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Matter as a Path to Reveal What Light Hides

Classical optical experiments face a fundamental limitation: a strictly one-way measurement requires two distant clocks that are already synchronised. Yet that synchronisation generally relies on electromagnetic signals, reintroducing the round-trip symmetry one sought to avoid.

Reciprocal paths thereby cancel out first-order directional asymmetries. The observed invariance may therefore reflect the structure of the measurement protocol just as much as a genuine absence of anisotropy.

This document explores a possible way to break that symmetry: the signal travels in one direction as light, then returns as a mechanical wave carried by matter. The aim is twofold, to test whether mechanical propagation reproduces the cancellation predicted by the relativistic velocity-addition formula, and to determine whether this invariance is a universal property or an artefact specific to reciprocal electromagnetic protocols.

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1 Central Idea

The objective is to investigate whether information transmitted by a mechanical wave through a solid body can break the symmetry inherent in reciprocal electromagnetic transmissions.

A purely optical device built on reciprocal paths tends to mask the first-order contributions associated with a potential motion through the energetic medium. The outward and return journeys are not individually identical, but their sum reconstructs a quantity that is insensitive to orientation.

The proposed idea is to break this reciprocity at the physical level. One leg of the journey remains optical, while the return leg is replaced by a mechanical wave propagating through a solid. The signal therefore no longer travels twice through the same physical channel.

Two principal effects may act on a material body moving through the energetic medium. Both follow from the finite propagation speed of the electromagnetic interactions that hold matter together: contraction of lengths along the direction of motion, and the slowing of internal processes linked to the increased electromagnetic inertia of the material constituents.

A mechanical wave corresponds to a collective perturbation of matter that propagates step by step through the internal bonds of a solid. Transmitting information by a mechanical wave is therefore equivalent to transmitting it through a local reorganisation of matter, rather than through free electromagnetic propagation in vacuum.

The central question then becomes:

> Does mechanical propagation in a solid moving through the energetic medium spontaneously produce exactly the anisotropy required to compensate for the directional term of the optical leg?

The answer must not be assumed in advance. Providing that answer is precisely the purpose of the test.

2 Why the Mechanical Return Must Not Be Relativised From the Outset

In a solid, the velocity of a longitudinal wave can be written, to order of magnitude, as:

$$u_m = \sqrt{\frac{E}{\rho}} \tag{1}$$

where E denotes an effective elastic modulus and ρ the mass density of the material.

A typical working value is:

$$u_m = 5\,000\,\mathrm{m\,s^{-1}} \tag{2}$$

whereas:

$$c = 299\,792\,458\,\mathrm{m\,s^{-1}} \tag{3}$$

This gives:

$$\frac{u_m}{c} = 1.6678204759907602 \times 10^{-5} \tag{4}$$

and:

$$\frac{c}{u_m} = 59\,958.4916 \tag{5}$$

A mechanical wave at $5\,000\,\mathrm{m\,s^{-1}}$ is therefore approximately 59 958.5 times slower than light.

This contrast is experimentally interesting, but it also introduces a conceptual difficulty. It might be tempting to apply the relativistic velocity-addition formula directly to the mechanical wave:

$$w_\pm = \frac{v \pm u_m}{1 \pm v u_m / c^2} \tag{6}$$

In standard relativity, this law is generalised to any composition of velocities and does not depend on the nature of the signal. In the framework considered here, its status is different: it is understood as a kinematic reconstruction law established under specific conditions—in particular from round-trip measurements of electromagnetic signals. It must not be automatically extended to mechanical propagation without first verifying that matter produces the same compensating structure.

Applying it directly to a mechanical return would therefore amount to assuming, from the outset, that propagation through matter obeys the same compensating structure as electromagnetic signals.

Mechanical propagation must therefore be treated as an intrinsic dynamical quantity, which may or may not exhibit an anisotropy induced by the motion of the solid through the energetic medium.

