The Two Velocities of Classical Waves

J.P. Wesley

Abstract

Classical waves in a medium, valid for light and for sound, involve two velocities, the phase velocity c′ and the energy velocity c, which in general are different both in direction as well as in magnitude. Doppler effects for a moving source and observer and for a wind are derived. The out-and-back phase velocity of a wave in a wind is proved to be isotropic according to classical wave theory, which explains the Michelson–Morley null result as simply a classical Doppler effect. Feist has recently experimentally demonstrated the isotropy of the out-and-back phase velocity of sound in a wind, thereby confirming classical wave theory and duplicating for sound the Michelson–Morley null result for light.

Key words: classical waves, light, sound, phase velocity, energy velocity, Michelson–Morley, Feist's results

1. THE DISTINCTION BETWEEN THE ENERGY AND PHASE VELOCITIES OF A CLASSICAL WAVE

A perturbation in a medium propagates with an *energy* velocity c characteristic of the medium. A sinusoidal time-varying perturbation far from the source produces a plane wave with an amplitude given by

$$\Psi = \sin(\mathbf{k}\cdot\mathbf{r} - \omega t), \tag{1}$$

where $\omega = 2\pi f$ is the angular frequency, $\mathbf{k}$ is the propagation constant, $\lambda = 2\pi/|\mathbf{k}|$ is the wavelength, and $\mathbf{c}' = \mathbf{k}\omega/k^2$ is the *phase* velocity. In a stationary medium for a stationary source and stationary observer the *phase* velocity $\mathbf{c}' = c$, the *energy* velocity. However, the *phase* velocity defines the velocity of a *surface* of constant phase ϕ, where

$$\phi = \mathbf{k}\cdot\mathbf{r} - \omega t = \text{constant}, \tag{2}$$

whereas the *energy* velocity $\mathbf{c}$ defines energy flow along a linear space curve perpendicular to the surfaces of constant phase given by

$$\mathbf{c} = \frac{\mathbf{S}}{E}, \tag{3}$$

where the energy flux $\mathbf{S}$ and the energy density E are defined by

$$\mathbf{S} = -\nabla\Psi\frac{\partial\Psi}{\partial t}, \qquad E = \frac{(\nabla\Psi)^2}{2} + \frac{(\partial\Psi/\partial tc)^2}{2}. \tag{4}$$

The meaning of the two different wave velocities is, thus, quite clear. The *phase* velocity $\mathbf{c}'$ defines in general an *apparent* velocity that carries information, the phase, and it need not have the same direction nor the same magnitude as the true physical *energy* velocity $\mathbf{c}$ (as shown in the examples below).

Since a transverse light wave may be specified by two coupled scalar wave-functions,(1) only scalar waves, valid for both sound and light, need be considered here (as is usually done in physical optics courses).

More general wave amplitudes may be defined as solutions to the wave equation

$$\nabla^2\Psi - \frac{\partial^2\Psi}{\partial t^2 c'^2} = 0 \tag{5}$$

in a source-free region for suitable boundary conditions.

2. DOPPLER EFFECT FOR A MOVING SOURCE

A source with a sinusoidal angular frequency ω_s moving with the constant velocity $\mathbf{v}_s$ with respect to a stationary medium produces a wave amplitude given by replacing $\mathbf{r}$ in (1) by $\mathbf{r} - \mathbf{v}_s t$, where the point of observation $\mathbf{r}$ is chosen relative to the moving source $\mathbf{v}_s t$; thus

$$\Psi_s = \sin[\mathbf{k}\cdot\mathbf{r} - (\omega_s + \mathbf{k}\cdot\mathbf{v}_s)t]. \tag{6}$$

The wave parameters for this wave generated by the moving source relative to the medium become

$$\begin{aligned} &\mathbf{k} = \frac{\mathbf{c}\omega_s}{c^2(1-\mathbf{c}\cdot\mathbf{v}_s/c^2)}, \quad \omega = \frac{\omega_s}{1-\mathbf{c}\cdot\mathbf{v}_s/c^2}, \\ &\mathbf{c}' = \frac{\mathbf{k}\omega}{k^2} = \mathbf{c}, \end{aligned} \tag{7}$$

where the *phase* velocity equals the *energy* velocity in this case.

