations, or non-trivial topology — it may constitute a physical interface with phenomena that exist beyond the lightspeed barrier.

3. Tachyons: Theoretical Status and Detection Challenges

3.1 What Are Tachyons? [H]

Tachyons are hypothetical particles characterized by an imaginary rest mass. In the framework of special relativity, imaginary rest mass implies that the particle is constrained to travel faster than light — the lightspeed barrier acts as an asymptote it cannot cross from above, just as ordinary matter cannot cross it from below. Tachyons were formally introduced into theoretical physics by Gerald Feinberg in 1967 and have since appeared in various contexts including bosonic string theory (as indicators of vacuum instability) and speculative cosmological models.

No tachyon has ever been experimentally confirmed. Attempts to detect them via Cherenkov radiation in vacuum, anomalous neutrino velocities (briefly a focus of the OPERA experiment before the result was attributed to instrumentation error), and cosmic ray shower analyses have all been inconclusive or negative.

3.2 Why Detection Is Hard

The detection problem for tachyons is severe for several reasons:

- Coupling mechanism unknown: No theoretical framework predicts how tachyons would interact with ordinary matter at experimentally accessible energies.
- Causality paradoxes: FTL particles imply potential causality violations in certain reference frames, creating deep theoretical resistance to their existence.
- Energy divergence: A tachyon's energy increases as it slows toward lightspeed, making it extraordinarily energetic — and potentially undetectable — near the subluminal boundary.
- Spectral invisibility: If tachyons couple only weakly to the electromagnetic spectrum, they would leave no photonic trace in conventional detectors.

This last point is where the optical vortex framework becomes relevant. A detector sensitive to vacuum fluctuations rather than direct photon emission might circumvent the spectral invisibility problem.

4. The Hidden Complement Hypothesis

4.1 The Symmetry Argument [H]

Physics is replete with symmetries that imply the existence of complementary phenomena: charge conjugation implies antiparticles, CPT symmetry implies time-reversal partners, particle-wave duality implies both wavelike and corpuscular behaviors. The optical vortex presents an analogous structural symmetry: a dark region (the singularity) moving superluminally within a bright field (the surrounding vortex beam).

The Hidden Complement Hypothesis proposes that this dark superluminal feature may have a complementary bright analog — a real electromagnetic signal or vacuum excitation that is also superluminal, but occupies a region of the spectrum or a field mode that standard detectors do not capture. This complement would not be visible light but might manifest in the microwave, terahertz, or extreme UV bands, or in the longitudinal mode of the electromagnetic field which is suppressed in free space but may be active near structured vacuum boundaries.

4.2 Virtual Photon Activity in the Dark Core [H]

In quantum electrodynamics, virtual photons mediate electromagnetic interactions and are not directly observable. However, their effects are measurable: the Casimir effect, Lamb shift, and anomalous magnetic moment of the electron are all manifestations of virtual photon activity in structured vacua. The dark core of an optical vortex may represent a uniquely structured vacuum region where virtual photon populations are not simply the standard Minkowski vacuum but are topologically modified by the surrounding helical field geometry.

If this modification is significant, it could produce anomalous Casimir-like forces, modified dispersion of other fields passing through the core, or even a weak coupling to tachyonic field modes if such modes exist in the underlying quantum vacuum.

5. Experimental Framework: How to Observe and Test

The following experimental program is proposed in five progressive phases, ordered from most feasible with current technology to most speculative. Each phase builds on the results of the previous one.

Phase 1: Baseline Vacuum Characterization of Vortex Dark Cores [Feasible Now]

Objective: Establish whether the vacuum state inside a high-topological-charge optical vortex core differs measurably from the standard Minkowski vacuum.

1. Generate high-topological-charge ($l = 10$ to $l = 100$) Laguerre-Gaussian beams using spatial light modulators to maximize the dark core diameter.
2. Place sensitive Casimir force microelectromechanical (MEMS) sensors within the dark core region to measure any anomalous radiation pressure or vacuum energy density.
3. Use single-photon avalanche diode (SPAD) arrays tuned to UV and near-UV frequencies to probe for anomalous photon emission from within the core.