3 Mixed Setup: Light Outward, Mechanical Wave Return

Consider two material points A and B that are rigidly attached to the same device. The proper distance between them, measured locally within the device, is denoted L.

The device moves at constant velocity v through the energetic medium. We first consider the case where the axis AB is collinear with this motion. Point A is at the rear, point B at the front, and the motion is directed from A toward B.

The outward leg is performed by a light signal. The return leg is performed by a mechanical wave propagating through a solid connecting B to A. The opto-mechanical conversion introduces a fixed delay τ_0.

In the reference frame of the energetic medium, the longitudinal material length is contracted:

$$L_{\text{abs}} = \frac{L}{\gamma} \tag{7}$$

with:

$$\gamma = \frac{1}{\sqrt{1 - v^2/c^2}} \tag{8}$$

3.1 Isolated Optical Leg

When the light signal propagates from A to B, in the direction of motion, point B recedes during propagation. The absolute travel time of the outward optical leg is:

$$t_{\text{L},+} = \frac{L_{\text{abs}}}{c - v} \tag{9}$$

that is:

$$t_{\text{L},+} = \frac{L}{\gamma(c - v)} \tag{10}$$

Using the identity:

$$\frac{1}{\gamma(1 - v/c)} = \gamma(1 + v/c) \tag{11}$$

one obtains:

$$t_{\text{L},+} = \frac{\gamma L}{c}(1 + v/c) \tag{12}$$

The proper time measured by a clock co-moving with the device is:

$$\tau_{L,+} = \frac{t_{L,+}}{\gamma} \tag{13}$$

Therefore:

$$\boxed{\tau_{L,+} = \frac{L}{c}(1 + v/c)} \tag{14}$$

If the setup is reversed, the light signal travels in the direction opposite to the motion. One then obtains:

$$\boxed{\tau_{L,-} = \frac{L}{c}(1 - v/c)} \tag{15}$$

The isolated one-way optical leg therefore retains a directional dependence on v/c.

3.2 The Mechanical Leg as a Quantity to Be Tested

Let $u_{m,+}(v)$ denote the effective velocity of the mechanical wave in the solid for propagation in the direction of the absolute motion, and $u_{m,-}(v)$ the effective velocity for propagation in the opposite direction.

If the internal mechanical propagation carries no directional anisotropy, then:

$$u_{m,+}(v) = u_{m,-}(v) = u_m \tag{16}$$

But if motion through the energetic medium modifies the internal dynamics of the solid in an anisotropic way, then:

$$u_{m,+}(v) \neq u_{m,-}(v) \tag{17}$$

It is precisely this potential difference that must be sought.

4 Central Result

In the first orientation, the light signal travels from A to B, and the mechanical wave returns from B to A. The mechanical return therefore travels in the direction opposite to the motion. Its local time is:

$$\tau_{\mathrm{M},-} = \frac{L}{u_{m,-}(v)} + \tau_0 \tag{18}$$

The total time is therefore:

$$T_+ = \tau_{\mathrm{L},+} + \tau_{\mathrm{M},-} \tag{19}$$

that is:

$$\boxed{T_+ = \frac{L}{c}(1 + v/c) + \frac{L}{u_{m,-}(v)} + \tau_0} \tag{20}$$

After reversing the device, the light signal travels opposite to the motion, while the mechanical return travels in the direction of motion. One obtains:

$$T_- = \tau_{\mathrm{L},-} + \tau_{\mathrm{M},+} \tag{21}$$

and therefore:

$$\boxed{T_- = \frac{L}{c}(1 - v/c) + \frac{L}{u_{m,+}(v)} + \tau_0} \tag{22}$$

The difference between the two orientations is:

$$\Delta T = T_+ - T_- \tag{23}$$

This yields:

$$\boxed{\Delta T = \frac{2Lv}{c^2} + L\left(\frac{1}{u_{m,-}(v)} - \frac{1}{u_{m,+}(v)}\right)} \tag{24}$$

This equation is the key result of this document.

