The Oscillation Project with Emulsion-Tracking Apparatus (OPERA) experiment: An argument for superluminal velocities?

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Abstract: The Oscillation Project with Emulsion-Tracking Apparatus (OPERA) experiment is regarded by some as an empirical confirmation of the special theory of relativity (STR). It is shown that this opinion is mistaken because STR cannot exclude superluminal velocities. Einstein's derivation of the Lorentz transformation was based on a contradiction, which can be reduced mathematically to $+ = -$. His premise that the speed of light in a vacuum is constant, independent of the motion of its source, is self-contradicting. Hence, by the laws of mathematics, every inference drawn from it is arbitrary, which includes that the speed of light cannot be exceeded. This inference has also been empirically refuted through the results of certain experiments on quantum mechanics, which can only be explained by either admitting superluminal velocities or by admitting miracles (action at a distance). The problems of light cannot be solved at the level of mathematics, but only at the level of physics through a new theory explaining the properties of light by physical parameters. © *2012 Physics Essays Publication*. [DOI: 10.4006/0836-1398-25.3.397]

Resumé: Les résultats trouvés par l'expérience OPERA sont considérés par certains comme ayant confirmé la théorie de la relativité restreinte. Il est démontré qu'il s'agit là d'une erreur, car la théorie de la relativité restreinte ne peut exclure les vitesses superluminiques. La dérivation des transformations de Lorentz, qu'Einstein employait, était fondée sur une contradiction qui se réduit mathématiquement à $+=-$. Sa prémisse, que la vitesse de la lumière ne dépend pas de la vitesse de sa source, est contradictoire en soi-même. Donc, selon les lois de la mathématique, toute conclusion dérivée de cette prémisse est arbitraire, y compris la conclusion que la vitesse de la lumière est indépassable. Cette conclusion a d'ailleurs également été réfutée par certaines expérimentations relatives à la mécanique quantique dont les résultats ne peuvent être expliqués qu'en admettant soit des vitesses superluminiques soit des miracles (actions à distance sans agent). Les problèmes concernant la lumière ne peuvent être résolus au niveau de la mathématique, mais seulement par une nouvelle théorie expliquant les propriétés de la lumière par des paramètres physiques.

Key words: Special Relativity Mathematically Refuted; Oscillation Project with Emulsion-Tracking Apparatus (OPERA) Neutrino Experiment No Empirical Confirmation; Self-Contradiction in Constancy of Speed of Light; Light Speed Is Iron Curtain of Science; Either Superluminal Velocities or Miracles (Action at a Distance).

I. INTRODUCTION

In September and November 2011 and February 2012, European Organization for Nuclear Research (CERN) reported on a joint experiment with the Oscillation Project with Emulsion-Tracking Apparatus (OPERA) collaboration in which superluminal velocities of neutrinos were measured over a distance of 730 km between Geneva and the Gran Sasso, Italy.[1] Many scientists were surprised because the findings clashed with the special theory of relativity (STR). CERN's press release considered them an "anomaly." Measurements were repeated after a change of the experimental settings and again showed superluminal velocities, which gave rise to further scrutiny. On March 26, 2012, it was reported that new measurements had now yielded results below the speed of light. CERN's research director, Sergio Bertolucci, was quoted with the words: "The evidence is beginning to point to the OPERA results being an artefact of the measurement."

CERN's latest update of June 8, 2012, refers to a paper read at the 25th International Conference on Neutrino Physics and Astrophysics in Kyoto. According to this report, recent measurements made by "Borexino, ICARUS, LVD and OPERA all measure a neutrino time of flight consistent with the speed of light." The initial OPERA measurement is now "attributed to a faulty element of the experiment's fibre optic timing system."

Thus, what appeared to be a serious challenge to STR on empirical grounds at the beginning of the OPERA experiment now seems to have resulted in its triumphant confirmation. But some outsiders may still have their misgivings; I avow myself one of them. There is, after all, a strong tendency in theoretical physics to mistrust

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experiments rather than discard STR, and there are far better reasons for having it the other way round.

