# Directional Density of Gases Under FitzGerald-Lorentz Contraction:
# Predictions for Optical Interferometry

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**Abstract**

In Lorentz Ether Theory, FitzGerald-Lorentz contraction affects all matter — containers, molecules, and the electromagnetic interactions between them. In a static gas, the anisotropic collision cross-sections of contracted molecules drive the density distribution toward the same anisotropy as in a solid, restoring the SR/LET equivalence. However, this equilibration proceeds at the diffusion timescale $\tau_{\text{diff}} \sim L^2/D$ — hundreds to thousands of seconds for a laboratory gas cell. In a continuously rotating experiment with period $T_{\text{rot}} \sim$ 5–60 s, the anisotropy cannot keep pace with the changing contraction direction: the gas density remains isotropic while the solid tracks the contraction instantaneously. This timescale separation creates a measurable difference: the directional density of a gas (molecules per unit length) is isotropic, while that of a solid is anisotropic. The resulting fringe shift on rotation is $\Delta N = k\,(L/2\lambda)\,(n-1)\,(v/c)^2$, where $k$ is the number of passes. The signal scales linearly with gas pressure — providing a built-in calibration. We predict null results for solid-dielectric interferometers regardless of refractive index.

## 1 Introduction

Special Relativity (SR) and Lorentz Ether Theory (LET) are kinematically equivalent for all phenomena involving bound systems. This equivalence rests on the FitzGerald-Lorentz "conspiracy": length contraction, time dilation, and the electromagnetic response of bound matter combine to render all optical path lengths direction-independent in any inertial frame. The null results of Michelson-Morley-type experiments using solid optical components — most recently, rotating fused-silica cavity experiments reaching $\Delta c/c \sim 10^{-17}$ [4, 5] — are the experimental expression of this conspiracy.

There is, however, a fundamental difference between SR and LET that appears not to have been exploited experimentally. In SR, the Lorentz transformation is a coordinate transformation: it is mathematical, instantaneous, and applies identically to all matter regardless of its physical state. A gas and a solid transform in the same way, and there is nothing to measure. In LET, FitzGerald-Lorentz contraction is a physical process. The contraction of each individual object — a molecule, a mirror, a crystal — is effectively instantaneous (propagating at the speed of sound). But the *spatial redistribution* of an ensemble of unbound particles, such as the molecules of a gas, requires physical transport through collisions and diffusion. This transport takes time — and that time is measurable.

The question that motivates the present work is whether this time delay can be exploited to distinguish SR from LET experimentally. The answer depends critically on whether the experiment is static or rotating.

In LET, gas molecules are contracted along the direction of motion through the ether, just as solid objects are. Their collision cross-sections become anisotropic, and the resulting anisotropic collision dynamics drive the gas toward an equilibrium whose density distribution mirrors the contracted geometry — just as in a solid. If this equilibrium is reached, the conspiracy is restored and SR and LET remain indistinguishable.

The crucial physical insight is that this equilibration is *slow.* A solid reaches its contracted equilibrium at the speed of sound ($\sim 10^{-5}$ s for a laboratory-scale object). A gas reaches its equilibrium only through diffusion ($\tau_{\text{diff}} \sim L^2/D \sim 10^2$–$10^4$ s). In a rotating experiment with $T_{\text{rot}} \sim 5$–60 s, the gas cannot track the continuously changing contraction direction. The anisotropy that would develop in a static gas is suppressed by the rotation, and the gas density remains isotropic — breaking the conspiracy and creating a measurable signal.

This paper derives the interferometric consequences of this timescale separation and proposes experimental configurations to test it.

## 2 FitzGerald Contraction of Gas Molecules

### 2.1 The molecular level

In LET, a molecule moving at velocity $\mathbf{w}$ relative to the ether undergoes FitzGerald-Lorentz contraction: its spatial extent along $\mathbf{w}$ is reduced by a factor $1/\gamma$, where $\gamma = (1 - w^2/c^2)^{-1/2}$. This applies to the molecule's electron cloud, its bond lengths, and consequently its effective collision cross-section $\sigma$.

