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

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Abstract

We show that the directional density of an ideal gas remains isotropic under FitzGerald-Lorentz contraction of its container, while that of a bound solid becomes anisotropic. Combined with the invariance of the optical phase delay per molecule, this yields parameter-free predictions for gas-filled interferometers under Lorentzian Relativity. For a gas cell of physical length L measured against a direction-independent reference, the peak-to-peak fringe shift on a full rotation is $\Delta N = k\,(L/2\lambda)\,(n-1)\,(v/c)^2$, where k is the number of passes through the gas ($k = 1$ for a single pass, $k = 2$ for a round trip). The signal arises from the orientation-dependent molecule count in the contracted gas path. We predict null results for solid-dielectric interferometers regardless of refractive index.

1 Directional Density

We define directional density $\rho_d(\hat{n})$ as the number of atoms per unit length along direction $\hat{n}$. For a homogeneous medium with uniform number density, directional density is the same in all directions.

Bound systems. In a crystal moving at velocity v, FitzGerald-Lorentz contraction compresses lattice spacings along $\mathbf{v}$ by a factor $1/\gamma$ while leaving perpendicular spacings unchanged. The directional density along $\mathbf{v}$ increases by γ; perpendicular directions are unaffected. Atoms cannot redistribute — they are held by binding forces. The anisotropy is $\Delta\rho_d/\rho_d \approx \beta^2/2$.

Unbound systems. For an ideal gas, the spatial distribution remains uniform regardless of container shape or velocity distribution anisotropy. Consider a particle bouncing between walls separated by L_x, moving to the right at speed v_1 and to the left at speed v_2 (in LET these differ because molecules travelling in opposite directions relative to the ether have different relativistic energies; in SR the container frame is symmetric and $v_1 = v_2$). The time spent in any interval dx per full cycle is $dx/v_1 + dx/v_2 = dx(v_1 + v_2)/(v_1 v_2)$; the oscillation period is $L_x/v_1 + L_x/v_2 = L_x(v_1 + v_2)/(v_1 v_2)$. The ratio — the time-averaged density — is $1/L_x$, independent of either speed, because the factor $(v_1 + v_2)/(v_1 v_2)$ cancels exactly. For N non-interacting particles, the number density is $N/V = \text{const}$ throughout the volume.

This generalises to three dimensions and to any number of particles with any velocity distribution. The cancellation is algebraic and does not require equal speeds in opposite directions.

Therefore, when a gas container contracts along $\mathbf{v}$, the gas redistributes uniformly in the new volume. FitzGerald-Lorentz contraction is a linear transformation with Jacobian $1/\gamma$: the volume of any container, regardless of shape or orientation, decreases to V/γ. Crucially, when the container is rotated, the contracted volume remains V/γ — only the shape changes, not the volume. A container aligned with $\mathbf{v}$ is shorter and wider; rotated 90°, it is longer and narrower; but in both cases the enclosed volume is the same. Gas, having no shear modulus and no shape memory, is insensitive to container shape — it fills whatever volume is available, uniformly. The

3D density is therefore $N/(V/\gamma) = \gamma N/V$, isotropic and independent of container orientation. The directional density remains the same in all directions (Fig. 1).

In a rotating interferometer, gas redistribution is further ensured by molecular collisions with the container walls. One might ask whether molecular trajectories in a static container could retain some directional "memory" imposed by the contracted geometry — for example, if the velocity distribution acquired a subtle anisotropy that persisted over time. In a rotating apparatus, this concern is eliminated: as the container turns, the walls continuously change orientation in space, and each molecular reflection randomizes the trajectory relative to the new geometry. The rotation acts as a physical mixer. At thermal velocities (~500 m/s in air), molecules undergo hundreds of wall collisions per second in a meter-scale container — far faster than any plausible rotation rate. The gas is therefore fully re-thermalized at every instantaneous orientation, with the spatial density uniform throughout the volume at all times.

A solid, by contrast, deforms with the container: its atoms are bound to lattice sites and follow the shape change. The directional density of a crystal becomes anisotropic under contraction.