II. SELF-CONTRADICTIONS IN STR

The only argument for rejecting the *possibility* of superluminal velocities is STR. According to STR, light is a limiting velocity prescribed by nature itself, a velocity that cannot be exceeded under any circumstances whatsoever. Einstein deduced this by strictly mathematical inference from the most important premise in his famous paper "Zur Elektrodynamik bewegter Körper,"[2] the premise that the speed of light in a vacuum is constant, independent of the motion of its source. Among other things, he inferred that the energy of a moving body, which is not completely without mass at rest, would be infinite if it reached the speed of light[a] and also that objects moving at the speed of light would lose their third dimension and be only "planar structures."[b] These inferences have led to a general admission that superluminal velocities are incompatible with STR.

But Einstein's deductions were not valid because his premise that the speed of light in a vacuum is constant, independent of the motion of its source, is *self-contradicting*. Any inference drawn from it is therefore arbitrary. STR can thus be no reason for rejecting the possibility (not the existence) of superluminal velocities.

STR began with Einstein's famous paper "Zur Elektrodynamik bewegter Körper"[3] where he introduced the following equations[c]:

$$t_B - t_A = t'_A - t_B,\tag{1}$$

$$t_B - t_A = \frac{r_{AB}}{V - v},\tag{2}$$

$$t'_A - t_B = \frac{r_{AB}}{V + v}.\tag{3}$$

Inserting the right sides of Eqs. (2) and (3) in Eq. (1), we have

$$\frac{r_{AB}}{V - v} = \frac{r_{AB}}{V + v},\tag{4}$$

which can be reduced to

$$V - v = V + v,\tag{5a}$$

$$+v = -v,\tag{5b}$$

$$+ = -.\tag{5c}$$

That shows the contradiction. Einstein neither mentioned

it in his paper nor explained it anywhere else. It was never discussed in literature on STR.[d]

Adherents of STR have argued that there is no contradiction because in Eq. (1) Einstein defined the "synchrony condition" ("simultaneousness") for clocks at rest, while his Eqs. (2) and (3) only apply to clocks moving with velocity v. The facts underlying this allegation are mistaken, and the argument would not be valid even if they were correct.

The facts are mistaken. Einstein introduced Eqs. (2) and (3) on page 896 of his paper[e] and explained their notation in a footnote. It reads like this (with my italics for text put in quotation marks by Einstein): "*Zeit* bedeutet hier *Zeit des ruhenden Systems* und zugleich *Zeigerstellung der bewegten Uhr, welche sich an dem Orte, von welchem die Rede it, befindet*." In English, "*Time here* stands for *time of the system at rest* and also *position of the hands of the moving clock which is at the place under discussion*."[f],[4]

Einstein could hardly have said more clearly that the concept of "time" underlying t and t' in his Eqs. (2) and (3) was to be that of the system at rest, i.e., of Eq. (1). And he also said clearly that he was applying this concept to the moving system *and* to the system at rest.

The argument is also invalid. Even if Einstein had *intended* Eq. (1) to apply only to systems at rest and Eqs. (2) and (3) only to moving systems, this would not resolve the contradiction between his equations. The contradiction itself is mathematically indisputable. The proof shown in the previous equations is cogent. If Eq. (1) is true, then Eqs. (2) and (3) cannot both also be true. The following will show that Einstein's further inferences were based on this contradiction.

Adherents of STR have also argued that there are different ways of deducing the Lorentz transformation. They believe that a mistake made by Einstein need not impair the results he reached. In this case the facts underlying the argument are true. There are, indeed, various ways of deducing the Lorentz transformation. Einstein himself showed at least two of them,[g],[5] but the argument is nevertheless invalid because every deduction of the Lorentz transformation must start from the same self-contradicting premise and is therefore arbitrary.

If two premises contradict each other, then only one of them can be true. Statement "A" and statement "non-A" cannot both be true in the same context. That is implied in the definition of "contradiction" and also in that of "truth."[h],[6] Hence, if an inference has been drawn from contradicting premises, then the rules of mathematics or of logic cannot tell us whether or not it is true. That

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[a] Ref. 2, p. 920.

[b] Ref. 2, p. 903.

[c] Ref. 2, pp. 894, 896, and 897. In Einstein's notation AB denotes a system ("rod") with the ends A and B. t denotes the time in the system at rest, t'_A the time at A after reflection of light in B. V denotes the velocity of light, v the speed of the moving system, and r_{AB} the length of the moving system.

[d] It was first published and explained in detail in Ref. 3, pp. 214–222, 291. On the Internet it was demonstrated on my homepage from 2005 to 2011.

[e] Ref. 2.