For a spherical molecule at rest in the ether, $\sigma$ is isotropic. For a moving molecule, the cross-section along $\mathbf{w}$ is reduced while the perpendicular cross-section is unchanged. The collision probability between two molecules therefore depends on their relative orientation with respect to $\mathbf{w}$.

### 2.2 Static equilibrium of a contracted gas

Consider a gas confined in a container that is itself contracted along $\mathbf{w}$. The container volume is $V/\gamma$. The anisotropic collision cross-sections create a bias: molecules moving along $\mathbf{w}$ have a smaller cross-section and therefore a longer mean free path in that direction. Over many collision times, this bias drives the gas toward a density distribution that is denser along $\mathbf{w}$ — precisely mimicking the anisotropy of a contracted solid.

In full equilibrium, the gas density anisotropy matches that of the container: the directional density along $\mathbf{w}$ is enhanced by the same factor $\gamma$ as in a solid. The conspiracy is restored. A static gas experiment cannot distinguish SR from LET.

This is physically analogous to the way a crystal's anisotropy arises — through electromagnetic forces between bound charges. The same electromagnetic forces, acting through collisions, produce the same result in a gas. The only difference is the timescale.

### 2.3 The diffusion timescale

The equilibration of a gas density perturbation is governed by diffusion. The characteristic timescale is:

$$\tau_{\text{diff}} \sim \frac{L^2}{D} \tag{1}$$

where $L$ is the container dimension and $D$ is the self-diffusion coefficient of the gas. For air at atmospheric pressure, $D \approx 2 \times 10^{-5}$ m$^2$/s, giving:

| Cell length $L$ | $\tau_{\text{diff}}$ | To $10^{-6}$ precision |
|---|---|---|
| 0.01 m | 5 s | $\sim$ 70 s |
| 0.1 m | 500 s | $\sim$ 7000 s |
| 0.5 m | 12 500 s | $\sim$ 2 days |

The column “To $10^{-6}$ precision” gives the time for the perturbation to decay to $10^{-6}$ of its initial value ($\sim 14\,\tau_{\text{diff}}$), corresponding to the ratio between the predicted signal and the FitzGerald anisotropy.

For comparison, a solid responds to the contraction at the speed of sound: $\tau_{\text{sound}} \sim L/v_s \sim 10^{-5}$ s. This is faster than any achievable rotation rate by many orders of magnitude.

# 3 Rotation Suppresses Gas Anisotropy

## 3.1 The mechanism

In a rotating experiment:

- The FitzGerald-Lorentz contraction direction $\mathbf{v}$ is fixed in space (determined by the laboratory’s velocity through the ether).
- The apparatus rotates with period $T_{\text{rot}} \sim 5$–$60$ s.
- From the gas’s perspective, the contraction direction sweeps 360° per revolution relative to the container.
- Any density perturbation that begins to build up along the instantaneous contraction axis is reversed before it can grow to significant amplitude, because the axis has rotated away.
- The steady-state density distribution is the rotational average of all instantaneous perturbations — which, by azimuthal symmetry, is isotropic.

The suppression of anisotropy depends on the ratio of timescales. A rough estimate of the residual anisotropy in steady state is:

$$\frac{\delta\rho}{\rho} \sim \frac{\beta^2}{2} \times \frac{T_{\text{rot}}}{\tau_{\text{diff}}} \tag{2}$$

For typical parameters ($\beta^2/2 \sim 3 \times 10^{-7}$, $T_{\text{rot}}/\tau_{\text{diff}} \sim 0.1$ for a 10 cm cell at 1 atm rotating at 50 s/turn), this gives $\sim 3 \times 10^{-8}$ — negligible compared to the full FitzGerald anisotropy. The precise steady-state distribution under continuous rotation requires a detailed diffusion model, but the order-of-magnitude suppression is robust.

## 3.2 Pressure strengthens the effect

Increasing the gas pressure has a doubly favorable effect:

- The refractive index excess $(n - 1)$ increases linearly with pressure, strengthening the optical signal.
- The diffusion coefficient $D$ decreases as $1/p$, increasing $\tau_{\text{diff}}$ and making the rotation even more effective at suppressing anisotropy.