4. Compare vacuum fluctuation measurements inside the core vs. adjacent beam regions and free space as controls.

Phase 2: Broadband Spectral Survey of the Core Region [Feasible Now]

Objective: Test whether any non-visible electromagnetic emission is associated with the phase singularity, consistent with the Hidden Complement Hypothesis.

5. Survey the dark core simultaneously across microwave (1-300 GHz), terahertz (0.1-10 THz), far-infrared, and extreme UV bands using appropriate detector arrays.
6. Cross-correlate any detected signals with the topological charge l , beam power, and phase rotation rate to identify systematic dependence.
7. Apply coincidence counting between spectrally separated detection channels to distinguish correlated emission from background noise.

Phase 3: Entangled Vortex Pair Experiments [Feasible Near-Term]

Objective: Create two spatially separated optical vortices with quantum mechanically entangled OAM states and test whether any anomalous correlations exist between their dark cores beyond what quantum entanglement alone predicts.

8. Generate OAM-entangled photon pairs via spontaneous parametric down-conversion (SPDC) in nonlinear crystals, directing each photon to a separate spatial light modulator that imprints matching vortex phase profiles.
9. Separate the two vortex beams over distances ranging from 1 meter to the maximum achievable in the lab, monitoring the dark cores of both simultaneously.
10. Introduce a controlled perturbation (local field disruption or topological charge switch) at one vortex and measure the response time at the other, looking for correlations faster than lightspeed communication would permit.
11. *Note: quantum entanglement alone cannot transmit information, so anomalous results would require extraordinary verification. Any observed effect must be rigorously distinguished from standard entanglement correlations.*

Phase 4: Tachyon Coupling Probes [Highly Speculative]

Objective: If Phase 1 and 2 reveal anomalous vacuum activity in the dark core, design targeted experiments to test whether this activity couples to any FTL field mode.

12. Design a tachyonic field antenna based on theoretical predictions from string theory models: specifically, model the vortex core as a boundary condition for an open string endpoint and derive the expected emission spectrum of tachyonic modes.
13. Place multiple aligned vortex beams in a phased array geometry, with their dark cores collinear, to construct a one-dimensional tachyonic waveguide candidate.

14. Monitor for anomalous timing residuals in precision atomic clock comparisons between the two ends of the vortex array — any FTL signal propagation would manifest as a statistically significant timing anomaly.
15. Correlate any detected anomalies with cosmic ray flux, solar activity, and gravitational wave detector data to rule out environmental sources.

Phase 5: Dual-Vortex Bridge Configuration [Far-Term / Theoretical]

Objective: Construct the theoretical and, if warranted by prior results, experimental basis for a dual-vortex bridge — two phase singularities linked by a common quantum state, probing whether the linked structure can sustain any form of FTL information or energy channel.

16. Model the dual-vortex configuration as an analogue of an Einstein-Rosen bridge, using the ER=EPR conjecture (Maldacena and Susskind, 2013) as theoretical scaffolding: entanglement (EPR) may be geometrically equivalent to wormholes (ER).
17. Investigate whether the topological charge of the linked vortex pair corresponds to a conserved quantity that could encode traversable information analogously to the mass-energy threading a traversable wormhole.
18. Derive the minimum exotic energy conditions (negative energy density) required to stabilize such a configuration, and assess whether known Casimir geometries near vortex cores could supply any fraction of this requirement.
19. Publish a full theoretical treatment for peer review before any experimental implementation at this phase.

6. From Tachyon Monitor to FTL Travel: A Theoretical Path

6.1 Tachyon Monitoring as a First Step

If the experimental program described above successfully demonstrates that optical vortex dark cores exhibit anomalous vacuum activity that correlates with any FTL field mode, the first practical application would be a tachyon monitor: a passive detection instrument that registers the passage or presence of tachyonic field excitations. Even a purely passive monitor would be of extraordinary scientific value, confirming the existence of tachyons and providing the first empirical data on their properties.

A practical tachyon monitor based on this framework would likely take the form of a phased array of high-topological-charge vortex beams, with multi-band spectral detectors monitoring each dark core, networked to a coincidence-counting system capable of registering correlated anomalies across the array. The directional sensitivity of the array would be determined by its geometry, enabling not just detection but rough directional tracking of tachyonic sources.