[f] In Ref. 4 Einstein's footnote is endnote 4. Megh Nad Saha's translation of Einstein's paper on Wikisource omits this note.

[g] One is in his paper of 1905 (Ref. 2), and he showed a simpler derivation in Ref. 5, pp. 22 and 76–80.

[h] For Tarski's nominalistic definition of "truth," see Ref. 6, pp. 152–156.

is a well known truism of mathematics and of logic. The rules of mathematics or of logic can, of course, be applied with seeming correctness to contradicting premises, but it is generally acknowledged in mathematics and in logic and *can even be proved* by logical inference that from contradicting premises any inference whatsoever can be deduced.[i,7] *Every* result based on contradicting premises is therefore merely random because the process of mathematical or logical inference cannot tell us whether or not it is true.

It follows from this that if Einstein based his deduction that superluminal velocities cannot exist because the speed of light cannot be exceeded, on a self-contradicting premise, then the result of this deduction is arbitrary.

The contradiction shown in Eqs. (5a)–5(c) was caused by Einstein's definition of "V," standing for the speed of light in a vacuum. According to this definition, V stands for a speed that is constant and independent of the motion of its source. In physics "speed" or "velocity" stand for "distance divided by time." Assuming this definition applies also to the speed of light and applying it consistently in v and in V, then, seen from the system at rest, the speed of light in the moving system would result from an addition or a subtraction of the speed of the moving system and the speed of light. Einstein himself has shown this very clearly in his well-known example of the moving person in a moving railway carriage.[j] Relative to Earth, the speed of a person walking forward in the carriage would be calculated by adding the speed of the person to that of the carriage. For light, however, Einstein postulated that the addition theorem does not apply because, so he claimed, the speed of light in a vacuum is constant and independent of the motion of its source.

In terms of mathematics there is no way of expressing this postulate other than saying that as seen from a system at rest, the speed of light in a moving system may *not* be added to, or subtracted from, the speed of its source. But in Eqs. (2) and (3) Einstein violated his own definition by inserting the denominators $V + v$ and $V - v$. And he continued to use additions of v to, or subtractions of v from, V in his later equations[k] without ever introducing a new and different definition of "t." By assuming Eqs. (2) and (3) both to be true, he also contradicted Eq. (1). This self-contradiction not only explains why most people find it so difficult to understand STR but also why it is impossible to feed computers with its formulae. Human beings may put up with contradictions, but computers are unable to do so because contradictions cannot be expressed in a binary code.

It follows from this that the contradiction shown in Eqs. (5a)–5(c) can only be avoided by giving up Einstein's premise that the speed of light is independent of the motion of its source. As long as we retain this premise, we must also retain his definition of V, according to which the speed of light in a moving system may not be added to, or subtracted from, the speed of its source. As long as we retain this self-contradicting definition, any inference based on it will always be arbitrary and includes the inference that the speed of light cannot be exceeded under any circumstances whatsoever. I have demonstrated this elsewhere[l] for several other derivations of the Lorentz transformation,[8] including (in English) that shown by French in his MIT standard textbook on special relativity.[9] They all start from contradicting premises and therefore lead with seeming accuracy to random results.

The problems of light are not mathematical but physical problems. Einstein's already-mentioned famous example of the moving railway carriage clearly shows this.[m] If, as he assumed, the addition theorem applies to a moving person in a moving railway carriage but not to light, then the difference between the behavior of light and that of a moving person in a moving railway carriage cannot lie in logic or mathematics but must lie in the physical properties of light. The problems of light cannot, therefore, be solved at the level of mathematics but must be solved at the level of physics.[10] What we need is not a mathematical theory based on contradictions but a new and better understanding of the physical behavior of light.[n]

Some may wonder whether Einstein had seen the self-contradiction in his equations. I think it would be unfair to assume this. The reason for his mistake lay in a misunderstanding of the relationship between mathematics and physics, which was widespread in his time and still prevails in the theoretical physics of our days. I have explained this elsewhere[o] and will not go into details here. But clearly, if Einstein had noticed that he was contradicting himself, we would either have to assume that he was not acquainted with the truism that inferences drawn from contradicting premises will be arbitrary, which is hardly credible, or we would have to assume that he was acting unethically by knowingly concealing a contradiction. For if he had seen it, then it would have been an obvious imperative of scientific honesty to point it out and try to explain how it could be done away with, rather than lead generations of scientists astray. That attitude would be incompatible with Einstein's character as reflected in literature, and I see no indications pointing that way. On the contrary, the fact that in more than a century, Einstein's mathematical self-contradiction was never discussed in literature indicates that it was overlooked also by others. So why not by him?