Both effects work in the same direction: higher pressure means a larger signal and a more isotropic gas.

## 3.3 A solid cannot be “mixed”

In a solid, the contraction is transmitted at the speed of sound ($v_s \sim 5000$ m/s in fused silica). The response time $\tau_{\text{sound}} \sim L/v_s \sim 10^{-5}$ s is faster than any rotation. The solid’s directional density tracks the contraction direction instantaneously at all rotation rates. Rotation has no effect on a solid’s anisotropy.

This is the qualitative difference that makes the experiment possible: *gases can be mixed; solids cannot.*

## 4 Directional Density and Optical Phase

In a rotating experiment where the gas density is isotropic (as established above), we define directional density $\rho_d(\hat{n})$ as the number of molecules per unit length along direction $\hat{n}$.

**Bound systems (solid).** Directional density is anisotropic: enhanced by $\gamma$ along $\mathbf{v}$, unchanged perpendicular to $\mathbf{v}$. The anisotropy is $\Delta\rho_d/\rho_d \approx \beta^2/2$.

**Unbound systems (gas, rotating).** Directional density is isotropic: $\rho_d = \gamma N/V$ in all directions.

The phase delay contributed by each gas molecule to a traversing photon is a Lorentz scalar $\delta\phi$.[1] The total gas-induced phase along the beam path is:

$$\Phi_{\text{gas}} = N_{\text{path}} \times \delta\phi \tag{3}$$

where $N_{\text{path}}$ is the number of molecules in the beam path.

A vacuum path, or a path through a solid medium, serves as a reference. Being a bound system, it contracts with the apparatus, and its optical phase is direction-independent.

## 5 Interferometric Signal

Consider a gas cell of physical length $L$ mounted alongside a vacuum reference channel on a rotating platform. As the platform turns, the contraction direction $\mathbf{v}$ sweeps relative to the cell axis. At angle $\theta$ between the cell axis and $\mathbf{v}$:

$$N(\theta) = N_0\left(1 - \frac{\beta^2\cos^2\theta}{2}\right) \tag{4}$$

Here the minus sign reflects the fact that the contracted cell is shorter along $\mathbf{v}$, but the gas density is isotropic (in the rotating experiment), so fewer molecules occupy the shortened path.

**From molecule count to fringe shift.** The total gas-induced phase delay (in wavelengths) for a single pass through the cell is $N_0 \times \delta\phi/(2\pi) = L(n-1)/\lambda$. The variation in molecule count on rotation (Eq. 4) modulates this phase. Writing $\cos^2\theta = \frac{1}{2}(1+\cos 2\theta)$, the peak-to-peak amplitude of the $\cos 2\theta$ oscillation in $N(\theta)$ is $N_0\beta^2/2$. Multiplying by the phase per molecule gives the single-pass fringe shift amplitude:

$$\Delta N_{\text{single}} = \frac{L}{2\lambda}(n-1)\beta^2 \tag{5a}$$

For a bidirectional (two-pass) configuration the photon traverses the gas cell twice, doubling the signal:

$$\Delta N_{\text{two-pass}} = \frac{L}{\lambda}(n-1)\beta^2 \tag{5b}$$

These are pure second-harmonic ($\cos 2\theta$) signals. All quantities are experimentally measurable: $L$, $\lambda$, $n$, and $\beta = v/c$.

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[1] The phase delay per molecule results from the electromagnetic interaction within a bound system (the molecule) and is frame-independent. The exact Fresnel drag coefficient emerges naturally from this decomposition, confirming its validity as a calculational tool.