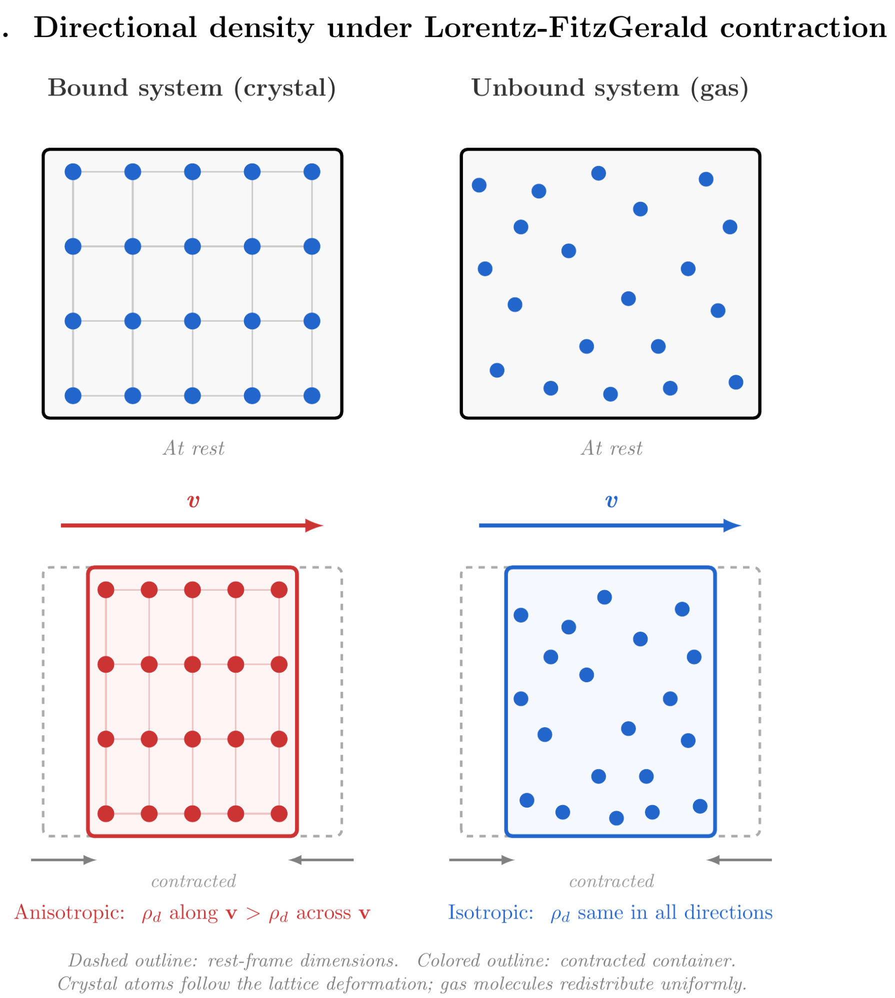

Figure 1: Directional density under FitzGerald-Lorentz contraction. Left: crystal (bound) — atoms follow lattice deformation, directional density becomes anisotropic. Right: gas (unbound) — molecules redistribute uniformly in the contracted volume, directional density remains isotropic. Dashed outline: contracted container. Grey outline: rest-frame dimensions.

2 Optical Phase in a Gas Path

The phase delay contributed by each gas molecule to a traversing photon is a Lorentz scalar $\delta\phi$ — it results from the electromagnetic interaction within a bound system (the molecule) and is frame-independent.[1] The total gas-induced phase along the beam path is:

$$\Phi_{\text{gas}} = N_{\text{path}} \times \delta\phi \tag{1}$$

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

A vacuum path, or a path through a solid medium (optical fiber, glass rod), serves as a reference. Being a bound system, it contracts with the apparatus, and its optical phase is direction-independent — this is the standard null result of vacuum interferometry.

3 Interferometric Signal

Consider a gas cell of physical length L (measured with a ruler at rest) mounted alongside a vacuum reference channel on a rotating platform. As the platform turns, both channels sweep all directions in the horizontal plane.

Three interferometric configurations are natural candidates for testing the prediction. (i) A single-pass Mach-Zehnder interferometer with parallel gas and vacuum paths, as employed by Manley [2,3]. (ii) A reflected (round-trip) Mach-Zehnder or parallel-arm Michelson, in which end mirrors send the beams back through the same paths, doubling the signal ($k = 2$). (iii) Two parallel Fabry-Perot cavities on a common rotating platform — one evacuated, one gas-filled — with lasers locked to their respective resonances and the beat frequency monitored during rotation; this is the minimal modification to existing rotating-cavity apparatus [6,7]. Each configuration has its own balance of signal strength, systematic control, and experimental complexity.

The vacuum channel provides a direction-independent phase reference — its optical phase is the standard null result of bound-system interferometry.

The gas channel, oriented at angle θ to $\mathbf{v}$, has contracted length $L(\theta) = L(1 - \beta^2 \cos^2\theta/2)$. Since the gas density is isotropic and constant (Section 1), the molecule count in the beam path is simply proportional to the path length:

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

where N_0 is the rest-frame molecule count along the cell. The path contracts — fewer molecules fit along it. The formula is the same as for length contraction, applied directly to molecule count.