III. FORWARD OR BACKWARD?

The final evaluations of the OPERA experiment were still unknown when I started on this paper. However, it

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[i] Karl Popper has demonstrated this in Ref. 7, Sec. 1.

[j] Ref. 5, pp. 10–13.

[k] They reappear, for instance, in the denominators of his monster equation on Ref. 2, p. 898 (Ref. 4, p. 8).

[l] Ref. 3, p. 293. The other derivations are from Ref. 5, p. 22 and 76, Ref. 7, p. 21, and Ref. 9, p. 76.

[m] Ref. 5, p. 10–13.

[n] I have proposed a new theory in Ref. 10, Ch. 6.

[o] Ref. 3, Ch. 2, also pp. 267–275.

was predictable even then that measurements would be repeated time and again as long as they showed super-luminal velocities and that they would soon come to an end once the results complied with STR.

The objections against the initial results of the OPERA experiment arose from the belief, deeply rooted in theoretical physics, that superluminal velocities are prohibited by nature itself. Without this belief the measurements made in 2011, showing that neutrinos were slightly faster than light, would barely have been worth writing home about. The cause of this belief was STR. Whatever the final results really were, the discovery of a self-contradiction in Einstein's STR is certainly a sound reason for at least accepting the *possibility* of super-luminal velocities as shown in the initial OPERA measurements. It is even a good reason for trying to bring them about, or for trying to find something other than neutrinos that will do so, instead of considering them a mere "anomaly" or an "artefact of the measurement."[p]

In an open-minded science, unaffected by the dogma of STR, the initial results of the OPERA experiment would have been considered an *exciting discovery*. Imagine what might be possible if light could be overtaken by other waves or particles! The neutrino experiments would then show that there are still things left to be discovered, and the world of physics would now be burning to see their results confirmed. Under such conditions, they might even have marked the beginning of a new era of science, an era like the 19th century when imaginative research was uninhibited and electrical induction, and x-rays, and electromagnetic waves were first observed, and many other wonderful discoveries were made. If superluminal velocities are possible, we might also, even in our time, begin to discover new effects, which are still unknown because, just like electrical induction and electromagnetic waves in the 19th century, they are normally hidden from us by the limitations of our sensory faculties. At present, however, there is no indication of this. The speed of light is acting as the Iron Curtain of science. It separates permitted research from forbidden research and thus prevents new discoveries. The danger is great that this dogmatism will prevail.

However, that is not the only reason for admitting the possibility of superluminal velocities. Another is that it would be unfair to Einstein to let him alone bear the blame for leading theoretical physics astray. He was by no means the sole culprit.

It does not appear to be widely known (or understood) that in his paper "Zur Elektrodynamik bewegter Körper," Einstein did not arrive at the hypothesis of constancy of the speed of light by deduction or by inference from other premises, but he merely *presupposed* it. That was the application of his famous

heuristic method that I have explained elsewhere.[q] At the very beginning of his paper, he explicitly introduced the premises ("Voraussetzungen") from which he was starting, and the hypothesis of constancy of the speed of light was his second premise.[r] A bit further down he said,[s] "Wir *setzen* noch der Erfahrung gemäß *fest*, daß die Größe . . . V eine universelle Konstante (die Lichtgeschwindigkeit im leeren Raume) sei" (my italics). There may be different ways of translating this sentence.[t] The best I can propose for the words "wir setzen . . . fest" is "we stipulate." The translation would then read: "We further stipulate in accordance with experience that . . . V is a universal constant (the speed of light in empty space)."

But whichever translation we prefer, "setzen . . . fest" can never stand for "infer", "deduce", or any other term indicating that Einstein was putting forward an *argument* in support of the validity of his premises. The only argument he made to this effect in the whole paper was his reference to experience ("Erfahrung") in the sentence just quoted. In his lectures on the theory of science, too, he always emphasized that experience must under all circumstances be the ultimate judge in physics.

