On Wavehood

Ignis the Navigator
and the Reality Infrastructure Company

April 11, 2026

Pulse

Physics knows a great deal about wave equations while saying surprisingly little about what makes wavehood possible at all. This note gives a minimal criterion. A wave is not certified by visible oscillation, by the existence of a medium, or by a second-order differential equation alone. It is certified when a distinction remains lawfully itself under phase-sensitive first-order continuation so that superpositions can interfere before finite custody forces a common codeword. Let $W \geq 0$ be a self-adjoint generator, with Poisson holding

$$\mathcal{P}_\sigma := e^{-\sigma W},$$

exact continuation

$$\mathcal{F}_t := e^{-itW},$$

and heat rebuild

$$\mathcal{H}_\tau := e^{-\tau W^2}.$$

Wavehood belongs to continuation classes that survive both holding and exact continuation under this one family. Second-order wave equations then appear as phase-quotient shadows of the deeper first-order law; localization becomes packetization; uncertainty becomes rival quoting; and measurement becomes custody, with interference lost exactly when record states become orthogonal. Photonhood is the surfaced role of a near-ideal export mode of wavehood in a common long-range lane. The result is a reordered ontology: wavehood is primary, while particles, trajectories, and common objects are finite stabilized quotes of wavehood under custody.

1 Introduction

Physics knows a great deal about wave equations while saying surprisingly little about what makes wavehood possible at all. A wave is usually recognized by symptoms: visible oscillation, interference patterns, a medium in motion, or obedience to a familiar second-order law. But these are downstream signs. They do not yet answer the primitive question.

What makes a wave a wave in the first place?

The usual answers start too late. Visible wiggle is a public appearance, not a criterion of kind. Interference is an important diagnostic, but it does not yet say what sort of object is being carried. A medium may host waves, but wavehood cannot be reduced to mediumhood. And a second-order law, however useful, leaves a prior question untouched.

A second-order law is not yet an answer. One must ask: second order of what?

This note starts from that cut. Let $\mathscr{H}$ be a complex coherence space and let $W \geq 0$ be a self-adjoint generator on $\mathscr{H}$. In the surfaced geometric lane one may take

$$W = \sqrt{-\Delta_g},$$

but the main argument does not depend on that particular realization. The deeper continuation law is first order:

$$i\partial_t \Psi = W\Psi.$$

Its three canonical faces are

$$\mathcal{P}_\sigma := e^{-\sigma W}, \qquad \mathcal{F}_t := e^{-itW}, \qquad \mathcal{H}_\tau := e^{-\tau W^2},$$

namely holding, exact continuation, and rebuild.

The claim of the paper is simple. A wave is not first certified by how it looks, nor by a second-order public law alone. It is certified when one and the same object belongs to a first-order continuation family in which phase remains physically consequential before finite custody has forced a common codeword. On that basis, second-order equations become surfaced shadows of a deeper law, localization becomes packetization, measurement becomes custody, and photonhood becomes the surfaced role of a particularly clean export mode of wavehood.

The sections that follow make that reordering precise. Section 2 states the minimal criterion for wavehood. Section 3 shows that holding, exact continuation, and rebuild are three faces of one generator. Section 4 explains why second-order equations appear at all. Section 5 treats localization and uncertainty as rival finite quotings. Section 6 treats interference and measurement as consequences of record custody. Section 7 closes with photonhood and common worldhood.

2 Minimal criterion: wavehood as phase-carrying continuation

A wave is not fundamentally an oscillation. It is a distinction that remains lawfully itself through continuation while carrying phase in a way that can later matter. Phase is not decorative. It is one of the certification marks of wavehood.

Begin from the first-order law

$$i\partial_t \Psi = W\Psi,$$

with $W \geq 0$ self-adjoint on $\mathscr{H}$. This generates the unitary family

$$\mathcal{F}_t = e^{-itW}.$$

The structural advantage of the first-order law is immediate: it does not merely say that something propagates; it says what is preserved while propagation occurs.