The wave parameters relative to the moving source become

$$\begin{aligned} &\mathbf{k}_s = \mathbf{k} = \frac{\mathbf{c}\omega_s}{c^2(1-\mathbf{c}\cdot\mathbf{v}_s/c^2)}, \qquad \omega_s = \omega_s, \\ &\mathbf{c}'_s = \frac{\mathbf{k}_s\omega_s}{k_s^2} = \mathbf{c}\left(1-\frac{\mathbf{c}\cdot\mathbf{v}_s}{c^2}\right), \qquad \mathbf{c}^*_s = \mathbf{c}-\mathbf{v}_s, \end{aligned} \tag{8}$$

where the energy velocity relative to the moving source is $\mathbf{c}^*$. The results (7) and (8) are the usual well-known Doppler formulas.[2]

3. DOPPLER EFFECT FOR A MOVING OBSERVER

A plane wave in a stationary medium, (1), as observed by an observer moving with the velocity $\mathbf{v}_0$ with respect to the medium, may be obtained by replacing $\mathbf{r}$ by $\mathbf{r} + \mathbf{v}_0 t$ in (1), yielding

$$\Psi_s = \sin[\mathbf{k}\cdot\mathbf{r} - (\omega - \mathbf{k}\cdot\mathbf{v}_0)t]. \tag{9}$$

The wave parameters for the moving observer then become

$$\begin{aligned} &\mathbf{k}_0 = \mathbf{k} = \frac{\mathbf{c}\omega_s}{c^2}, \quad \omega_0 = \omega - \mathbf{k}\cdot\mathbf{v}_0 = \omega\left(1-\frac{\mathbf{c}\cdot\mathbf{v}_0}{c^2}\right), \\ &\mathbf{c}' = \frac{\mathbf{k}_0\omega_0}{k_0^2} = \mathbf{c}\left(1-\frac{\mathbf{c}\cdot\mathbf{v}_0}{c^2}\right), \quad \mathbf{c}^* = \mathbf{c}-\mathbf{v}_0, \end{aligned} \tag{10}$$

the *phase* velocity $\mathbf{c}'$ being again different from the *energy* velocity $\mathbf{c}^*$.

4. DOPPLER EFFECT FOR BOTH SOURCE AND OBSERVER MOVING

When (8) and (10) are combined, the general Doppler effect for both source and observer moving with velocities $\mathbf{v}_s$ and $\mathbf{v}_0$ is given by the wave parameters

$$\begin{aligned} &\mathbf{k}_0 = \frac{\mathbf{c}\omega_s}{c^2(1-\mathbf{c}\cdot\mathbf{v}_s/c^2)}, \\ &\omega_0 = \frac{\omega_s(1-\mathbf{c}\cdot\mathbf{v}_0/c^2)}{(1-\mathbf{c}\cdot\mathbf{v}_s/c^2)}, \\ &\mathbf{c}'_0 = \mathbf{c}\left(1-\frac{\mathbf{c}\cdot\mathbf{v}_0}{c^2}\right), \quad \mathbf{c}^*_0 = \mathbf{c}-\mathbf{v}_0. \end{aligned} \tag{11}$$

5. DOPPLER EFFECT IN A WIND

The case of a wind is of particular interest because of the unsuccessful attempt by Michelson and Morley to detect the luminiferous ether wind. For a wind the source and observer may be taken as fixed relative to each other and with the same velocity $\mathbf{v} = \mathbf{v}_s = \mathbf{v}_0$ relative to the medium, so the wind has velocity $-\mathbf{v}$. In this case the wave parameters from (11) become

$$\begin{aligned} &\mathbf{k} = \frac{\mathbf{c}\omega}{c^2(1-\mathbf{c}\cdot\mathbf{v}/c^2)}, \quad \omega_0 = \omega_s = \omega, \\ &\mathbf{c}' = \mathbf{c}\left(1-\frac{\mathbf{c}\cdot\mathbf{v}}{c^2}\right), \qquad \mathbf{c}^* = \mathbf{c}-\mathbf{v}. \end{aligned} \tag{12}$$

6. A SIGNAL TRANSMITTED THROUGH A WIND

The results in (12), derived analytically, are presented in Fig. 1 as a vector diagram. A source moving with velocity $\mathbf{v}$ sends a signal to a receiver a vector distance $\mathbf{L}$ from the source, which is also moving with precisely the same velocity $\mathbf{v}$. The signal follows the path $\mathbf{R}$ in the medium from the source to the receiver (the medium being taken stationary) with *energy* velocity $\mathbf{c}$ relative to the medium.

