The Velocity of Light In Relation to Moving Bodies

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A proposal for an experiment

This paper remains in the form in which it was written over a decade ago. Ed.

The Michelson-Morley experiment performed in 1886 demonstrated that a beam of light that issues from a terrestrial source and travels in the direction of terrestrial motion, East-West-East or West-East-West, needs the same time to traverse a laboratory distance as a beam that travels at right angles to that motion (North-South-North or South-North-South). The undulatory theory of light transmitted by waves in the ether anticipated detection of a difference in the velocities of the two beams due to the orbital velocity of the earth through absolute ether-filled space. Half a year later, when the earth was on the opposite side of its orbit, the same experiment again disclosed no difference in the velocities of the beams; any possible compensatory motion on the part of the solar system or the entire galaxy thus was excluded.

The explanation first offered was the supposition that any material object (also a measuring rod) traveling through the ether is shortened by a very small amount; the East-West distance in the laboratory apparatus (interferometer), being shorter, is traversed by a beam of light traveling a little slower in the same time that the longer North-South distance is crossed by a swifter beam (1). Einstein, however, generalized this idea by assuming that the velocity of light in vacuum is constant in relation to all bodies, whether in motion or at rest. The ether was discarded in the Special Theory of Relativity, and Einstein embraced the quanta theory of light. Both space and time lost the attribute of constancy, and light (its velocity) acquired it.

Ritz objected to the thesis of constancy, claiming that the velocity of an illuminating body adds itself to the velocity of propagation of light c, the resultant being c + v. De Sitter disposed of Ritz' argument by offering to consider a case of a double star whose two members revolve around the common center of gravity on orbits situated in the plane of the observer on earth. If the velocity of light from each of the stars is c - v while receding from the observer and c + v while approaching, the beams of light, after traveling at varying speeds for many years to reach the observer, would present the pair in a most chaotic motion, definitely not in harmony with the Keplerian laws of motion for celestial bodies (2). The idea developed by de Sitter originated with D. Comstock (3).

This argument for a constant velocity of light was regarded as conclusive and the question was not raised again for over three decades. However, in 1932, Sir Oliver Lodge wrote (4): "'that the velocity of light in space is really constant, in itself, may be fully granted ... but that its apparent speed when determined by an observer moving to meet it, should be unaffected likewise is extraordinary. Yet this is the postulate *of* the relativity doctrine propounded in 1905. The doctrine certainly explains the Michelson experiment, and my experiment; nor has any experiment ever negated it so far; and yet--well, it hardly seems consistent with common sense. It seems to me that posterity will formulate the doctrine a little differently. I had hopes that if Michelson had lived (5) --he might have tackled it by some hitherto unimagined experiment, and separated the velocity from the Doppler change of frequency with which it is closely associated. Something might possibly be done with a pair of rapidly revolving cameras. Every terrestrial determination of c involves a to and fro journey of some kind, and therefore is inconclusive. It is now orthodox to assert that no one will ever measure the velocity of light differently by moving towards the source. They would certainly not observe any change in velocity if the source moved toward them; and it is inconsistent with relativity that there should be any difference between the two cases. If there were, we should have to take the ether as our standard of rest (as I want to do), and begin to apprehend absolute motion through the emptiness of space, as well as the familiar relative motion with reference to other portions of matter. Let us try to keep the question open."

Actually the Michelson-Morley experiment is not a direct test; it depends on assumptions and analogies. The beam of light travels both directions; whatever might be won in time on approach to a mirror may be lost in retreat from it; this is also expressed thus: "Because transits to and fro are involved, the Michelson-Morley experiment does not prove anything about the velocity of light *in one direction" (6).* Therefore, this experiment by itself does not prove the proposition that the velocity of light is the same in all directions and for all observers. Besides, in the estimate of the expected results, analogy with a body propelled upstream and then downstream as compared with one propelled forth and back across the stream is assumed, and the different times needed for these two types of travel are computed accordingly. But motion through a resisting fluid is not necessarily analogous to the case of light transmitted by waves in the ether.

A direct experiment to measure the velocity of light relative to moving bodies was devised by me as long ago as 1944, and in December of 1945 it was submitted to the National Academy of Sciences (7) (also copyrighted as lecture on February 23, 1945); but at that time and until recently, such an experiment was considered unnecessary. This I also learned from a letter written to me by Professor Paul Epstein of Cal. Inst. Tech. on March 7, 1945. However, I thought that an experiment, if one could be devised, should also be performed to verify the Michelson-Morley results. On theoretical grounds, it appeared to me that de Sitter's argument is not necessarily valid: an illuminating body might not impart to an erupting photon its own velocity of motion, so instantaneous, most probably, is the eruption; perhaps the light travels with constant velocity c in relation to the illuminating body and also with a velocity c + v in relation to an illuminated body or an observer traveling toward or away from the source of light. De Sitter's argument may have been valid against Ritz, but Ritz' conjecture did not encompass the proposition made here and, in fact, contradicted it.