It clearly separates two contributions. The first is the directional contribution of the optical leg:

$$\frac{2Lv}{c^2} \tag{25}$$

The second is the intrinsic contribution of the mechanical return:

$$L\left(\frac{1}{u_{m,-}(v)} - \frac{1}{u_{m,+}(v)}\right) \tag{26}$$

For exact cancellation, one would require:

$$L\left(\frac{1}{u_{m,-}(v)} - \frac{1}{u_{m,+}(v)}\right) = -\frac{2Lv}{c^2} \tag{27}$$

that is:

$$\boxed{\frac{1}{u_{m,-}(v)} - \frac{1}{u_{m,+}(v)} = -\frac{2v}{c^2}} \tag{28}$$

In standard relativistic interpretation, this cancellation is guaranteed by the invariance of physical laws and by the relativistic velocity-addition formula. In the energetic-medium framework, its status is different: it cannot be postulated from the outset, because the relativistic composition is here understood as a kinematic reconstruction established under specific conditions—in particular from reciprocal electromagnetic measurements.

The preceding condition is therefore highly constraining. For it to be satisfied, it would need to emerge from the intrinsic dynamics of the solid: its internal bonds, its effective inertia, its elastic constants, and the manner in which a mechanical wave propagates through it.

The setup is therefore not merely searching for a time difference. It tests whether matter genuinely produces the expected cancellation through its internal dynamics, or whether this cancellation belongs specifically to reciprocal optical protocols. In other words, it questions the very status of the relativistic velocity-addition formula: a universal law governing all propagation, or a reconstruction law proper to electromagnetic measurements.

5 Differential Measurement with a Single Clock

The setup requires no distant synchronisation. A single clock placed at point A is sufficient, since the experiment does not seek to measure separately the propagation time from A to B and then from B to A. It measures only the total round-trip time, between emission of the signal from A and its return to the same point.

In the first orientation of the device, the signal departs from A as light, reaches B, then returns to A as a mechanical wave. The local clock then measures the total time:

$$T_+ = T_{\text{phys},+} + \tau_0 \tag{29}$$

where $T_{\text{phys},+}$ represents the physical time associated with the outward optical leg plus the mechanical return in this orientation, and where τ_0 groups together the internal delays of the setup: emission, detection, opto-mechanical conversion, transducer response, and readout electronics.

After reversing the device—that is, after a 180° rotation—one measures in the same way:

$$T_- = T_{\text{phys},-} + \tau_0' \tag{30}$$

The experimental observable would be the difference between the two orientations:

$$\Delta T = T_+ - T_- \tag{31}$$

If the internal delays of the setup remain stable during the comparison, one has:

$$\tau_0' \simeq \tau_0 \tag{32}$$

The measured difference then becomes:

$$\Delta T \simeq T_{\text{phys},+} - T_{\text{phys},-} \tag{33}$$

Fixed delays thus cancel by subtraction. The essential point is that the measurement does not depend on synchronisation between A and B. It depends only on the differential stability of the setup between the two orientations.

This experimental structure therefore circumvents one of the classical difficulties of one-way measurements. The outward optical time is not measured in isolation; it is included in a local round-trip time. What is being tested is not a distant synchronisation, but the possible existence of a variation in total time when the orientation of the mixed light-matter path is reversed.

6 What Matter May Potentially Compensate

The mechanical velocity depends on the internal constants of the material. These constants are not independent of the electromagnetic structure of matter. The bonds between constituents, the equilibrium distances, the elastic moduli, and the effective inertia of atoms all result, directly or indirectly, from the electromagnetic interactions that maintain the cohesion of the solid.

In the framework considered here, a material body moving through the energetic medium undergoes two fundamental physical effects: contraction of lengths along the direction of motion, and slowing of internal processes associated with the increased electromagnetic inertia of the material constituents.