While the signal is traveling with this *energy* velocity $\mathbf{c}$ toward the receiver, the source is also traveling toward the receiver with velocity $v\cos\alpha$, so the apparent distance traveled by the energy signal is less by the amount

$$v\cos\alpha\Delta t, \tag{13}$$

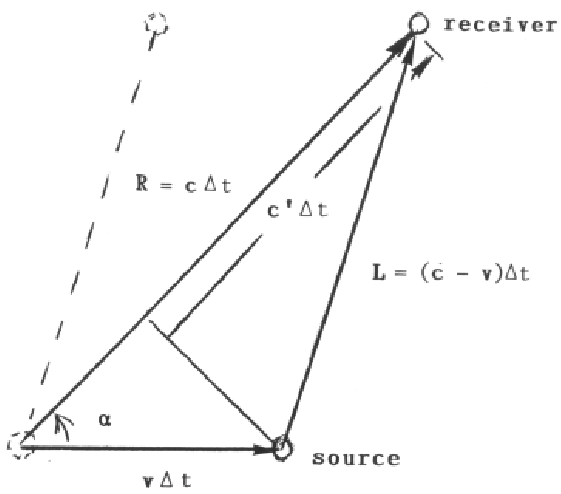

Figure 1. Vector diagram for a signal sent from a source to a receiver in a wind of velocity $-\mathbf{v}$, indicating the smaller apparent *phase* velocity $c' = c(1 - \mathbf{v} \cdot \mathbf{c}/c^2)$ resulting from the motion of the source toward the receiver, according to (12).

where $\Delta t = R/c$ is the total time the energy signal takes to travel the entire distance R from the source to the receiver. Relative to the source, as well as the receiver, the signal has traveled only the shorter distance

$$R - v\cos\alpha\Delta t \tag{14}$$

in the same time Δt with a consequently smaller apparent *phase* velocity given by

$$c' = \frac{R}{\Delta t} - v\cos\alpha = c\left(1 - \frac{\mathbf{v}\cdot\mathbf{c}}{c^2}\right), \tag{15}$$

since $v\cos\alpha = \mathbf{v}\cdot\mathbf{c}/c$.

The source and receiver both observe this velocity c' to be directed along the distance $\mathbf{L}$ from the source to the receiver. This *phase* velocity is a pseudovelocity, as the actual *energy* signal travels along $\mathbf{R}$ with velocity $\mathbf{c}$.

It may be noted that instantaneously the signal always lies somewhere along the line $\mathbf{L}$ between the source and the receiver, so the signal actually travels along $\mathbf{L}$ also, but with a slower velocity.

7. PROOF OF THE ISOTROPY OF THE OUT-AND-BACK PHASE VELOCITY IN A WIND

The Michelson–Morley[3] experiment involves the comparison of the *phases* of two coherent light beams sent out and back in perpendicular directions. The null phase difference that they found will now be proved to be simply a classical Doppler effect: the out-and-back *phase* velocity of a classical wave in a wind is independent of the out-and-back direction of the wave and also independent of the direction of the wind.

Considering Fig. 2, it is convenient to denote the outward *energy* velocity as $\mathbf{c}_+$ and the return *energy* velocity as $\mathbf{c}_-$, so the respective *phase* velocities taken along $\mathbf{L}$ out and back become

$$c'_+ = c\left(1 - \frac{\mathbf{c}_+\cdot\mathbf{v}}{c^2}\right), \qquad c'_- = c\left(1 - \frac{\mathbf{c}_-\cdot\mathbf{v}}{c^2}\right). \tag{16}$$

It may be noted from Fig. 2 that

$$\begin{aligned} \mathbf{R}_+ &= \mathbf{L} + \mathbf{v}\Delta t_+ = \mathbf{L} + \frac{\mathbf{v}R_+}{c}, \\ \mathbf{R}_- &= -\mathbf{L} + \mathbf{v}\Delta t_- = -\mathbf{L} + \frac{\mathbf{v}R_-}{c}. \end{aligned} \tag{17}$$