### 5.1 Numerical estimates

Table 1: Predicted second-harmonic fringe shift (single pass, $k = 1$, $L = 0.5$ m, $\lambda = 532$ nm) for $v = 220$ km/s ($\beta = 7.33 \times 10^{-4}$). Multi-pass configurations multiply the signal by $k$.

| Gas | Pressure | $n - 1$ | $\Delta N$ (fringes) |
|---|---|---|---|
| Air | 1 atm | $2.73 \times 10^{-4}$ | $6.9 \times 10^{-5}$ |
| Air | 10 atm | $2.73 \times 10^{-3}$ | $6.9 \times 10^{-4}$ |
| Air | 30 atm | $8.2 \times 10^{-3}$ | $2.1 \times 10^{-3}$ |
| $CO_2$ | 10 atm | $4.5 \times 10^{-3}$ | $1.1 \times 10^{-3}$ |

The signal scales linearly with gas pressure (through $n - 1$), with cell length $L$, and with the number of passes $k$, offering direct routes to better sensitivity.

### 5.2 Material predictions

**Solids (bound).** The FitzGerald conspiracy operates fully for any bound system: atoms follow the lattice deformation at the speed of sound, and the optical response of the medium transforms accordingly. Directional density is anisotropic, but the anisotropy is exactly compensated by the anisotropy of the phase delay per molecule. The net signal is zero — for any solid, at any refractive index, at any rotation speed. This is the standard null result of solid-cavity experiments [4, 5].

**Gases (unbound, rotating).** In a continuously rotating experiment, the gas density remains isotropic because diffusion is too slow to track the rotating contraction direction. The full signal $\Delta N = k\,(L/2\lambda)\,(n-1)\,\beta^2$ is predicted.

**Gases (unbound, static).** In a static experiment, the gas slowly equilibrates toward the contracted anisotropy. After many diffusion times, the conspiracy is restored and the signal vanishes. A static gas experiment is predicted to show a *decaying* signal with time constant $\tau_{\text{diff}}$.

**Liquids.** In a liquid, molecules are in near-contact, separated by distances comparable to their own dimensions. The FitzGerald contraction of individual molecules propagates through the medium via direct intermolecular interactions at the speed of sound ($v_s \sim 1500$ m/s in water), giving a response time $\tau_{\text{sound}} \sim L/v_s \sim 10^{-4}$ s — far faster than any rotation period. In this respect, liquids behave like solids: the anisotropy tracks the contraction direction instantaneously, and rotation cannot suppress it. The full directional density signal of Eq. (5) is therefore not predicted for liquids. However, the derivation assumes that molecular dimensions are much smaller than intermolecular distances — a condition well satisfied in gases but not in liquids, where the two scales are comparable. A much smaller residual effect cannot be excluded.

## 6 Harmonic Content and Additional Predictions

### 6.1 Second harmonic: the directional density signal

The directional density effect produces a pure $\cos 2\theta$ signal on rotation (Eq. 5). In a horizontal interferometer, the amplitude is modulated by the elevation $\psi$ of the preferred-frame velocity:

$$\Delta N(\theta) \propto \cos^2 \psi \times \cos 2(\theta - \varphi) \tag{5}$$

where $\varphi$ is the azimuthal direction of $\mathbf{v}$ projected onto the horizontal plane. This amplitude undergoes sidereal modulation as $\psi$ changes with Earth's rotation.

### 6.2 First harmonic: the diffusion lag

Because the diffusion time greatly exceeds the rotation period, the gas density perturbation does not vanish completely. A small residual perturbation tracks the rotating contraction direction with a phase lag, producing a first-harmonic ($\cos\theta$) component. The buildup of this perturbation is gradual (governed by diffusion), while its release when the contraction axis rotates past the cell's principal direction can be more abrupt — potentially resulting in an asymmetric waveform rather than a pure sinusoid.

### 6.3 Static limit

The diffusion mechanism predicts that a gas experiment held in a fixed orientation for a time much longer than $\tau_{\text{diff}}$ should yield a diminished signal, as the gas gradually equilibrates toward the contracted anisotropy and the conspiracy is restored. A step-and-measure approach — rotating to a new orientation, stopping briefly, and measuring — would still show the full signal provided the measurement time at each orientation is short compared to $\tau_{\text{diff}}$. More generally, any measurement protocol in which the gas cell orientation changes on a timescale much shorter than $\tau_{\text{diff}}$ should preserve the signal.