Wavehood requires four things at once: lawful continuation, superposability, physically consequential relative phase, and re-expression in different bases without loss of continuation class. The decisive point is phase. If two admissible states Ψ_1, Ψ_2 are combined coherently, then for any bounded observable A,

$$\langle \Psi_1 + \Psi_2,\, A(\Psi_1 + \Psi_2)\rangle = \langle \Psi_1, A\Psi_1\rangle + \langle \Psi_2, A\Psi_2\rangle + 2\Re\langle \Psi_1, A\Psi_2\rangle.$$

The last term is the mark of wavehood. If such cross terms can remain physically consequential, then relative phase matters. If they are unavailable from the start, one has at most a mixture of already separated alternatives.

Proposition 2.1 (Minimal wavehood criterion). *A mode of being counts as wave-capable when its continuation law preserves superposable distinctions in a phase-sensitive way, so that relative phase remains physically consequential before common custody forces codeword separation.*

Proof. The first-order law

$$i\partial_t \Psi = W\Psi$$

preserves linear combinations because $\mathcal{F}_t = e^{-itW}$ is linear, and it preserves exact continuation because $\mathcal{F}_t$ is unitary. For coherent sums, expectation values contain cross terms of the form

$$\langle \Psi_1, A\Psi_2 \rangle.$$

If such terms remain available, relative phase is physically consequential; if they are destroyed by irreversible record separation or phase-forgetting, one no longer has coherent wavehood in the relevant public lane. Thus phase-sensitive superposability under lawful continuation is the minimal operator criterion. □

Two clarifications follow immediately. First, wavehood is not identical to visible sinusoidal appearance. Sinusoids are convenient public normal forms, not primitive certifiers. Second, wavehood is not identical to second-order burden. A second-order wave equation may be a valid public law while still leaving open the deeper question of what continuation structure has been squared away in order to obtain it.

3 One generator, three faces

One generator is enough. Holding, exact continuation, and rebuild are not separate mechanisms patched together after the fact. They are three analytic faces of one law, read under different public demands.

Let $W \geq 0$ be the self-adjoint generator introduced above. Its three canonical faces are

$$\mathcal{P}_\sigma := e^{-\sigma W}, \qquad \mathcal{F}_t := e^{-itW}, \qquad \mathcal{H}_\tau := e^{-\tau W^2}.$$

These are, respectively, Poisson holding, exact continuation, and heat rebuild.

The role of $\mathcal{F}_t$ is exact phase continuation. It preserves the continuation class without forcing it into an already local public form. The role of $\mathcal{P}_\sigma$ is holding: coherence made holdable at declared depth σ. The role of $\mathcal{H}_\tau$ is rebuild: the local smoothing law by which a finite public world refreshes and remakes a usable regime. None of these is imported from elsewhere. All three are generated by one operator.

Proposition 3.1 (Three faces of one law). *Holding, exact continuation, and rebuild are three functional calculi of the same generator:*

$$\mathcal{P}_\sigma = e^{-\sigma W}, \qquad \mathcal{F}_t = e^{-itW}, \qquad \mathcal{H}_\tau = e^{-\tau W^2}.$$

In particular,

$$\mathcal{P}_{\sigma_1}\mathcal{P}_{\sigma_2} = \mathcal{P}_{\sigma_1+\sigma_2}, \qquad \mathcal{F}_{t_1}\mathcal{F}_{t_2} = \mathcal{F}_{t_1+t_2}, \qquad \mathcal{H}_{\tau_1}\mathcal{H}_{\tau_2} = \mathcal{H}_{\tau_1+\tau_2},$$

and

$$[\mathcal{P}_\sigma, \mathcal{F}_t] = [\mathcal{P}_\sigma, \mathcal{H}_\tau] = [\mathcal{F}_t, \mathcal{H}_\tau] = 0.$$

Proof. Each operator is obtained by functional calculus of the same self-adjoint W. The composition laws follow by multiplying the corresponding scalar functions, and commutation is automatic because all three are functions of the same operator. $\square$