Solving (17) for the magnitudes R_+ and R_- yields

$$R_\pm = \sqrt{b^2 + L^2\left(1 - \frac{v^2}{c^2}\right)} \pm b, \tag{18}$$

where

$$b = \frac{\mathbf{v}\cdot\mathbf{L}}{c(1 - v^2/c^2)}. \tag{19}$$

From the directions of $\mathbf{c}_+$ and $\mathbf{c}_-$ parallel to $\mathbf{R}_+$ and $\mathbf{R}_-$ the scalar products in (16) become

$$\frac{\mathbf{c}_+\cdot\mathbf{v}}{c} = \frac{\mathbf{v}\cdot\mathbf{L}}{R_+} + \frac{v^2}{c}, \qquad \frac{\mathbf{c}_-\cdot\mathbf{v}}{c} = -\frac{\mathbf{v}\cdot\mathbf{L}}{R_-} + \frac{v^2}{c}, \tag{20}$$

and the phase velocities from (20), (19), and (16) become

$$\begin{aligned} c'_+ &= c\left(1 - \frac{v^2}{c^2}\right)\left(1 - \frac{b}{R_+}\right), \\ c'_- &= c\left(1 - \frac{v^2}{c^2}\right)\left(1 - \frac{b}{R_-}\right). \end{aligned} \tag{21}$$

The net out-and-back phase velocity $\overline{c'}$ is then given by

$$\frac{\Delta t}{L} = \frac{2}{\overline{c'}} = \frac{1}{c'_+} + \frac{1}{c'_-}, \tag{22}$$

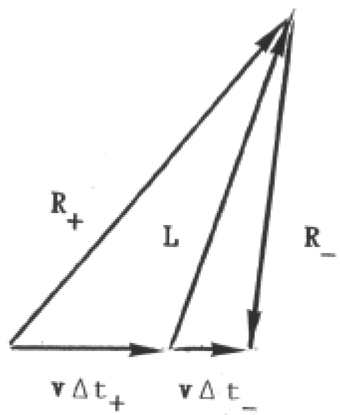

Figure 2. Diagram for the out-and-back *energy* wave paths out $\mathbf{R}_+ = \mathbf{c}_+\Delta t_+$ and back $\mathbf{R}_- = \mathbf{c}_-\Delta t_-$ in a wind.

where Δt is the total out-and-back transit time for the phase velocity along **L**.

From (22), (21), and (18) the net out-and-back phase velocity $\overline{c'}$ is given by

$$\frac{2c(1-v^2/c^2)}{\overline{c'}} = \frac{R_+}{R_+ - b} + \frac{R_-}{R_- + b} = \frac{N}{D}, \qquad (23)$$

where the numerator N and the denominator D are given by

$$\begin{aligned} N &= 2R_+R_- + b(R_+ - R_-), \\ D &= (R_+ + b)(R_- - b). \end{aligned} \qquad (24)$$

From (18) we have

$$R_+ - R_- = 2b, \quad R_+R_- = L^2\left(1 - \frac{v^2}{c^2}\right). \qquad (25)$$

Introducing (25) into (24) yields

$$\frac{N}{D} = 2, \qquad (26)$$

so the out-and-back phase velocity from (26) and (23) becomes

$$\overline{c'} = c\left(1 - \frac{v^2}{c^2}\right), \qquad (27)$$

which is independent of the direction of observation **L** or the direction of the wind **–v**. Thus the out-and-back phase velocity is isotropic, as was to be proved.

8. THE CONCLUSION TO BE DRAWN FROM THE MICHELSON–MORLEY NULL RESULT

Michelson and Morley obtained a null result for every orientation of their setup in the laboratory and not merely with one interferometer arm in the presumed direction of the ether wind and the other arm perpendicular to the wind, as generally pictured. Their experiment reveals the fact that the out-and-back *phase* velocity of light is isotropic to the out-and-back direction and to the direction of the ether wind. From other observations[(4–9)] an ether wind passes through the solar system at about 300 km/s, so they would have detected the wind if their experimental design had permitted it.