In recent years (1959-1960), Professor Herbert Dingle raised a question that lay dormant for decades when he wrote (8):

"In view of recent difficulties that have arisen in connection with the [Special Relativity] theory, and particularly in view of the fact that an alternative theory of Ritz's, which was thought to have been disproved, has now been shown to be a distinct possibility (9) ... it is claimed that at present there is no experimental evidence for or against the kinematical requirements of the [Relativity] theory. . ."

"For all practical purposes, then, the choice lies between Einstein and Ritz, and at present there is not a scrap of experimental evidence even to make one appear more probable than the other ... We have not sufficient evidence on observational grounds to give one even a greater or less probability than the other:

we await the verdict of experiment." Professor Dingle challenged experimental physicists to find a method for "the comparison of the velocity of light, with respect to the laboratory, from relatively moving sources," and expressed hope that "the crucial experiment will be undertaken without delay if it is practically possible."

An experiment involving measurement of time on moving clocks is also mentioned in general terms but conceded to be less simple. Professor Dingle stressed that "all experiments in which an atom is regarded as a clock are powerless to answer our question" (10).

It follows that Professor Dingle did not consider that in addition to the hypotheses of Einstein and Ritz a third is possible, namely, that an observer traveling toward a source may meet its light at velocity c + v, while the light travels at constant speed c in relation to neither observer nor source but to the point in space at which it was emitted.

P. Moon and D. Spenser, before Dingle, tried to show that observations of double stars do not justify de Sitter's argument against Ritz (11).

Dingle's reference to "recent difficulties" that have encountered the Special Relativity theory has its basis in W. Heisenberg (1955):

"Relativity Theory assumes that in principle no effect can be propagated faster than the velocity of light. Now this trend in Relativity Theory leads to difficulties in connection with the uncertainty relations of quantum theory ... We have found that in quantum theory a clear determination of position-- in other words, a sharp delimitation of space--presupposes an infinite uncertainty of velocity and thus also of momentum and energy" (12).

By 1956, Russian physicists, too, recognized the need for proof of constant velocity of light; they were not guided by doubts regarding the truth of the postulate but by the realization that the theory of relativity lacks experimental verification of this basic postulate. A. M. Bonch-Bruevich presented in that year a paper entitled: "An experimental verification that the velocity of light is independent of the velocity of the source with respect to an observer" (13), in which the author claimed to have "for the first time performed a direct experiment."

The experiment was based on an idea offered by S. I. Vavilov and before him by G. S. Landsberg. Of the two equatorial points at the limbs of the rotating sun, one retreats from the observer, the other approaches, and the velocity difference is almost 4 kilometers per second. The experiment was performed in Pulkovo on a stretch of two kilometers. The procedure, though complicated in apparatus, was not sufficiently sensitive to measure a time differential of less than one ten billionth of a second, a requirement in the method. Therefore, a statistical treatment was applied to over 1700 measurements, yielding a result that "satisfies the hypothesis of relativistic theory."

The experiment and its result were disqualified by another Russian physicist, A. G. Baranov, who wrote (1961): "On the one hand, the author begins with some a priori assumptions concerning the speed of light after reflection from a mirror; on the other hand, owing to the low accuracy inherent in the method, the observed results have a large scatter, several times larger than the effects expected from classical theory" (14). To this, I may add that in the experiment only the influence of the motion of the illuminating object on the velocity of light was queried, whereas the problem is also whether the motion of an illuminated object in relation to a photon can result in c ± v velocity.

Baranov, in turn, proposed "A Method to verify experimentally that the speed of light is independent of the velocity of the source" (the title of the paper), claiming it to be "a scheme by which to verify directly in the laboratory the postulate of the constancy of the speed of light," the two claims being not identical. Also, the method (no experiment was performed) is not well devised. A beam of light is split in two by a semi-silvered mirror; the split portions of the beam travel, with the help of reflecting mirrors, the same route but in opposite directions; a movable system of two mutually perpendicular mirrors is inserted (closer to one end of the route) so that its motion lengthens the distance more for that beam which has the movable system close to the end of its route. The speed of the mirror is of the order of one meter per second. The interferometer must show no fringe shift if the speed of light depends on the velocity of the source (the value c + 2v after reflection from the movable mirrors would be compensated by the difference in the lengths of the paths).

However, in this project, the source of light and the observer are stationary, and only the mirror is moving; also, the problem remains whether the (hypothetical) c ± v velocity of light traveling toward a mirror remains the same after being reflected (related to the mirror), or becomes c ± v. Light loses energy when it exerts pressure on reflecting surfaces and when it encounters resistance in various transparent media, like air, water, or glass. In Baranov's scheme one half of the beam is reflected from four mirrors and passes through two semi-silvered ones, whereas the other half of the beam is reflected from six mirrors and passes through none.

In my experiment, as devised in 1944, a beam of morning sunlight is permitted to travel through a slit provided with a shutter toward a rotating, multifaced mirror at a distance; through a parallel slit operated by the same shutter travels light from a source on earth. From the rotating mirror the beams are reflected to a sensitive plate not far away. The apparatus travels toward the sun with velocity due to the earth's rotation amounting to somewhat less than half a kilometer per second, depending on latitude (40,000 kilometers in ca. 86,000 seconds at equator). If the solar light approaches the apparatus with velocity $c + v_t$, then it will mark its appearance on a sensitive plate in advance of the mark made by the light from the terrestrial source, which travels with the apparatus and is stationary with respect to it.