Two exact identities make the relation sharper. First,

$$\mathcal{P}_\sigma = \int_{\mathbb{R}} \frac{1}{\pi} \frac{\sigma}{\sigma^2 + t^2} \, \mathcal{F}_t \, dt,$$

so holding may be read as exact continuation with phase left unkept. Second,

$$\mathcal{P}_\sigma = \int_0^\infty \eta_\sigma(\tau) \, \mathcal{H}_\tau \, d\tau, \qquad \eta_\sigma(\tau) = \frac{\sigma}{2\sqrt{\pi}} \tau^{-3/2} \exp\left(-\frac{\sigma^2}{4\tau}\right),$$

so holding is also the exact gathered envelope of rebuild over all local times. Exact continuation, depth-holding, and local rebuild are therefore not rival stories. They are three public faces of one continuation family.

4 Why second-order equations appear at all

A second-order wave equation is not false; it is late. It is what a public lane sees when exact phase orientation has been quotiented away while burden remains. The second-order law is therefore not the primitive certifier of wavehood but its surfaced shadow.

Starting from

$$i\partial_t \Psi = W\Psi,$$

one immediately obtains

$$\partial_t^2 \Psi + W^2 \Psi = 0.$$

If

$$W = \sqrt{-\Delta_g},$$

then this becomes

$$\partial_t^2 \Psi - \Delta_g \Psi = 0.$$

The familiar second-order wave equation is therefore not denied. It is derived. The important question is what has been forgotten in passing to it.

The answer is visible already in the operator family. The second-order law depends only on W^2, not on the exact phase orientation carried by W. The two continuation branches

$$e^{-itW} \qquad \text{and} \qquad e^{itW}$$

solve the same second-order equation. What survives is propagation burden; what is no longer explicit is the exact direction of the underlying continuation class.

Proposition 4.1 (Second-order as phase-quotient shadow)**.** *Let $W \geq 0$ be self-adjoint on $\mathscr{H}$. If*

$$i\partial_t \Psi = W\Psi,$$

then

$$\partial_t^2 \Psi + W^2 \Psi = 0.$$

Conversely, if Ψ satisfies

$$\partial_t^2 \Psi + W^2 \Psi = 0$$

with initial data

$$\Psi(0) = \Psi_0 \in D(W), \qquad \partial_t \Psi(0) = -iW\Psi_0,$$

then

$$\Psi(t) = e^{-itW}\Psi_0.$$

Thus the second-order law is the phase-insensitive public shadow of the deeper first-order continuation law.

Proof. Differentiate

$$i\partial_t \Psi = W\Psi$$

once more:

$$i\partial_t^2 \Psi = W\partial_t \Psi = -iW^2\Psi,$$

hence

$$\partial_t^2 \Psi + W^2\Psi = 0.$$

For the converse, define

$$Y(t) := \partial_t \Psi(t) + iW\Psi(t).$$

Then

$$\partial_t Y = iWY,$$

and the stated initial data give $Y(0) = 0$. By uniqueness of the first-order evolution, $Y(t) \equiv 0$, so $\partial_t \Psi = -iW\Psi$ and therefore $\Psi(t) = e^{-itW}\Psi_0$. □

A second-order law is therefore what remains when exact phase orientation has been forgotten while propagation has not. It is a valid public tangent law of a deeper continuation family, not the first certifier of wavehood.

5 Localization, packets, and uncertainty

Localization is not the primitive opposite of wavehood. It is wavehood packetized into a finite codeword. The uncertainty principle is not first ignorance; it is the tax a finite world pays for trying to sharpen incompatible quotes of one and the same continuation.

If wavehood is primary, then localization cannot be its primitive opposite. A localized wave packet is not a different kind of being from a wave. It is a finite-vantage quote of a deeper continuation class.

On $\mathbb{R}^d$, this is already visible in the Fourier representation

$$\Psi(x) = \frac{1}{(2\pi)^{d/2}} \int_{\mathbb{R}^d} \widehat{\Psi}(k) e^{ik\cdot x}\, dk.$$

The position-like quote $\Psi(x)$ and the continuation-like quote $\widehat{\Psi}(k)$ are not two different objects. They are two surfaced quotings of one and the same continuation class. To localize sharply in one quote is to delocalize in the other.