From molecule count to fringe shift. The total gas-induced phase delay (in wavelengths) for a single pass through the cell is $N_0 \times \delta\phi/(2\pi) = L(n-1)/\lambda$ (this is simply the well-known excess optical path $(n-1)L$ divided by λ). The variation in molecule count on rotation (Eq. 2) 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:

$$\Delta N_{\text{single}} = \frac{L}{2\lambda}(n-1)\beta^2 \tag{3a}$$

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

$$\Delta N_{\text{two-pass}} = \frac{L}{\lambda}(n-1)\beta^2 \tag{3b}$$

[1] The phase delay per molecule can be derived by decomposing the photon transit into free propagation (at speed c) and interaction with the bound molecular system (Lorentz-transformed from the molecule's rest frame). The exact Fresnel drag coefficient emerges naturally from this decomposition, confirming its validity as a calculational tool without requiring a specific physical model of ether drag.

In compact notation: $\Delta N = k\,(L/2\lambda)\,(n-1)\,\beta^2$, where k is the number of passes through the gas ($k=1$ single, $k=2$ reflected). This is a parameter-free prediction: L and λ are apparatus constants, n is the measured refractive index, and v (hence β) is the velocity to be determined.

Numerical examples for air ($n-1 = 2.73\times10^{-4}$ at 1 atm), gas cell length $L = 1$ m, $\lambda = 532$ nm, two-pass ($k=2$):

	v (km/s)	β^2	ΔN
Galactic orbit (Cygnus)	220	5.4×10^{-7}	$2.7\times10^{-4}\ \lambda$
CMB dipole (Leo)	370	1.5×10^{-6}	$7.7\times10^{-4}\ \lambda$
At 10 atm ($n-1 = 2.73\times10^{-3}$):			
Galactic orbit (Cygnus)	220	5.4×10^{-7}	$2.7\times10^{-3}\ \lambda$
CMB dipole (Leo)	370	1.5×10^{-6}	$7.7\times10^{-3}\ \lambda$

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.

Harmonic content. If the velocity vector $\mathbf{v}$ makes angle ψ with the horizontal plane, the horizontal projection of the contraction is reduced by $\cos^2\psi$. The signal on rotation remains a pure second harmonic:

$$\Delta N(\theta) \propto \cos^2\psi \times \cos 2(\theta - \varphi) \tag{4}$$

where φ is the azimuthal direction of $\mathbf{v}$ projected onto the horizontal. The elevation ψ modulates the amplitude but does not change the harmonic order. A first-harmonic ($\cos\theta$) component in a horizontal interferometer therefore cannot arise from directional density — its presence indicates systematic effects (gravity, thermal gradients).

However, if the gas cell is tilted at angle h relative to the rotation plane — for example, to sample a wider range of sky directions — the contraction factor $\cos^2\theta$ in Eq. (2) is evaluated along the tilted beam axis rather than in the horizontal plane. Decomposing $(\hat{n}\cdot\hat{v})^2$ for a beam tilted at angle h and velocity elevation ψ gives both a second-harmonic component (amplitude $\propto \cos^2 h \cos^2\psi$) and a first-harmonic component (amplitude $\propto \sin 2h \sin 2\psi$). Their ratio is $4\tan h \tan\psi$. This has two consequences: (i) the first harmonic vanishes when either $h = 0$ (no tilt) or $\psi = 0$ (velocity in horizontal plane), and (ii) even a moderate tilt can produce a large first harmonic when ψ is large — for example, at $h = 10^\circ$ and $\psi = 48^\circ$ (Cygnus from mid-latitudes) the ratio is already $\sim$0.8. Data taken at different tilt angles must be analyzed separately, and the harmonic content itself becomes a diagnostic of the geometry.

4 Predictions Across States of Matter

The analysis yields clean predictions for two limiting cases and an intermediate one.

Gases (unbound). Any gas whose molecules move freely — that is, not trapped by external electric or magnetic fields — qualifies as an unbound system. Molecules redistribute uniformly in the contracted volume, directional density remains isotropic, and the full signal $\Delta N = k\,(L/2\lambda)\,(n-1)\,\beta^2$ is predicted. This applies equally to air, helium, CO_2, or any other gas at any pressure.

Solids (bound). Atoms in a crystal or amorphous solid are locked to their equilibrium positions by binding forces. When the solid contracts, its atoms follow the deformation and the directional density becomes anisotropic. However, the optical response per unit cell transforms correspondingly — this is the FitzGerald-Lorentz "conspiracy," in which length contraction, time dilation, and the electromagnetic response of bound matter combine to render the optical phase direction-independent. Predicted signal: zero. This holds for any solid dielectric regardless of refractive index, consistent with the null results of modern rotating-cavity experiments using fused silica resonators [6,7].

