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Did Günter Nimtz discover tachyons?

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It is argued that in the famous G. Nimtz experiment tachyons were produced and annihilated. We base our considerations on the new version of Special Relativity elaborated recently by one of the authors.

Recently, it has been shown [1] that the most general linear transformations of spacetime coordinates for which there exists an invariant in magnitude velocity c are of the following form

$$t \to t' = At + \vec{B} \cdot \vec{x}, \tag{1}$$

$$\vec{x} \to \vec{x}' = \sqrt{A^2 - c^2 \vec{B}^2}(R\vec{x}) + \frac{A - \sqrt{A^2 - c^2\vec{B}^2}}{\vec{B}^2}(R\vec{B})(\vec{B} \cdot x) + c^2(R\vec{B})t. \tag{2}$$

Here A and $\vec{B} = (B_1, B_2, B_3)$ are arbitrary parameters which satisfy the inequality

$$A^2 - c^2\vec{B}^2 > 0. \tag{3}$$

and *R* denotes an orthogonal matrix which describes rotations of space coordinates.

According to these transformations the relative velocity $\vec{V}$ of the unprimed reference frame with respect to the primed one is given by

$$\vec{V} = \frac{c^2}{A} R\vec{B} \tag{4}$$

and according to (3) it follows that

$$\vec{V}^2 < c^2. \tag{5}$$

The transformations (1) and (2) form a group with the composition law

$$A_{21} = A_2 A_1 + c^2(\vec{B}_2 \cdot \vec{B}_1), \tag{6}$$

$$\vec{B}_{2,1} = \sqrt{A_1^2 - \vec{B}_1^2 c^2} R_1^{-1} \vec{B}_2 + \frac{A_1 - \sqrt{A_1^2 - \vec{B}_1^2 c^2}}{\vec{B}_1^2} (\vec{B}_2 \cdot R_1 \vec{B}_1)\vec{B}_1 + A_2 \vec{B}_1 \tag{7}$$

and a more complicated composition law for space rotations R_1 and R_2. Here, $A_1, \vec{B}_1$ and $A_2, \vec{B}_2$ are the parameters of two consecutive transformations while $A_{2,1}$ and $\vec{B}_{2,1}$ are the parameters of the resulting transformation which is of the same form as (1) and (2).

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From the above transformations it follows that the velocities of moving bodies transform as

$$\vec{V}' = \frac{\sqrt{A^2 - c^2\vec{B}^2}(R\vec{V}) + \frac{A-\sqrt{A^2-c^2\vec{B}^2}}{\vec{B}^2}(R\vec{B})(\vec{B}\cdot\vec{V}) + c^2(R\vec{B})}{A + \vec{B}\cdot\vec{V}}. \tag{8}$$

Therefore, assuming that some body is at rest in the unprimed reference frame we get that in the primed frame the body moves with the velocity

$$\vec{v} = \frac{c^2}{A} R\vec{B} \tag{9}$$

which coincides with the velocity $\vec{V}$ of the unprimed frame with respect to the primed one and from the inequality (3) we get that

$$\vec{v}^2 < c^2. \tag{10}$$

Expressing the vectorial parameter $\vec{B}$ by the velocity $\vec{v}$ we get

$$t' = A\left[t + \frac{(\vec{V}\cdot R\vec{x})}{c^2}\right], \tag{11}$$

$$\vec{x}' = A\left[\sqrt{1 - \frac{\vec{V}^2}{c^2}}(R\vec{x}) + \left(1 - \sqrt{1 - \frac{\vec{V}^2}{c^2}}\right)\frac{\left(\vec{V}\cdot R\vec{x}\right)}{\vec{V}^2}\vec{V} + \vec{V}t\right]. \tag{12}$$

This almost coincides with the standard Lorentz transformations with the exception of the arbitrary factor A. Assuming that this factor is a form invariant function of the velocity $\vec{v}$ the composition rule (6) becomes a functional equation for the function $A(\vec{v})$ of the form

$$A(\vec{v}_{21}) = A(\vec{v}_2)A(\vec{v}_1)\left(1 + \frac{\vec{v}_1\cdot\vec{v}_2}{c^2}\right), \tag{13}$$

where $\vec{v}_{21}$ is the composition of two velocities $\vec{v}_1$ and $\vec{v}_2$ the form of which follows from (6) and (7) after using (9). It is easy to show that the only solution of (13) is

$$A = \gamma = \left(1 - \frac{\vec{v}^2}{c^2}\right)^{-1/2} \tag{14}$$

and substituting such A into (1) and (12) we arrive to the standard form of Lorentz transformations. We should however stress the fact that the assumption about the dependence of A on $\vec{v}$ is not necessary for considering Special Relativity.

