Finite Photon Packets and the Double Slit: Overlap, Not Self-Interference

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Abstract

The double-slit experiment is often cited as proof that a photon must somehow spread laterally to traverse both slits simultaneously and then "interfere with itself." We show this premise is unnecessary. Photons are finite spatiotemporal electromagnetic packets of length

$$\ell \equiv c\,\tau_{\text{emit}}\,\kappa, \tag{1}$$

defined by their emission time. Each packet follows a definite trajectory and always passes through only one slit. Electromagnetic boundary conditions at slit edges deflect packets slightly, producing angular spread but never fringes. Interference requires a second coherent stream of packets through the other slit: only when two independent streams overlap on the detection screen—with relative phase shifts ranging from 0 to π—do constructive and destructive outcomes arise. The interference pattern is thus a statistical outcome of overlapping coherent streams, not self-interference of single photons. This extends the ontology introduced in *Finite Photon Packets and the Bell Threshold: Overlap, Not Superposition* to the canonical two-slit case.

1. Introduction

Copenhagen interpretations of the double slit assert that a photon exists in a superposition across both slits, spreading laterally and interfering with itself. This picture demands that a single particle be simultaneously divided, a claim contradicted by every actual detection event: each photon registers as a localized dot.

In prior work ([1]), we demonstrated that Bell violations require spatiotemporal overlap of finite packets, not nonlocal superposition. Here we apply the same ontology to the double slit: interference requires two overlapping coherent streams of packets. No packet ever traverses both slits.

High-speed single-photon detection confirms this: individual photons appear as dots, never as partial fringes. Only when many events accumulate does the familiar interference pattern emerge [2, 3].

2. Single Slit: Deflection Without Fringes

A finite packet passing through a slit experiences boundary-induced nudges:

- **Central passage.** A packet centered in the slit continues on its original trajectory.
- **Edge passage.** A packet near a knife edge encounters stronger near-field gradients. Maxwell boundary conditions require vanishing tangential fields at a conducting edge, producing enhanced local fields and small angular nudges (the same physics underlying classical diffraction).

The outcome is a broadened diffraction envelope with node structure, but no alternating bright and dark fringes. A single slit yields angular spread, never interference.

3. Two Slits: Necessary Second Stream

Opening a second slit introduces a second coherent stream of packets. On the detection plane, the two streams overlap. Path-length differences $\Delta L(\theta)$ vary with detection angle θ, producing relative phases

$$\Delta\phi(\theta) = \frac{2\pi}{\lambda}\,\Delta L(\theta). \tag{2}$$

As θ varies across the screen, $\Delta\phi$ spans 0 to π, yielding constructive $(0, 2\pi, \dots)$ and destructive $(\pi, 3\pi, \dots)$ outcomes. Thus the familiar fringe pattern is not due to one photon self-interfering, but to the overlap of two coherent packet streams.

4. Measurement and Decoherence

When one slit is monitored, packets in that stream decohere. Only one coherent stream reaches the screen, and no fringes appear. This also resolves delayed-choice experiments: once a packet has passed a slit, its trajectory is fixed. Later decisions cannot retroactively alter the outcome. What matters is whether one or two coherent streams overlap at detection.

5. Experimental Predictions

1. **Single slit:** produces only a diffraction envelope, no fringes.
2. **Two slits:** produces fringes via overlap of coherent streams.
3. **Ultra-fast build-up:** each detection is a localized dot; the pattern emerges statistically, never from individual photons [2, 3].
4. **Which-path detectors:** decohering one stream suppresses fringes.
5. **Delayed-choice:** outcomes depend solely on stream overlap at detection; future measurement choices have no effect.

6. Conclusion

The double slit does not require photons to self-interfere or spread across both slits. Each photon is a finite packet that passes through one slit only. A single slit yields only angular spread; two slits supply a second coherent stream, enabling relative phases and fringes. This packet-based ontology explains the double slit without paradox, aligns with single-photon build-up experiments, and extends the overlap principle already established in Bell tests.

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References

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