6.2 The Road to FTL Propulsion [Highly Speculative]

FTL travel — in the sense of moving a macroscopic object faster than light — faces profound physical barriers that go well beyond the tachyon detection problem. The leading theoretical candidates for FTL travel in mainstream physics are the Alcubierre warp drive (which requires exotic matter with negative energy density far beyond anything achievable) and traversable wormholes (which require similar exotic energy conditions and stable topology). Neither is experimentally accessible with known physics.

The optical vortex framework could contribute to FTL propulsion research in the following theoretical pathway:

20. **Confirm tachyon existence via vortex dark core detection.** Without empirical confirmation that FTL particles exist, propulsion research remains pure speculation.
21. **Characterize tachyon interaction cross-sections.** Understanding how tachyons interact with matter is prerequisite to harnessing them.
22. **Investigate tachyon-induced spacetime distortion.** If tachyons carry energy and couple to gravity, a concentrated beam of tachyons might produce local spacetime curvature effects analogous — but perhaps more accessible — to the Alcubierre metric.
23. **Design a tachyon beam projector.** If vortex dark cores can not only detect but amplify or redirect tachyonic field modes via OAM coupling, a steerable array of vortex emitters might serve as a directed tachyon beam source.
24. **Couple tachyon beam to a spacetime metric modification.** In the most optimistic scenario consistent with this framework, a sufficiently powerful tachyon beam projector, tuned via a vortex array, could induce the negative energy density region required to initiate an Alcubierre-type warp bubble or to stabilize a micro-wormhole throat.

7. Critical Obstacles and How to Address Them

No honest theoretical exposé of this kind can omit the obstacles. The following are the primary barriers, along with how the proposed framework attempts to address each:

7.1 The No-Communication Theorem

Quantum mechanics' no-communication theorem rigorously proves that quantum entanglement cannot be used to transmit information superluminally. This applies to entangled vortex pairs. However, the proposed framework does not rely on quantum entanglement as the FTL channel — it proposes that a classical tachyonic field mode (not quantum information) may couple to the dark core vacuum state. The no-communication theorem does not apply to hypothetical classical tachyonic fields.

7.2 Causality Violation

FTL signaling in special relativity implies the possibility of sending signals into the past in some reference frames, creating causal paradoxes. Some theorists argue this is a

reductio ad absurdum against tachyons. Others propose that the Feinberg reinterpretation principle (negative-energy tachyons traveling backward in time are equivalent to positive-energy tachyons traveling forward) may resolve these paradoxes. This remains an open theoretical question that experimental detection would help resolve.

7.3 Exotic Energy Requirements

Traversable wormholes and warp drives require negative energy density at scales far beyond what Casimir effects can provide. The proposed framework does not claim to solve this problem — it only suggests that vortex core Casimir effects might be an entry point to understanding and eventually engineering negative energy density at larger scales, a process that would likely require breakthroughs in quantum vacuum engineering far beyond current capability.

8. Conclusion

The framework presented here is speculative but not unscientific. It proceeds from established phenomena — optical vortices, phase singularities, superluminal phase velocity, OAM entanglement — and extends them through a chain of theoretical reasoning to hypothetical phenomena — tachyon coupling, dual-vortex bridges, FTL propulsion. Each step in the chain is clearly labeled and each can, in principle, be independently tested.

The key contribution is the proposal that the dark core of an optical vortex — a region of structured vacuum with topologically protected superluminal phase motion — may represent the first experimentally accessible interface between standard physics and whatever physics operates beyond the lightspeed barrier. If even Phase 1 of the experimental program yields anomalous vacuum measurements, it would constitute a significant scientific result independent of any connection to tachyons or FTL travel.

The path from curiosity to confirmation in physics is long and full of null results. But the history of science is equally full of cases where probing an unexplained phenomenon at the margin of established theory — a dark line in the solar spectrum, an anomalous orbital precession, an unexplained radioactive decay — opened entirely new chapters of physics. The dark core of an optical vortex deserves to be probed with the same rigor.

The absence of light at the center of a vortex is not nothing. It may be the most structured nothing in physics — and in physics, structure is everything.

Selected References and Further Reading

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