Careful reading would thus have shown at any time that Einstein's paper gave no reason to regard the hypothesis of constancy of the speed of light as an irrefutable dogma. That only came later when others had declared him to be a genius. Einstein introduced the constancy of the speed of light as a hypothesis, which he believed to be empirically true, but he never said it was not open to refutation by experiment. Even if he himself had believed it to be true beyond doubt, that would be no excuse for others. The objectivity of science can only be safeguarded by criticism, and if a discipline like theoretical physics cannot procure sound criticism in a whole century then something is rotten in its institutions. STR was, in fact, criticized in Einstein's time both on empirical and theoretical grounds.[11,12] It was owing to very unfortunate circumstances that this criticism remained unheard then,[u] but at least after World War II, the situation had changed. However, tradition proved stronger than reason. At present the common attitude appears

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[p] Ref. 1, update March 16, 2012.

[q] Ref. 3, Ch. 4. I consider this method as his greatest achievement. It gave Karl Popper the most important inspiration for his *Logik der Forschung* (1934), English translation, *The Logic of Scientific Discovery* (1959).

[r] Ref. 2, pp. 891–892.

[s] Ref. 2, p. 894.

[t] Ref. 4, p. 4, proposes "In agreement with experience we further assume the quantity to be a universal constant—the velocity of light in empty space."

[u] The strongest empirical criticism was put forward in 1913 by the French scientist Georges de Sagnac in Ref. 11. But at that time, shortly before the outbreak of World War I, nobody in Germany took notice of criticism coming from the archenemy France. In 1920 a very strong theoretical criticism was put forward by the German scientist Fricke (Ref. 10) who even spoke of the "reign of terror" ("Schreckensherrschaft") of mathematicians in physics. Almost at the same time, the British astronomer Eddington reported that Einstein's predictions, in his general theory of relativity, of light deflection in the gravitational field of the Sun had been experimentally confirmed in the British expeditions for the observation of sun eclipses of 1919 and 1922. In subdued postwar Germany, this praise, coming from the former enemy of war Great Britain, was much preferred to criticism. It made Einstein world famous and practically silenced criticism until the outbreak of World War II.

to be to go almost any lengths to adapt the interpretation of empirical findings to STR rather than adapt the theory of light and matter to the empirical findings.[13,14,v]

The OPERA measurements made in 2011 were by no means the first to be at odds with STR. They were only the first in which superluminal velocities of particles were (correctly or not) directly measured. Other experiments had been made before that showed superluminal velocities indirectly, but they were misinterpreted. One example will show this.

There have been, ever since the famous "EPR" paper by Einstein, Podolsky, Rosen,[15] endless discussions of whether or not quantum mechanics is "complete" or whether there can be "hidden variables." There is no need to go into details here.[w] The only relevant fact in our context is that experiments were made in which the question was put to the test.

The principle of these experiments was that pairs of photons were made to interact, and their polarization was subsequently measured in such a way that the first measurement of photon A could be assumed not to influence the later measurement of photon B. The independence of both measurements was substantially improved in the course of the experiments, and in compliance with a postulate by Bell and Bohm, the settings were changed during the flight of the particles in the final setup. This was to ensure that an influence of the measurement of A on the subsequent measurement of B would have presupposed physical effects of *superluminal velocity*.[x] The strong correlation between the measurments for A and B observed in all experiments in spite of maximum precautions has been considered by some to confirm the implication of quantum theory that our mere *knowledge* of the polarization of A will influence the corresponding polarization of B. The outcome of these experiments has been regarded as a decisive argument against "realistic local theories."[y16]

The setup as well as the interpretation of these experiments relied entirely and exclusively on the assumption that the velocity of light cannot be exceeded by any physical effect. Only if this assumption were true could we know that the physical process of measuring A had no influence on the subsequent measurement of B. If, on the other hand, superluminal velocities are possible, then physical effects can be faster than observation, and the inference that our mere knowledge may cause physical effects would no longer be valid.

Thus, the present state of affairs shows that we are faced, not only in theoretical physics but also in experimental physics, with the choice between rationalism and irrationalism. The question whether or not superluminal velocities exist arises in quantum theory as well as in the theory of light or the speed of other particles, such as neutrinos. We can either treat the hypothesis that the speed of light cannot be exceeded as an empirical hypothesis in the sense of Popper's theory of science in which case we must accept that superluminal velocities are possible, or we can treat it as an irrefutable dogma. Then, we must accept that our mere knowledge of the polarization of a particle A will influence the corresponding polarization of a particle B even after they have been separated. In other words, we would have to admit the possibility of *action at a distance*, meaning that physical effects of particles can influence each other without any connection between them.