Let

$$(X_j\Psi)(x) := x_j\Psi(x), \qquad (K_j\Psi)(x) := -i\partial_{x_j}\Psi(x),$$

with common dense domain, and let

$$\Delta_\Psi A := \|(A - \langle A\rangle_\Psi)\Psi\|, \qquad \langle A\rangle_\Psi := \langle \Psi, A\Psi\rangle.$$

Since $[X_j, K_j] = iI$, one gets the standard lower bound.

Proposition 5.1 (Uncertainty as rival quoting). *For every normalized Ψ in the common domain of X_j and K_j,*

$$\Delta_\Psi X_j \, \Delta_\Psi K_j \geq \frac{1}{2}.$$

Thus position-like localization and continuation purity are incompatible finite-vantage quotings of one underlying continuation.

Proof. Set

$$\widetilde{X}_j := X_j - \langle X_j \rangle_\Psi, \qquad \widetilde{K}_j := K_j - \langle K_j \rangle_\Psi.$$

By Cauchy–Schwarz,

$$\Delta_\Psi X_j \, \Delta_\Psi K_j = \|\widetilde{X}_j \Psi\| \, \|\widetilde{K}_j \Psi\| \geq \left| \langle \widetilde{X}_j \Psi, \widetilde{K}_j \Psi \rangle \right|.$$

Taking imaginary parts and using

$$[\widetilde{X}_j, \widetilde{K}_j] = [X_j, K_j] = iI,$$

one obtains

$$2 \, \Delta_\Psi X_j \, \Delta_\Psi K_j \geq \left| \langle \Psi, [X_j, K_j] \Psi \rangle \right| = 1.$$

Hence

$$\Delta_\Psi X_j \, \Delta_\Psi K_j \geq \frac{1}{2}.$$

□

The conceptual content is more important than the inequality itself. Uncertainty is not first about ignorance. It is the geometry of trying to sharpen two incompatible public quotes of one continuation class at once. A packet is therefore not the negation of wavehood but its finite local codeword.

6 Interference and measurement as custody

Interference is what wavehood looks like before alternatives have been forced into separate common facts. Measurement is not passive observation. It is custody: the absorption of a distinction into a record architecture strong enough to orthogonalize alternatives.

The double-slit experiment is usually narrated as though the mystery lies in "wave-particle duality." But once wavehood has been reordered, the real question is simpler. Have the alternatives been forced into distinct common codewords, or are they still part of one coherent continuation?

Let $\psi_1(x)$ and $\psi_2(x)$ denote two path amplitudes arriving at a screen, and let r_1, r_2 be corresponding record states in an auxiliary record space. The joint state is

$$\Psi = \psi_1 \otimes r_1 + \psi_2 \otimes r_2.$$

At screen point x, the intensity is just the squared norm of the record-valued amplitude

$$\psi_1(x) r_1 + \psi_2(x) r_2.$$

Proposition 6.1 (Measurement as custody). *For the two-path state*

$$\Psi = \psi_1 \otimes r_1 + \psi_2 \otimes r_2,$$

the screen intensity is

$$I(x) = |\psi_1(x)|^2 + |\psi_2(x)|^2 + 2\Re\big(\psi_1(x)\overline{\psi_2(x)}\langle r_2, r_1\rangle\big).$$

Hence interference is suppressed exactly by record overlap and vanishes when the record states are orthogonal.

Proof. By definition,

$$I(x) = \|\psi_1(x)r_1 + \psi_2(x)r_2\|^2.$$

Expanding the norm gives

$$I(x) = |\psi_1(x)|^2\|r_1\|^2 + |\psi_2(x)|^2\|r_2\|^2 + 2\Re\big(\psi_1(x)\overline{\psi_2(x)}\langle r_2, r_1\rangle\big).$$

If r_1, r_2 are normalized, this is exactly the stated formula. If $r_1 \perp r_2$, the cross term vanishes. □

This formula is the observer effect in its clean form. It is not first about awareness or knowledge. It is about whether alternative continuations have entered a record architecture strongly enough that the record states become orthogonal in the common lane. Once that has happened, the screen receives a mixture rather than a coherent sum.

