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Are Phonons Particles?

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If phonons are particles, they must be attached to absolute space through their proper masses, which depend on the absolute velocities. In such a case one should be able to register with phonons the Sagnac and Marinov effects which have been observed with massless and massive particles (photons and neutrons). The experimental possibilities for such experiments are analyzed.

According to my absolute space–time theory,[1-3] the proper mass of a particle depends *not* on its velocity with respect to the inertial frame of reference used, but on its *velocity with respect to absolute space*. I call the first (*relative*) form of the proper mass *Einstein's* and the second (*absolute*) form *Marinov's*. As I showed recently,[3,4] if a particle with a mass m, moving at a velocity $v = c/n$ in the inertial frame of reference used (where c is the velocity of light and $n \geqslant 1$ is a number), strikes perfectly elastically another particle with mass M which is at rest in the frame, and $m \ll M$, then, proceeding from the absolute form of the laws of momentum and energy conservation, one obtains for the recoil velocity of the impringing light particle

$$v' = \frac{c}{n} + \frac{V}{n^2}(\cos\theta - \cos\theta') + \frac{V^2}{cn^3}(\cos\theta - \cos\theta')^2 \qquad (1)$$

where $\mathbf{V}$ is the velocity of the inertial frame in absolute space, θ is the angle between $\mathbf{v}$ and $\mathbf{V}$, and θ' is the angle between $\mathbf{v}'$ and $\mathbf{V}$; the equation is written within an accuracy of second order in V/c. Thus, measuring the velocity of the light particle before and after the collision, one can calculate the absolute velocity of the frame. Such experiments with massless particles,

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$n = 1$ (photons), were performed by Harress[5] and Sagnac[6] on a rotating disk in a laboratory, by Michelson *et al.*[7] on the spinning Earth, and by me[8,9] in the inertially moving laboratory. The first authors measured the so-called *Sagnac effect*, which is proportional to the absolute *angular* velocity of the *area* covered by the photons in mutually opposite directions after their "collision" with a semitransparent mirror (the heavy mass M), while I measured the *Marinov effect*, which is proportional to the absolute *linear* rotational velocity of the *straight path* covered by the photons in mutually opposite directions. The verification of formula (1) for massive particles, $n > 1$ (neutrons), was performed recently by Werner *et al.*,[10] who measured a Sagnac effect. I proposed[2] an experiment for measurement of the Marinov effect with the help of neutrons.

According to my theory, the energy e and the mass m are two different names (with different dimensions!) of the same entity, which represents the third one axiomatically introduced in physics (after space and time). In my theory, the equation $e = c^2m$ says no more than the equation $1\ \text{m} = 100\ \text{cm}$. If the propagation of sound represents the transfer of energy, then a mass is also transferred. The proper mass and proper energy of massive and massless particles are attached to absolute space. Is the sound energy also attached to absolute space, i.e., are phonons (until now considered as particles only for mathematical convenience) real particles or not? The most definite answer can be given by measuring the Sagnac and Marinov effects with phonons. If the effects exist, phonons are to be considered as real particles; if not, the essence of sound energy will pose *terrible difficulties* to theoretical physics. Indeed, if the propagation of sound is an isotropic phenomenon, i.e., if sound propagates with the same velocity along any direction in a homogeneous medium, independently of the absolute velocity of the medium, then one can realize (if not practically, at least theoretically) a transfer of energy *with respect to absolute space* by a velocity higher than that of light. So, for certain directions of propagation the proper energy of sound will become equal to infinity and for others it will become imaginary. Thus phonons will represent the mysterious tachyons to which so many scholastic papers have been dedicated in recent years. However, I cannot imagine a physicist with a sound mind who can imagine energy as an imaginary quantity, and the mess in theoretical physics will become complete. According to my current conceptions,[11] the Sagnac and Marinov effects for phonons must be present and phonons are to be considered as particles similar to neutrons and electrons.

At the present state of technique, a "rotating disk" experiment with sound cannot lead to a reliable result. Indeed, if at the rim of a rotating disk one separates a sound wave (or sound pulses), half of which proceeds along the direction of rotation and the other half oppositely, the "direct" wave, on the grounds of formula (1), will reach the separation point with the following time delay after the "opposite" wave:

$$\Delta t = \frac{d}{v'_{\text{dir}}} - \frac{d}{v'_{\text{opp}}} = \frac{2dV}{c^2} = \frac{4\Omega S}{c^2} \tag{2}$$

where d is the path covered, S is the area encircled by this path, and Ω is the angular velocity of the disk (any angular velocity is taken with respect to absolute space). The last transition in this formula can be obtained in an elementary way by supposing that the closed path represents a polygon circumscribed around a circle with a radius R and by making the substitutions $d = 2S/R$, $V = \Omega R$. If ν is the frequency of the phonons (the frequency of the sound pulses), the phase difference between the "direct" and "opposite" phonons will be

$$\Delta\psi = 2\pi\nu\,\Delta t = 4\pi\nu dV/c^2 = 8\pi\nu\Omega S/c^2 \tag{3}$$

Using ultrasonic waves with a frequency $\nu = 1$ MHz and supposing $\Omega = 900$ rad/sec, $S = 1\ \text{m}^2$, one obtains $\Delta\psi = 8\pi \times 10^{-8}$ rad. Let me note that the "rotating disk" experiment with light leads to reliable results because the frequency of light is much higher.