Since the out-and-back *phase* velocity of light in the ether wind is isotropic, there will be no phase difference between any two coherent light beams returning at 90° with respect to each other or at any other angle with respect to each other. To make this point more evident the two arms of the Michelson interferometer may be chosen to have another orientation with respect to each other, other than 90°, as indicated in Fig. 3. The same Michelson–Morley null result can be expected.

9. FEIST'S[(10)] OBSERVATIONS OF THE ISOTROPY OF THE OUT-AND-BACK PHASE VELOCITY OF SOUND IN A WIND

Practical equipment[(11)] has become available to measure distances to an accuracy of 0.1 mm by employing sounding, or echo, methods with ultra high frequency in air of the order of 60 KHz. A coded signal is sent through the air a distance D to a surface where it is reflected. The time out and back Δt is then measured to yield the desired distance

$$D = \frac{c\Delta t}{2}, \qquad (28)$$

where c is the velocity of sound in still air. In still air the *energy* velocity **c** and the *phase* velocity **c′** are the same. But once the source or the reflector moves relative to the air, the peculiarities of how the information, such as the phase, is fed into the air and read out again become significant. In this case it becomes necessary to distinguish between the *phase* velocity and the *energy* velocity.

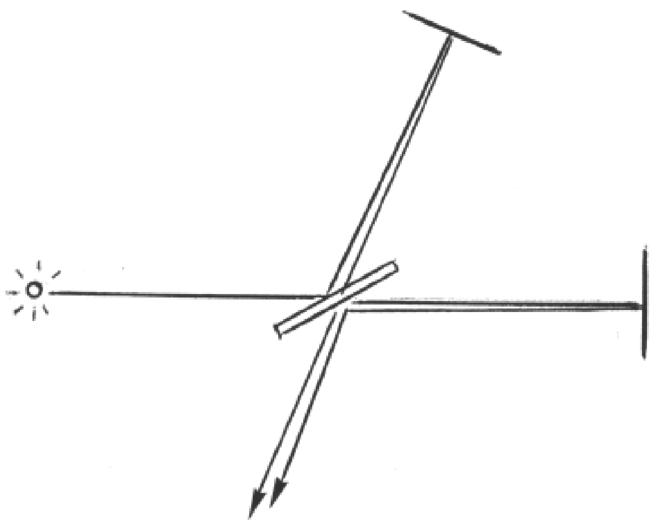

Figure 3. A variation of the Michelson–Morley experiment to make it evident that their null result was not due to the fact that the arms of their interferometer were perpendicular to each other.

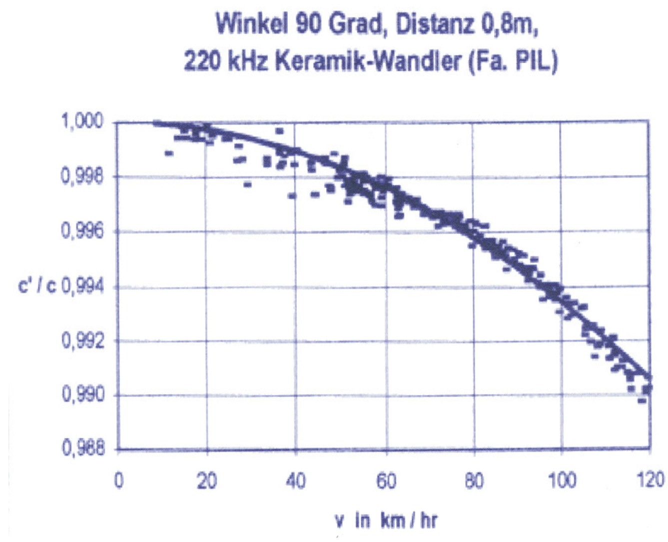

Figure 4. A series of observations at 220 KHz ultrasound made at θ = 90° to the forward velocity of the automobile from 0 to 120 km/h with an arm of length L = 0.8 m yielding the out-and-back *phase* velocity of sound as a fraction of the velocity of sound in still air of c = 343.37 m/s at 20°C, revealing the relationship $\overline{c}'/c = (1 - v^2/c^2)$, as in (27). (Reproduced by permission of N. Feist.)