However, these effects must not be added separately to travel times already expressed in local coordinates. The length L is a proper length measured with the device's own rulers, and the times T_+ and T_- are measured by the clock on board at point A. These rulers and this clock are affected in the same way as the setup itself. The global effects of length contraction and clock slowing are therefore already incorporated in the definition of the local quantities used above.

The still-open question is different. It does not concern the conversion between absolute and local quantities, but the intrinsic dynamics of mechanical propagation within the solid. A mechanical wave is not an abstract signal travelling through an unchanged medium. It is a collective perturbation transmitted step by step through the internal bonds of the material. If motion through the energetic medium modifies the effective elastic constants, the volumetric inertia, or the directional response of the material lattice, then the local mechanical velocity may itself become anisotropic.

The effective mechanical velocity must therefore be understood starting from:

$$u_m = \sqrt{\frac{E}{\rho}} \tag{34}$$

but taking into account that the elastic modulus E and the effective inertial density ρ may depend on the orientation of the solid and on its motion through the energetic medium.

This dependence can be summarised as:

$$E \to E_{\parallel}(v),\ E_{\perp}(v) \tag{35}$$

$$\rho \to \rho_{\parallel}(v),\ \rho_{\perp}(v) \tag{36}$$

$$u_m \to u_{m,+}(v),\ u_{m,-}(v) \tag{37}$$

The question is therefore not whether local rulers contract or whether the local clock slows—those effects are already integrated into the measured quantities. The question is whether mechanical propagation, expressed in those same local quantities, possesses an intrinsic anisotropy capable of exactly compensating the directional term of the optical leg.

This compensation would require:

$$\frac{1}{u_{m,-}(v)} - \frac{1}{u_{m,+}(v)} = -\frac{2v}{c^2} \tag{38}$$

As long as this relation has not been derived dynamically from the structure of the solid, it is not possible to assert that the mechanical return necessarily masks the one-way optical term.

The conceptual conclusion is therefore as follows: the mixed setup is relevant not because it guarantees a detection, but because it shifts the question toward the internal dynamics of matter. It forces one to determine whether mechanical propagation produces, in the local quantities already corrected by the device's rulers and clocks, the exact compensation that reciprocal electromagnetic paths impose naturally.

7 Variant: Return by an Isolated Material Body

A mechanical return via a wave in a solid is not the only possibility.

One may envisage a more radical variant: replacing the mechanical wave with the displacement of an isolated material body. The return signal would then no longer be a stress propagating through a continuous network, but a localised object travelling from B to A.

This distinction is important.

In the case of a solid connecting A and B, the mechanical information propagates inside a continuous material medium whose dynamical properties may be affected by its motion through the energetic medium.

In the case of an isolated body, there is no longer a continuous material medium between A and B. The moving body traverses the space separating the two endpoints of the device without being carried by any intermediate material structure. It interacts with the setup only at the moment of its emission at B and its reception at A.

Consequently, if the return is provided by an isolated body, it becomes difficult to identify an additional mechanism capable of producing an exact compensation.

The question then becomes:

> Can an isolated material body, launched between two points of the device, introduce a return delay that exactly compensates the asymmetry of the outward optical leg?

At this stage, nothing appears to impose such a compensation.

This variant is therefore conceptually interesting, but experimentally more demanding: reproducible launching, velocity control, mechanical disturbances, interaction with emission and reception devices, residual friction, and so on.

The distinction may be summarised as follows:

$$\begin{aligned} \text{return by mechanical wave} &= \text{propagation through a continuous material medium} \\ \text{return by isolated body} &= \text{transport of a localised material structure} \end{aligned} \tag{39}$$

The first path is more experimentally realistic. The second is more conceptually decisive, but considerably more demanding.

8 Experimental Considerations

The experimental objective is not to measure an absolute propagation time. It is to search for a differential variation when the orientation of the device is reversed.

The minimal setup uses two points A and B separated by a proper distance L. The outward leg is optical. The return leg is mechanical. The measurement compares two opposite orientations of the same device.