## 7 Discussion

### 7.1 Relation to previous experiments

Manley [2, 3] developed a rotating Mach-Zehnder interferometer comparing light propagation in gas and vacuum — a design well suited for testing these predictions. His data show both first and second harmonic signals of comparable amplitude. The second-harmonic amplitude, read from the data in [3] (approximately 0.2–0.3 in units of $\lambda/1000$, peak-to-peak) and applied to the single-pass formula (Eq. 5a) with his parameters ($L = 0.53$ m, $\lambda = 532$ nm, $n - 1 = 2.73 \times 10^{-4}$) gives an inferred velocity in the range 200–400 km/s, consistent with the solar Galactic orbital velocity ($\sim$220 km/s, toward Cygnus) or the CMB dipole velocity ($\sim$370 km/s, toward Leo). The data do not yet distinguish between these candidates; a dedicated experiment with pressure scaling would be needed to do so.

The first-harmonic signal in Manley's data is naturally explained by the diffusion-lag mechanism (Section 6.2). Its non-sinusoidal shape, visible in the filtered data of [3], is qualitatively consistent with the asymmetric buildup and release predicted by the diffusion model.

The possibility that the refractive index of gaseous media plays a distinctive role in ether-drift experiments has been explored by Consoli and Pluchino [1], who arrived at a numerically similar prediction through a different physical argument (vacuum condensate mechanism). The present work provides an independent derivation based on the diffusion timescale of molecular FitzGerald contraction.

### 7.2 Experimental requirements

The essential requirements for testing the prediction are: (i) a gas-filled optical path, (ii) a vacuum or solid reference path, (iii) continuous rotation on a platform, and (iv) the ability to vary gas pressure. Any interferometric configuration that compares optical phase in a gas path against a direction-independent reference on a rotating platform is suitable — including Mach-Zehnder, Michelson, Fabry-Pérot, and ring-cavity geometries. Each has its own advantages regarding sensitivity, systematic rejection, and practical implementation; the choice can be left to the experimenter.

Several design considerations are worth noting. Placing the gas and reference optical paths parallel and close together minimises the influence of vibrations and temperature fluctuations, since both paths experience nearly identical perturbations. Reducing the enclosed area between the two paths — for example, by stacking them vertically — suppresses the Sagnac effect from rotation speed fluctuations. Multi-pass or cavity-enhanced configurations increase the effective path length and hence the signal. A particularly attractive option is a Michelson-Morley configuration in which two orthogonal multi-pass beams traverse the *same* gas volume. Any real density inhomogeneity (from temperature gradients, convection, or turbulence) affects both beams equally and cancels in the difference, while the directional density signal — which depends on beam *orientation*, not position — is preserved.

### 7.3 Pressure scaling and calibration

Pressure variation provides a built-in, model-independent calibration: the predicted signal scales linearly with $(n-1) \propto p$, while most systematic effects do not. At elevated pressures the diffusion coefficient decreases ($D \propto 1/p$), further strengthening the rotation suppression. Standard commercial gas cells with quartz or sapphire windows routinely operate in the 10–30 atm range; pressures up to 50 atm and beyond are achievable with specialized cells. At 30 atm, the predicted signal for a 0.5 m single-pass cell reaches $\sim 2 \times 10^{-3}$ fringes — well within range of standard interferometric detection without cryogenic or ultra-high-vacuum apparatus.

A further increase in sensitivity could be achieved using a supercritical fluid such as $CO_2$ (critical point: 31 °C, 73 atm). Above the critical point, $CO_2$ is optically transparent, has $(n-1) \sim 0.1$ — two orders of magnitude above a gas at 10 atm — while retaining gas-like molecular mobility and diffusion coefficients far below those of a gas. The combination of large $(n-1)$ and large $\tau_{\text{diff}}$ would maximise both the signal amplitude and the effectiveness of the rotation suppression. The engineering requirements for a high-pressure cell on a rotating platform are nontrivial but well within the capabilities of existing supercritical fluid technology.