Liquids (intermediate). Molecules in a liquid are mobile but interact strongly, with short-range order and characteristic relaxation times. Whether they redistribute fully (as in a gas) or partially follow the container deformation (as in a solid) depends on the balance between intermolecular forces and molecular mobility. Quantitative predictions for liquids require molecular dynamics simulations beyond the scope of this work.

The most unambiguous experimental test is therefore the comparison of a gas-filled interferometer (full signal predicted) with a vacuum or solid-reference interferometer (null predicted). The gas-versus-vacuum comparison involves no intermediate states and no modelling assumptions beyond ideal gas statistics.

5 Discussion

The signal in gas-filled interferometers arises from a counting asymmetry: a contracted arm contains fewer gas molecules than an uncontracted one, because gas redistributes isotropically while the arm does not. No vacuum condensate or ether drag model is invoked — only FitzGerald-Lorentz contraction and ideal gas statistics.

The prediction $\Delta N = k\,(L/2\lambda)\,(n-1)\,\beta^2$ coincides with the formula obtained by Consoli and Pluchino [1] through an independent analysis based on the non-trivial vacuum structure of quantum field theory. That two different approaches — one from statistical mechanics, one from vacuum condensate physics — yield the same functional dependence on $(n-1)$ and β^2 supports the validity of both results.

Manley [2,3] developed a rotating Mach-Zehnder interferometer comparing light propagation in gas and vacuum in parallel adjacent paths — a design well suited for testing these predictions. In his analysis [4], the combined signal amplitude is interpreted as a first-order effect ($\Delta N \propto v/c$), yielding an inferred velocity of ~0.17 km/s. We were unable, however, to identify a physical mechanism by which the laboratory velocity $\mathbf{v}$ could produce a first-harmonic ($\cos\theta$) signal of the observed magnitude in a gas-filled interferometer; the directional density effect is strictly second order. We therefore focus on the second harmonic, which is the component predicted by the present analysis and whose amplitude is in good agreement with the formula of Consoli and Pluchino [1].

Reading the second-harmonic amplitude from the data in [3] (approximately 0.2–0.3 in units of $\lambda/1000$, peak-to-peak) and applying the single-pass formula (Eq. 3a) $\Delta N = (L/2\lambda)(n-1)\beta^2\cos^2\psi$ with Manley's parameters ($L = 0.53$ m, $\lambda = 532$ nm, $n-1 = 2.73\times10^{-4}$) gives an inferred velocity in the range 200–400 km/s, depending on the geometric projection factor $\cos^2\psi$. Two cosmic velocities fall in this range: the solar orbital velocity about the Galactic center (~220 km/s, apex toward Cygnus) and the motion of the solar system relative to the CMB rest frame (~370 km/s, apex toward Leo). The data in [3] do not yet distinguish between these candidates; a dedicated experiment with pressure scaling and diurnal tracking of the preferred direction would be needed to do so.

In any of the configurations described in Section 3, pressure variation provides a built-in calibration: the signal should scale linearly with gas pressure through $n-1$. Comparing signals at several pressures — easily achieved with a roughing pump — would confirm or exclude the directional density mechanism independently of absolute amplitude.

We note that the historical Fresnel drag coefficient $f = 1 - 1/n^2$, being a first-order approximation, is not valid for second-order (β^2) calculations. The exact expression — the relativistic velocity addition applied to the phase velocity c/n — must be used at this order [5]. Care must be taken to distinguish kinematic effects (which are compensated by the exact Fresnel drag) from the directional density effect (which is not).

The decisive experimental test is a comparison of interferometric signals in gas versus vacuum (or solid) reference paths, where the prediction is unambiguous. We note that modern rotating optical cavity experiments — which compare resonance frequencies of fused silica resonators on precision turntables — have reached sensitivities of $\Delta c/c \sim 10^{-17}$ and report null results [6,7]. Since these experiments use solid dielectrics, a null is exactly what the present analysis predicts (Section 4). A gas-filled cavity will not achieve this sensitivity: pressure and temperature fluctuations, molecular scattering losses, and reduced finesse will degrade performance by several orders of magnitude. Nevertheless, the predicted signal of order $(n-1)\beta^2 \sim 10^{-10}$ for air at atmospheric pressure leaves ample margin even with substantially degraded sensitivity. Increasing the gas pressure to 10 atm raises the signal to $\sim 10^{-9}$, further relaxing the requirements on instrumental stability.

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