Fixed delays arising from optical emission, detection, opto-mechanical conversion, and electronics may be large. They are not problematic provided they remain stable between the two orientations.

One writes:

$$T_{\text{meas}} = T_{\text{phys}} + \tau_0 \tag{40}$$

After reversal:

$$T'_{\text{meas}} = T'_{\text{phys}} + \tau_0 \tag{41}$$

The difference eliminates the fixed offset:

$$\Delta T_{\text{meas}} = T'_{\text{meas}} - T_{\text{meas}} = T'_{\text{phys}} - T_{\text{phys}} \tag{42}$$

The experimental criterion is therefore not an absolute knowledge of τ_0, but its stability over the duration of the comparison.

8.1 Order of Magnitude of the Expected Signal

The expected directional light term is:

$$\Delta T_{\text{L}} = \frac{2Lv}{c^2} \tag{43}$$

For:

$$v = 30\,000\,\text{m}\,\text{s}^{-1} \tag{44}$$

and:

$$L = 1\,\text{m} \tag{45}$$

one obtains:

$$\Delta T_{\text{L}} \simeq 6.67 \times 10^{-13}\,\text{s} \tag{46}$$

that is:

$$\Delta T_{\mathrm{L}} \simeq 0.67\,\mathrm{ps} \tag{47}$$

For:

$$L = 10\,\mathrm{m} \tag{48}$$

one obtains:

$$\Delta T_{\mathrm{L}} \simeq 6.67\,\mathrm{ps} \tag{49}$$

This level is small, but may become accessible through phase comparison and statistical accumulation, rather than direct timing of a single pulse.

8.2 Recommended Mechanical Support

The mechanical support should be simple, stable, and well characterised.

A reasonable first choice is a metal rod, a rigid fibre, or a straight mechanical guide excited by piezoelectric transducers.

With:

$$u_m = 5\,000\,\mathrm{m\,s^{-1}} \tag{50}$$

and:

$$L = 10\,\mathrm{m} \tag{51}$$

the mechanical travel time is:

$$T_m = \frac{L}{u_m} = 2.0 \times 10^{-3}\,\mathrm{s} \tag{52}$$

that is:

$$T_m = 2\,\mathrm{ms} \tag{53}$$

The difficulty is immediately apparent: one must search for a variation of a few picoseconds within a mechanical travel time of the order of one millisecond. The required relative stability is therefore of order:

$$\frac{6.7\,\mathrm{ps}}{2\,\mathrm{ms}} \simeq 3.3 \times 10^{-9} \tag{54}$$

This requirement is demanding. It becomes more realistic if one measures the difference between two orientations using the same support, the same transducers, and the same electronics.

8.3 Measurement Method: Phase Rather Than Pulse

It is preferable not to measure an absolute time of flight using isolated pulses.

The recommended method is periodic excitation with phase measurement. A reference oscillator drives the optical emission from A. The signal received at B triggers the mechanical excitation. The mechanical wave returns to A, where it is detected by a piezoelectric transducer.

The total time is converted into a phase relative to the oscillator:

$$\phi = 2\pi f T_{\mathrm{meas}} \tag{55}$$

A time variation produces:

$$\Delta\phi = 2\pi f \Delta T \tag{56}$$

For:

$$f = 10\,\mathrm{MHz} \tag{57}$$

and:

$$\Delta T = 6.7\,\mathrm{ps} \tag{58}$$

one obtains:

$$\Delta\phi \simeq 4.2 \times 10^{-4}\,\mathrm{rad} \tag{59}$$

This variation is small, but accessible by lock-in detection if slow drifts are sufficiently suppressed.

8.4 Reversing the Device

The measurement must be performed in two opposite orientations. Let T_+ denote the time measured in the first orientation and T_- the time measured after a 180° rotation.

The relevant observable is:

$$\Delta T = T_+ - T_- \tag{60}$$

This difference offers several advantages:

- it eliminates fixed electronic delays
- it reduces the influence of synchronisation offsets
- it suppresses a large share of common-mode drifts
- it isolates the term that changes sign with orientation

It is therefore preferable to rotate or invert the complete device periodically, rather than comparing two separate setups.