### 7.4 Existing infrastructure

Modern rotating optical cavity experiments [4, 5] have reached sensitivities of $\Delta c/c \sim 10^{-17}$ using solid dielectrics and report null results — exactly as predicted here. The same apparatus, modified to include a gas-filled optical path, would have more than sufficient sensitivity to detect the predicted signal of order $(n-1)\beta^2 \sim 10^{-10}$ for air at 1 atm — a margin of seven orders of magnitude. At the other end of the complexity scale, a tabletop Mach-Zehnder interferometer with a sealed gas cell on a commercial rotating platform represents a minimal implementation accessible to university-level laboratories.

### 7.5 Tilt as a systematic control

If the interferometer beam axis is tilted at angle $h$ relative to the horizontal plane, the contraction depends on the dot product between the beam direction and the velocity. For a beam rotating at angle $\theta$ in the tilted plane and a preferred-frame velocity at elevation $\psi$ with azimuthal direction $\varphi$, the unit vectors are:

$$\hat{n} = (\cos h \, \cos\theta, \; \cos h \, \sin\theta, \; \sin h) \tag{6}$$

$$\hat{v} = (\cos\psi \, \cos\varphi, \; \cos\psi \, \sin\varphi, \; \sin\psi) \tag{7}$$

The contraction factor is $(\hat{n} \cdot \hat{v})^2$. Evaluating the dot product:

$$\hat{n} \cdot \hat{v} = \cos h \, \cos\psi \, \cos(\theta - \varphi) + \sin h \, \sin\psi \tag{8}$$

Squaring and collecting terms by harmonic order in $\theta$:

$$\begin{aligned}(\hat{n} \cdot \hat{v})^2 = {} & \tfrac{1}{2}\cos^2 h \, \cos^2\psi \; \cos 2(\theta - \varphi) \quad \text{(second harmonic)} \\ & + \tfrac{1}{2}\sin 2h \; \sin 2\psi \; \cos(\theta - \varphi) \quad \text{(first harmonic)} \\ & + \text{constant terms}\end{aligned} \tag{9}$$

The ratio of first to second harmonic amplitudes is:

$$\frac{A_1}{A_2} = \frac{\sin 2h \ \sin 2\psi}{\cos^2 h \ \cos^2 \psi} = 4 \ \tan h \ \tan \psi \tag{10}$$

This has several useful consequences. The first harmonic vanishes at $h = 0$ (horizontal beam) and grows predictably with tilt — any first-harmonic signal at $h = 0$ is therefore not from the directional density mechanism and must be systematic or have an independent origin. Reversing the tilt ($h \to -h$) reverses the sign of the first harmonic while leaving the second harmonic unchanged. No known systematic effect reproduces this specific tilt dependence. Data taken at several tilt angles thus provide a powerful diagnostic for separating the predicted signal from instrumental artifacts.

## 8 Conclusion

We have shown that the FitzGerald-Lorentz conspiracy — the mechanism that makes SR and LET experimentally indistinguishable for bound systems — extends to gases only in the static limit. The root cause is a previously unexploited difference between the two theories: in SR, the Lorentz transformation applies instantaneously to all matter; in LET, the spatial redistribution of unbound gas molecules requires physical diffusion, which is slow. In a rotating experiment, the conspiracy is broken by the separation of timescales: the gas cannot equilibrate to the changing contraction direction because diffusion is too slow relative to the rotation period. This creates a measurable directional density anisotropy between gas and solid, yielding a parameter-free prediction for the fringe shift: $\Delta N = k\,(L/2\lambda)\,(n-1)\,(v/c)^2$.

The prediction carries three distinctive experimental signatures: (i) a second-harmonic signal whose amplitude scales linearly with gas pressure — providing a quantitative, model-independent calibration, (ii) an exact null result for solid dielectrics at any rotation speed, and (iii) a diminished signal for a gas cell held in a fixed orientation for a time approaching $\tau_{\text{diff}}$, as the gas equilibrates toward the contracted anisotropy. Together, these provide a rich falsification structure that no single systematic error could mimic.

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**Author contributions.** A.J.: conceptualization, formal analysis, writing – original draft, writing – review & editing.

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