Thus one must try to measure the Marinov effect with sound because (i) for the Marinov effect the velocity V is much higher, and (ii) the path d can be made much longer. So, taking in formula (3) the same frequency of ultrasonic signals as above, $V = 300$ km/sec,[9] and $d = 10$ km, one obtains a phase difference $\Delta\psi = 0.4\pi$ rad.

For the measurement of the Marinov effect, however, one must be able to realize a *Newtonian time synchronization*[12] between space-separated points. There are two methods for realization of a Newtonian time synchronization: (i) by the help of a rotating axle, a method already experimentally verified,[8,9] and (ii) by the help of two parallel light clocks, a method only recently proposed.[13] Obviously, since for the detection of a Marinov effect with phonons a very long basis is needed, one can use only the second method. The rotating axle can be used only if one succeeds in mastering a reliable detection of small phase shifts of sound pulses.

However, since the direction dependence of light velocity is already firmly established,[9] a type of Briscoe experiment[11,14,15] can decide whether the velocity of sound is also anisotropic. Namely, if a type of Briscoe experiment gives a null result, i.e., if with this experiment the Earth's absolute velocity cannot be measured, then the velocity of sound is *anisotropic* and both anisotropy effects—of sound and of light—annihilate each other. If, however, the result is positive, this will signify that the velocity of sound is isotropic in any medium moving in absolute space. In

Briscoe's proposal[14] one sends parallel light (electromagnetic) and sound waves and one measures the anisotropy in light velocity *assuming* that the velocity of sound is isotropic. Briscoe's proposal was published as a patent and remained unnoticed by the scientific community. After the revival of Briscoe's ideas in two of my publications,[1,11] only one article dedicated to this method has appeared.[15] The author, Dr. H. Yilmaz, who visited me in Cleveland in June 1978, has tried to realize his variation of Briscoe's experiment,[16] but no information has reached me about the results obtained and one is impelled to suppose that either Yilmaz' method has not given the necessary accuracy (Yilmaz expected[15] a fantastic accuracy of m/sec in the determination of V) or the results obtained are null. If Yilmaz' method has given a null result, this must be published, as, together with the positive result in my "coupled-mirrors" experiments,[8,9] one obtains an experimental confirmation of my hypothesis that phonons are particles and theoretical physics is saved once again from an unpleasant mess.

I should like to point out that if the ultrasonic "coupled-shutters" experiment proposed by me in Ref. 11 were to be carried out with the effective technique of the differential "coupled-shutters" experiment,[17] then the basis between the shutters can be reduced from kilometers to meters and the experiment can be performed in the laboratory. The method is essentially that previously discussed.[11] However, it is now proposed to replace the observers by transducers of light into electric current, photodiodes. The difference in the currents produced by the two photodiodes can be detected by a sensitive galvanometer (see Ref. 17). It is proposed to generate the two necessary light beams from a single laser source, so as to avoid inevitable differential intensity fluctuations. The material conducting the sound signals must be chosen to have good thermal stability. The "creep" of the small pulses over the oscilloscope screen (see the figure in Ref. 11) can be considerably reduced or totally excluded during the short time of measurement if a rotating platform is used (if necessary, one should make a thermal stabilization).

The "functioning" of the experiment can be well understood by consulting Table I. The table is set at the condition that the absolute velocity of the apparatus is perpendicular to its axis. The first line gives the number of light "waves" n along the distance d, i.e., the number of light pulses which can be counted between both shutters on a *momentary photograph*. The second line gives the number of sound "waves" n_s along distance d, i.e., the number of sound pulses which can be counted between both shutters at an *instant*. The third line gives the "phase difference" between both shutters in radians. So, if the phase difference is $\psi = 0$, both shutters are opened or closed together; if $\psi = \pi/2$ (or $3\pi/2$) one of the shutters is half-opened and the other is half-closed; if $\psi = \pi$, one of the shutters is opened when the other