In the case of a *wind*, the ultra high frequency sound equipment used to measure distances can no longer yield the desired distances. However, Feist recognized that this equipment can be used to measure the out-and-back *phase* velocity of sound in a wind by measuring the time a signal takes to travel from the source until its echo returns from a reflector a known vector distance **L** in a wind of known direction and velocity –**v**.

Feist chose a 50 KHz Folienwandler LR53 Type 262 manufactured by the Format Messtechnik Company, 76187 Karlsruhe, Germany. He mounted it on the roof of his automobile with a 1.35 m arm that could be oriented at various angles θ with respect to the forward motion of the automobile and with an 8 cm × 8.5 cm reflector on the end. The wind was created by driving the automobile from 0 to 100 km/h (27.78 m/s). He took out-and-back time measurements about every 0.5 km/h interval. He made five such runs for θ = 0°, 22°, 45°, 68°, and 90°. One special series of measurements is reproduced here in Fig. 4.

All six of his experimental curves of the out-and-back phase velocity of sound c' as a function of the wind velocity v yielded precisely the same theoretical result given by $\overline{c}' = c(1 - v^2/c^2)$, (27), for all of the five directions θ that he observed to within a very convincing accuracy.

Feist's results presented in Fig. 4 for θ = 90° do not fit at all the out-and-back *energy* velocity naively and erroneously assumed by Michelson for light, namely $\overline{c}'$ (Michelson) $= c(1 - v^2/c^2)^{1/2}$.

10. SOME CONCLUSIONS, DISCUSSION, AND SPECULATION

The present results appear to have some far-reaching implications for the study of light that may be briefly mentioned:

1. Since the out-and-back *phase* velocity of light is isotropic in an ether wind, standing light, or electrodynamic, waves, involving back and forth traveling waves, will reveal no orientation effects with respect to the ether wind or due to the direction of the setup's motion with respect to absolute space. The resonating frequency in a cavity is, thus, unaffected by its orientation in space, as is empirically observed. Similarly, no alteration in the standing electrodynamic wave pattern on a wire has ever been detected with a change in the direction of the wire.
2. Since the out-and-back *phase* velocity of light is $\overline{c}' = c(1 - v^2/c^2)$ in an ether wind of velocity **v**, the

phase velocity in a resonating cavity is $\vec{c}'$ and not the *energy* velocity *c*. Since the velocity of the ether wind, the absolute velocity of the solar system, as determined by various methods,[4–9] is about 300 km/s, and $v^2/c^2 \sim 10^{-6}$, the value for the "velocity of light" listed to nine places in the tables of physical constants, which is erroneously chosen as the cavity value $\vec{c}'$, is in error in the sixth place.

3. Since the Fizeau[12]–Michelson method that is supposed to measure the energy velocity of light *c* depends on the out-and-back time for a light signal to travel a known distance, it also measures instead the out-and-back *phase* velocity $\vec{c}'$ in the ether wind. It is, thus, also subject to precisely the same error as the cavity method.
4. To correct the *phase* velocity $\vec{c}'$ to obtain the true *energy* velocity *c* to better than six places, a reliable value for the absolute velocity of the solar system, or the ether wind, is needed, and is best determined by Marinov's[4] coupled-mirrors method with the improvements suggested by Wesley.[13]
5. Since the Michelson–Morley null result is readily explained as simply a classical Doppler effect, it is unlikely that any nonclassical transverse Doppler effect actually exists, such as reported by Ives and Stilwell,[14] Kaivola et al.,[15] and Klein et al.,[16] observing rapidly moving radiating molecular beams at a perpendicularity that may not have been sufficiently accurately achieved. Thim[17] has recently observed the classical null transverse Doppler effect using a fast source and microwaves.
6. The nonphysical nature of the *phase* velocity in contrast to the true physical *energy* velocity helps to indicate the nonphysical nature of the *mathematical* "superposition principle," which is primarily a function of *phase* differences. For example, only the *energy* flow through Young's[18] double pinholes can reveal the true causality for the irreversible interference pattern produced on a photographic plate.
7. Since light is a real physical phenomenon that transports energy, the *phase* behavior of light must be imprinted upon a more or less continuous physical medium. However, there is no evidence for any fixed physical luminiferous ether. It appears thus that the flux of physically real photons that carry energy must themselves act as the more or less continuous medium, or luminiferous ether, that registers the *phase*. A sinusoidally varying light wave may then be likened to a fixed ripple on the surface of a stream that is carried along with the stream. The evidence of Panarella[19] and Dontsov and Baz[20] indicates that no *phase* phenomenon can arise if the photon density becomes sufficiently low.
8. This photon medium should also account for the electric and magnetic fields observed in transverse light waves. These fields may be readily accounted for if the photons themselves are electric dipoles, as suggested by Wesley.[21]