I have shown elsewhere that this would be the end of science.[z] For if we deem possible that two events may influence each other without any connection between them, then we no longer search for explanations but are willing to believe in miracles. There can be no serious doubt, I think, that in science believing in miracles would be far worse than giving up STR. If we assume that the experiments on the "completeness" of quantum mechanics or the existence of "hidden variables" were made correctly, then the only way of giving them a rational interpretation is to admit that there are superluminal velocities.

IV. CONCLUSION

STR has now prevailed for more than 100 years. I have been accused of poisoning the atmosphere of science by venturing to criticize it. However, I firmly believe, as Karl Popper did, that the progress of science depends entirely on disagreement and on scientists criticizing others and being criticized by others. As Karl Popper said, "A rationalist is simply a man who is more eager to learn than to be right." If theoretical physics is to be a rational discipline, it will, therefore, have to accept that we cannot have it both ways. We cannot consider STR to be an empirical theory and at the same time believe it to be irrefutable. If superluminal velocities are not excluded by logic or mathematics, then the task of empirical science must be to find out whether or not they exist.

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[v] One example will show this. In 1995 the Irish physicist Kelly had remembered the almost forgotten Sagnac effect and explained its conflict with STR (Ref. 12). Thereupon, the French physicist Vigier came to the rescue of STR and suggested to equip the photon with a tiny rest mass (Ref. 13). He did not mention the objection, so obvious from the point of view of STR, that since photons travel at the speed of light, even the tiniest rest would make their energy infinite.

[w] For details, see Ref. 10, pp. 168–176.

[x] I am not entirely convinced that this postulate was actually complied in the setup. For Aspect *et al.* mention that "the settings of the instruments were made sufficiently in advance to allow them to reach some mutual rapport by exchange of signals with velocity less than or equal to that of light" (Ref. 15, p. 1805). In that case, an influence of the setting of the instruments on the outcome of the experiment would not require superluminal velocity. But my reasoning following in the text does not depend on this interpretation.

[y] Ref. 15, p. 91.

[1] CERN, press release, September, 23, 2011; November 18, 2011; February 23, 2012; March 26, 2012; and June 8, 2012. CERN Web site.

[2] A. Einstein, Ann. Phys. (Leipzig) **17**, 891 (1905).

[z] Ref. 9, pp. 174–176.

[3]C. v. Mettenheim, *Albert Einstein oder: Der Irrtum eines Jahrhunderts* (Books on Demand GmbH, Norderstedt, Germany, 2009).

[4]A. Einstein, *The Principle of Relativity* (Methuen and Co., Ltd., London, 1923).

[5]A. Einstein, *Über die spezielle und die allgemeine Relativitätstheorie* ([Vieweg, Braunschwieg, 1917] Springer, 1988 Reprint), p. 23.

[6]A. Tarski, *Logic, Semantics, Metamathematics,* 2nd ed. (Hackett, 1983).

[7]K. Popper, Mind, New Series **49**, 403 (1940).

[8]W. Greiner and J. Rafelski, *Spezielle Relativitätstheorie*, 3rd. ed. (Harri Deutsch, Frankfurt, 1992).

[9]A. P. French, *Special Relativity*, *MIT Introductory Physics Series* ([Norton, New York, 1968] 1997 Reprint).

[10]C. v. Mettenheim, *Popper versus Einstein: On the Philosophical Foundations of Physics* (Mohr Siebeck, Tübingen, Germany, 1998).

[11]H. Fricke, *Der Fehler in Einsteins Relativitätstheorie* (Heckner, Wolfenbüttel, Germany, 1920).

[12]G. de Sagnac, C. R. Acad Sci., **157**, 708 (1913); **157,** 1410 (1913).

[13]A. G. Kelly, *A New Theory on the Behaviour of Light* (Monograph No. 2, The Institution of the Engineers of Ireland, Dublin, 1995).

[14]J. P. Vigier, Phys. Lett. **A**, 75 (1997).

[15]A. Einstein, B. Podolsky, and N. Rosen, Phys. Rev. **47**, 777 (1935).

[16]A. Aspect, P. Grangier, and G. Roger, Phys. Rev. Lett. **49**, 91 (1982).