Table I

$n = d/\lambda$	m				$m + \frac{1}{4}$				$m + \frac{1}{2}$				$m + \frac{3}{4}$			
$n_s = d/\lambda_s$	m_s	$m_s + \frac{1}{4}$	$m_s + \frac{1}{2}$	$m_s + \frac{3}{4}$	m_s	$m_s + \frac{1}{4}$	$m_s + \frac{1}{2}$	$m_s + \frac{3}{4}$	m_s	$m_s + \frac{1}{4}$	$m_s + \frac{1}{2}$	$m_s + \frac{3}{4}$	m_s	$m_s + \frac{1}{4}$	$m_s + \frac{1}{2}$	$m_s + \frac{3}{4}$
ψ	0	$\pi/2$	π	$3\pi/2$	0	$\pi/2$	π	$3\pi/2$	0	$\pi/2$	π	$3\pi/2$	0	$\pi/2$	π	$3\pi/2$
O_A sees	max	av	min	av	av	min	av	max	min	av	max	av	av	max	av	min
O_B sees	max	av	min	av	av	max	av	min	min	av	max	av	av	min	av	max

is closed. It is important to note that if the phase shift of the detecting shutter near the first of the observers O_A is ψ with respect to its chopping shutter, then the phase shift of the detecting shutter near the second observer O_B is $-\psi$ with respect to its chopping shutter. The fourth line gives the light intensities registered by the observer O_A, and the fifth line gives those registered by O_B.

Let us suppose, for example, $n = m$, $n_s = m_s + 1/4$, where m and m_s are integers. Thus we shall have $\psi = \pi/2$ for one observer and $\psi = -\pi/2$ for the other one. In this case both observers see average light intensity. Let under these conditions an "aether wind" appear by rotating the axis of the apparatus over 90°. If the "aether wind" leads to a change $\Delta n = 1/4$ in the number of light waves, then, for the case shown in the figure of Ref. 11,

$$n_A = m + 1/4, \qquad n_B = m - 1/4 = (m - 1) + 3/4 \tag{4}$$

Thus, if the phase difference remains the same, $\psi = \pi/2$, both observers will register minimum light. This change in the illuminations can be achieved if, when there is no "aether wind," one changes the phase difference from $\psi = \pi/2$ to $\psi = \pi$, i.e., if one changes the number of sound waves along the tract d by $\Delta n_s = 1/4$. With the help of this table one can show that *always* an "aether wind" effect can be annulled by a corresponding change in the phase difference. Let me note that *this is the reason* that does *not* permit one to measure the absolute velocity of the laboratory by an "uncoupled shutters" experiment. Since in the "uncoupled shutters" experiment one cannot know which is the phase difference between the shutters, one is unable to distinguish the absolute effect due to an "aether wind" from the effect due to a change of the phase difference between the uncoupled shutters.

The sound signals give one permission to "couple" the independent shutters. If the propagation of sound is isotropic, i.e., if there is no "aether wind" for sound, then after the rotation of the apparatus the phase difference will remain the same and the appearing change in the light intensities registered by O_A and O_B will be attributed to the "aether wind." However, if there is an "aether wind" also for sound, the phase difference will change *exactly* by the amount to annihilate the "aether wind" effect for light. Thus, if the ultrasonic "coupled-shutters" experiment gives a null result, then, since the anisotropy of light propagation is already firmly established, one has to conclude that phonons are particles and they are attached to absolute space in the same manner as photons and electrons.

If we assume that the propagation of sound is isotropic and the "creep" of the sound waves is negligible, the measuring procedure in the ultrasonic "coupled-shutters" experiment is the following: One chooses the conditions $n = m + 1/4$ and $n_s = m_s$, i.e., $\psi = 0$. Rotating the platform with the apparatus in the laboratory, one eliminates the appearing difference current produced by the photodiodes by changing the paths of the "direct" and "opposite" light pulses (it is sufficient to change the path only of the "direct" or only of the "opposite" light pulses, but by double the amount). If the component of the absolute velocity of the laboratory along the axis of the apparatus changes from 0 to V, one has to change the paths of the "direct" and "opposite" light pulses by Δd, so that

$$v = (\Delta d/d)c \tag{5}$$

The sensitivity of the method can be established in practice extremely easily. If δd is the minimum shift which leads to an effect discernible from the fluctuations of the galvanometer, the accuracy with which the absolute velocity can be measured is

$$\delta v = (\delta d/d)c \tag{6}$$

In my differential "coupled-shutters" experiment[17] the rotating disks had 30 holes and when they rotated with a constant rate $N = 200$ rev/sec, i.e., when the chopping frequency was $f = 6$ kHz, the current fluctuation δI was about a 10^{-7} part of the current I produced by the photodiodes.

Take now formula (4) from Ref. 11 (see the same formula on p. 151 of Ref. 18), which says that if a δn part of the light pulses (in more in the "direct" pulses and in less in the "opposite" pulses) can be discerned from the fluctuation, then the absolute velocity can be measured with an accuracy

$$\delta v = c^2 \delta n / 2fd \tag{7}$$

For the differential "coupled-shutters" experiment,[17] the inaccuracy calculated according to this formula, where one puts $\delta n = \delta I/I$, is $\delta v = 500$ km/sec.

For the ultrasonic "coupled-shutters" experiment, using the same formula and putting there $\delta n = 10^{-7}$, $f = 0.3$ MHz, one obtains, for the same basis $d = 150$ cm, $\delta v = 10$ km/sec.

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