8.5 Thermal Stability

The principal practical difficulty is temperature.

The speed of sound in a solid depends on the elastic constants and the mass density, both of which are sensitive to temperature. A thermal variation therefore directly affects:

$$T_m = \frac{L}{u_m} \tag{61}$$

A small change in u_m can produce an effect far larger than the sought signal.

The strategy must therefore be differential:

- keep the support inside a thermally stable enclosure
- measure the two orientations rapidly
- use the same mechanical path in both directions
- search only for the component that changes sign upon reversal

Absolute thermal stability need not be perfect, provided that the drift is slow and common to both orientations. What matters is the differential stability during the reversal cycle.

8.6 Realistic Dimensions

A 1 m device is easy to stabilise, but the expected signal is below one picosecond.

A 10 m device yields a signal of a few picoseconds while remaining feasible in a laboratory in the form of a rod, a rail, a coiled fibre, or a mechanical guide.

A 100 m device improves the signal but becomes very sensitive to thermal gradients, vibrations, mechanical stresses, and spurious delays.

A reasonable compromise for a first experiment is therefore:

$$L = 5 \text{ to } 10\,\text{m} \tag{62}$$

with a simple, rigid, thermally insulated mechanical support and phase measurement.

8.7 Minimal Configuration

For a first implementation, simplicity should be prioritised:

- a single reference oscillator
- a single mechanical path
- two identical piezoelectric transducers
- stable sinusoidal excitation

- lock-in phase detection
- rotation or full reversal of the device
- passive thermal enclosure

The following should be avoided in a first stage:

- multiple independent clocks
- different mechanical paths
- complex geometries
- composite materials
- isolated-body launching devices

These variants may be studied subsequently, but they introduce too many free parameters for an initial validation.

9 Decision Criterion

The experiment must answer a simple question:

> Does the total time for the outward optical leg plus the mechanical return change when the orientation of the device is reversed?

If no variation is observed at the expected level, this would indicate that the internal dynamics of the solid also produce an effective compensation.

If a variation is observed, if it changes sign with orientation, and if it follows the expected dependence on L, then it could indicate a break between electromagnetic and mechanical propagation.

The essential criterion is the length dependence. A propagation effect must grow linearly with L:

$$\Delta T \propto L \tag{63}$$

A spurious electronic delay, by contrast, remains largely independent of L.

A robust strategy therefore consists in repeating the measurement for several lengths:

$$L_1,\ L_2,\ L_3 \tag{64}$$

and checking whether the measured difference follows a linear law.

10 Conclusion

The light-outward, mechanical-wave-return setup constitutes a relevant experimental approach because it modifies the physical nature of reciprocity.

In a purely optical device, first-order directional effects are masked by the symmetry of the light paths and by the structure of round-trip measurements. In a mixed device, the return is no longer provided by the same propagation. It depends on the internal dynamics of matter.

Cancellation is therefore no longer automatic.

The point to be tested is not:

> Can the mechanical return be described by the same kinematic composition as light?

but:

> Does matter produce, through its internal dynamics, the exact anisotropy needed to erase the one-way optical term?

If so, apparent invariance would extend to internal material propagation. If not, the setup might reveal a measurable asymmetry linked to motion through the energetic medium.

The first realistic experiment should remain modest: a length of a few metres to about ten metres, a simple mechanical support, lock-in phase detection, periodic reversal of orientation, and analysis of the linear dependence on L.

The value of the setup does not reside in the promise of an immediate detection, but in the criterion it imposes. The twofold stake is this: to verify whether mechanical propagation through matter respects the same compensation as that predicted by the relativistic velocity-addition formula, and to determine whether that formula should be understood as a universal law governing all material dynamics, or as a reconstruction law specific to reciprocal electromagnetic protocols.

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