Acknowledgments

The author is indebted to Norbert Feist for his pioneering experiment revealing the isotropy of the out-and-back *phase* velocity of sound in a wind that made this paper possible. The help of Hartwig W. Thim and Harald van Lintel is also acknowledged.

Received 30 September 2003.

Résumé

Les ondes classiques dans un milieu impliquent deux vitesses: la vitesse de phase **c′** *et la vitesse de l'énergie* **c***; elles sont en général différentes, à la fois en direction et en grandeur. Ceci est valable, donc, pour le son comme pour la lumière. On dérive les effets Doppler pour les cas du mouvement de la source et de l'observateur ainsi que du vent. On démontre que la vitesse de phase aller/retour d'une onde dans un vent est isotropique, en accord avec la théorie classique. Ceci explique que le résultat nul de Michelson–Morley est un simple effet Doppler classique. Feist a récemment prouvé expérimentalement l'isotropie de la vitesse de phase aller/retour d'une onde sonore dans un vent, confirmant ainsi la théorie classique. Il a obtenu de nouveau pour le son le résultat nul que Michelson–Morley avaient obtenu pour la lumière.*

References

1. J.P. Wesley, *Causal Quantum Theory* (Benjamin Wesley, 78176 Blumberg, Germany, 1983), p. 195.
2. *Idem*, *Advanced Fundamental Physics* (Benjamin Wesley, 78176 Blumberg, Germany, 1991), pp. 126–130.
3. A.A. Michelson and E.W. Morley, Am. J. Sci. **34,** 333, 427 (1887).
4. S. Marinov, Czech. J. Phys. B **24,** 965 (1974); Gen. Relativ. Gravit. **12,** 57 (1980); Spec. Sci. Tech. **3,** 57 (1980).
5. E.K. Conklin, Nature **222,** 971 (1969).
6. G. de Vaucouleurs and W.L. Peters, Nature **220,** 868 (1968).
7. Ch. Monstein and J.P. Wesley, Apeiron **3,** 33 (1996).
8. G.F. Smoot, H.V. Gorenstein, and R.A. Muller, Phys. Rev. Lett. **39,** 898 (1977).
9. P.S. Henry, Nature **231,** 516 (1971).
10. N. Feist, 25-page monograph *Tiber die Lichtgeschwindigkeit in bewegten Systemen* (2001), available from author: Leo-Fall-Strasse 26, 86368 Gersthofen, Germany; http/arxiv.org/abs/physics/0104059
11. B.H.W. Hofmann, *Sensor 97 Kongressband IV* (Format Messtechnik, GmbH, Draisstrasse 1, 76571, Gaggenau, Germany), Vortrag A9.3, p. 17.
12. H.L. Fizeau, Comptes Rendues **29,** 90 (1849).
13. Ref. 2, pp. 91–93.
14. H. Ives and G.R. Stilwell, J. Opt. Soc. Am. **28,** 215 (1938); **31,** 369 (1941).
15. M. Kaivola, O. Poulsen, E. Riis, and S.A. Lee, Phys. Rev. Lett. **54,** 255 (1985).
16. R. Klein et al., Z. Phys. A **342,** 455 (1992).
17. H.W. Thim, IEEE Trans. Instrumentation Measurement **1,** 52 (2003).
18. Ref. 1, pp. 25, 184–189, 270–278.
19. E. Panarella, in *Proc. NATO Adv. Res. Workshop*, edited by W.M. Honig, D.W. Kraft, and E. Panarella (Plenum Press, Bridgeport, CT, 1986).
20. Yu.P. Dontsov and A.L. Baz, JETP **25,** 1 (1967).
21. J.P. Wesley, Phys. Essays **16,** 499 (2003).

J.P. Wesley
Weiherdammstrasse 24
78176 Blumberg, Germany