This also clarifies the quantum eraser. If

$$r_\pm := \frac{1}{\sqrt{2}}(r_1 \pm r_2),$$

then

$$\Psi = \frac{1}{\sqrt{2}}(\psi_1 + \psi_2) \otimes r_+ + \frac{1}{\sqrt{2}}(\psi_1 - \psi_2) \otimes r_-.$$

Conditioned on the r_+ or r_- branches, the screen intensities become

$$I_\pm(x) = \frac{1}{2}\,|\psi_1(x) \pm \psi_2(x)|^2.$$

So coherence is not gone because someone "looked." It is lost exactly to the extent that the alternatives have been written into orthogonal common records.

Interference means the alternatives are not yet separated enough to count as distinct common facts. Measurement means they are.

7 Photonhood and common worldhood

A common world is built from carriers that preserve distinction cheaply enough across range. A photon should not first be understood as a tiny particle of light, but as the surfaced role of a near-ideal export mode of wavehood.

A common world is not built from arbitrary local happenings alone. It is built from distinctions that can be carried far enough, cleanly enough, and cheaply enough that multiple finite vantages can stabilize the same public facts. The question is therefore not merely which continuations exist, but which continuations export well.

If $W\psi_\omega = \omega\psi_\omega$, then

$$\mathcal{F}_t\psi_\omega = e^{-it\omega}\psi_\omega, \qquad \mathcal{P}_\sigma\psi_\omega = e^{-\sigma\omega}\psi_\omega, \qquad \mathcal{H}_\tau\psi_\omega = e^{-\tau\omega^2}\psi_\omega.$$

A pure mode is therefore carried exactly by phase under continuation and altered under holding or rebuild only by scalar attenuation. That is the operator-theoretic normal form of an export mode.

This does not yet derive electrodynamics, and the present note does not attempt to. What it does say is more basic. In any common long-range lane, the cleanest surfaced messenger is the one whose continuation remains phase-faithful under exact transport and whose public handling burdens that continuation as little as possible. The surfaced role of such a messenger is what this note calls photonhood.

So a photon should not first be understood as a tiny pellet of light. The deeper fact is export. Common worldhood needs carriers that preserve distinguishability cheaply enough across range. Light is special because it is the nearest familiar public normal form of that export, not because it belongs to a separate magical ontology.

Conclusion

The point of this note has been to reverse the order of explanation. A wave is not one kind of thing among others. Wavehood is a deeper mode of being, and many familiar "things" are stabilized public quotes of it.

The paper began with a question that physics often postpones: what makes a wave a wave at all? The answer offered here is not visible oscillation, not obedience to a second-order law alone, and not the mere presence of a medium. A wave is certified when a distinction remains lawfully itself under phase-sensitive first-order continuation so that superposition and interference remain physically available before finite custody has forced a common codeword.

From that starting point, the ontology reorders itself. The first-order law

$$i\partial_t \Psi = W\Psi$$

comes before the second-order public equation. The three canonical faces

$$\mathcal{P}_\sigma = e^{-\sigma W}, \qquad \mathcal{F}_t = e^{-itW}, \qquad \mathcal{H}_\tau = e^{-\tau W^2}$$

belong to one generator. The ordinary wave equation is the phase-quotient shadow of that deeper law. Localization is packetization. Uncertainty is the geometry of rival finite quotings. Measurement is custody. Photonhood is the surfaced role of a near-ideal export mode.

The reordered picture may therefore be stated plainly:

> Wavehood is primary; particles, trajectories, and common objects are the finite normal forms of wavehood under custody.

Once that is seen, the old picture becomes hard to recover. A wave is not what oscillates on a stage. A wave is what remains itself through lawful phase-carrying continuation before a finite world forces it into local codewords.