A quite different situation arises when we assume that in the unprimed reference frame we have to do with a body which moves with an infinite velocity. Then from (8) it follows that in the primed reference frame this body moves with finite velocity $\vec{w}$ equal to[1]

$$\vec{w} = \frac{A}{\vec{B}^2} R\vec{B}. \tag{15}$$

Expressing this time the vector parameter $\vec{B}$ in the spacetime transformations (1) and (2) in terms of the velocity $\vec{w}$ we get

$$t' = A\left(t + \frac{\vec{w}\cdot R\vec{x}}{\vec{w}^2}\right), \tag{16}$$

[1] The easiest way to derive (15) is to put $\vec{V} = \lambda\vec{B}$ in (8) and take the limit $\lambda \to \infty$.

$$\vec{x}' = A\left[\sqrt{1-\frac{c^2}{\vec{w}^2}}\,(R\vec{x}) + \left(1-\sqrt{1-\frac{c^2}{\vec{w}^2}}\right)\frac{(\vec{w}\cdot R\vec{x})}{\vec{w}^2}\vec{w} + \frac{c^2}{\vec{w}^2}\vec{w}t\right] \tag{17}$$

with an arbitrary factor A. Again, assuming that this factor is a function of the velocity $\vec{w}$ from the functional equation which follows from the composition law (6) we get

$$A(\vec{w}) = \sqrt{1-\frac{c^2}{\vec{w}^2}} \tag{18}$$

and from the positivity condition (3) it follows that

$$\vec{w}^2 > c^2. \tag{19}$$

We may therefore conclude that apart from the standard version of Special Relativity which describes subluminal motions we may equally well consider another version of this theory which describes superluminal motions.

In particular, we may construct the energy momentum fourvector for the subluminal and superluminal particles. Proceeding in the way explained in [1] for the superluminal particles called tachyons we get the energy

$$E = \frac{E_\infty}{\sqrt{1-\frac{c^2}{\vec{w}^2}}} \tag{20}$$

and the momentum

$$\vec{p} = \frac{\vec{w}E_\infty}{\vec{w}^2\sqrt{1-\frac{c^2}{\vec{w}^2}}}, \tag{21}$$

where E_∞ is the energy of the tachyon for infinite velocity. It is easy to check that

$$E^2 - c^2\vec{p}^2 = E_\infty^2 > 0. \tag{22}$$

The above expressions for tachyonic energy and momentum are different from the corresponding expressions derived in [2] where the imaginary mass has been introduced into the standard relativistic expressions for energy and momentum. Our expressions (20) and (21) are direct consequences of the transformations (1) and (2) applied to particles for which there exists a reference frame in which they move with infinite velocity. In contradistinction to [2] our tachyonic energy-momentum four-vectors are always time-like. This significantly simplifies the construction of quantum field theory for tachyons [3, 4].

Two natural questions must be raised: are the superluminal tachyons real physical objects and how to produce and detect them?

To answer these questions let us remind that in the famous Nimtz experiment [5] electromagnetic signals were transmitted with superluminal velocities. The experiment several times has been repeated in different versions and always the results show that signals travel faster than light.

G. Nimtz [6, 7], as well as other authors [8], tried to explain this phenomenon either in terms of classical notion of evanescent waves or in terms of a quantum mechanical tunneling process. Evidently, such classical explanation of the complicated unusual transmission of signals through a solid must be treated as purely phenomenological one because light beams induce quantum processes in solids. Also the application of quantum mechanical notion of tunneling to macroscopic distances between barriers cannot be accepted as satisfactory.

It is well known that photons in incident light beams induce several collective excitations in solids [9]. In isolators, such as paraffin or perplex used by Nimtz as barriers, one of the most frequent excitations are Frenkel or Mott–Wannier excitons [10]. It is always assumed that finally the excitons recombine into photons which leave the solid. However, it is highly probable that the interaction of excitons with the molecular lattice leads to some *Umklapp processes* which clearly distort the energy-momentum balance characteristic to photons and the final photons cannot be created. The remaining energy and momentum however easily may be taken away by the creation of tachyons for which instead of the photonic relation

$$E^2 - c^2\vec{p}^2 = 0 \tag{23}$$

we have the less restrictive relation (22). It also has to be taken into account that in solids we have to do with energies of the order of eV's and within this energy scale no known elementary particle can be produced. To prevent the production of known elementary particles it is sufficient therefore to assume that $E_\infty \sim 1$ eV.

It is clear that tachyons produced in solids may also be annihilated in them. Therefore, the only outgoing tachyons may come from the surface of solids. In order to detect them the second piece of the same solids is needed in which the tachyons are annihilated with the final production of real photons which are detected after they leave the second barrier. The fact that in the gap between barriers the tachyons travel with superluminal velocities is the reason that the final photons are detected earlier than the electromagnetic signal which all the time travels with the velocity of light.

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