Before sunset the experiment is repeated as the apparatus retreats before the solar beam. This time the shutter is placed west of the rotating mirror; precise equality of distances between shutter and mirror in the morning and afternoon is not of prime importance. The results of the morning and afternoon experiments are compared.

In this experiment, the light does not travel in two opposite directions before its velocity is measured by comparison with a parallel beam from a terrestrial source. The solar light coming from the central portion of the disc is utilized.

The following quantities may be taken as guides: The distance between shutter and mirror--one kilometer; the shutter opens for 10^{-5} of a second; the mirror rotates 5,000 times per second and has the form of a decagonal prism; each facet replaces the previous in 2×10^{-5} sec.; the distance from the decagon mirror to the detection device is ca. 2 meters. If there is a difference in velocity between the solar and terrestrial light signals, it would amount to ca. 10^{-6} km per sec.; the difference in time would be 3.3×10^{-12} second; at a radius of 2m., ten microns subtend nearly 1" of arc; the angular rotation of a reflected beam of light being twice the angular rotation of the mirror, at 5,000 rotations per second, the light beam that precedes by 3.3×10^{-12} sec. would mark itself on a sensitive plate half a micron in advance of the other beam of light.

Half a micron is at the limit of optical observation, but we are left with a reserve in the possibilities for increasing mirror speed or passage and projection distances. An optical dispersion device might be inserted before the sensitive plate, unless another method (photoelectric) proves to be superior. Half a micron being the wave length of green light, an interferometer device could be utilized for checking the comparative velocities of the two beams.

In this form I communicated my experiment plan to Dr. H. K. Ziegler, Chief Scientist, U. S. Army Signal Research and Development Laboratory, Fort Monmouth, N.J., in April-May 1961.

Originally I considered passing the beams of light through a prism between the rotating mirror and the sensitive plate and comparing the positions of the spectral lines in the solar light with those from terrestrial source (neon) in the morning and before evening, but this arrangement requires a very fast shutter to obtain unsmudged spectral lines. To distinguish in this arrangement between a shift due to the changed velocity of light and a shift due to a Doppler effect, the mirror should be rotated both ways: the Doppler shift would be toward the violet in the morning and toward the red in the evening, but a displacement due to the change in velocity of light would follow the direction of the mirror's rotation.

In both versions of the proposed experiment, we have a direct method to compare the velocity of a beam of light in relation to an observer moving toward the source of light or away from it with the velocity of light from a source that is stationary in relation to the observer. Travel of beams of light "to and fro" is avoided in this arrangement.

Should the experiment result in velocity c for the light arriving from the terrestrial source and $c \pm v$ for the light from the sun, then Einstein's postulate of constant light velocity would be disproven; Ritz, however, would not yet be proven because, though we can regard the sun as moving and the observer as stationary, yet we cannot reverse the illuminating faculty and consider the observer illuminating and the sun illuminated. Ritz claimed that the motion of a source is transferred to the photons and results in $c + v$ where v is the velocity of the source with respect to the observer. Yet we may, consider that the photons do not inherit the inertia of motion of the source from which they erupt, but an observer traveling toward h source of light would meet the photons at a speed surpassing c. In order to substantiate or eliminate Ritz, a control experiment should be instituted: beams from both equatorial edges of the solar disk are compared as to their velocity; an arrangement similar to that of the original experiment is employed.

In case, however, the original experiment should result in equal velocities for the solar and terrestrial beams of light in relation to the observer, Ritz would be disproven, but Einstein not yet proven. This is seen from the following: If in the experiment performed in the morning the velocities of the solar and terrestrial beams are c in relation to the points in space where they were emitted, but $c + v_t$ in respect to the mirror, then the two beams will arrive at the same speed and there will be no immediate way to determine whether velocity c ± v in relation to a moving body does or does not exist.

To solve this part of the problem, an experiment must be devised in which light (laser) signals from two terrestrial sources equidistant from a detector and coming from opposite directions (east and west) are competing. Also radio signals substituting for fight could be sent to the sun and registered upon their return, the passage time being measured and compared in the morning and afternoon. In view of turbulent conditions above the photosphere and in the corona, such an experiment needs to be repeated several times in order to obtain mean values. The moon, too, after rising and before setting may serve as the reflecting body; it has no magnetosphere worth considering and it may prove to be a preferable target, though the sun offers an almost 400 times longer route; the time difference for the passage time of morning and afternoon signals to the sun and back, if not zero, may be close to one three-hundredth second.

Experiments concerned with the problem of absolute space need to be repeated at certain time intervals: The orbital and the rotational speeds of the earth and the motion of the solar system in its entirety will affect any experiment devised to solve the problem of constancy of velocity of light in relation to a point in absolute space where the photon left its source.

The main experiment described in this paper will eliminate either Ritz' or Einstein's solution of the problem, leaving the winner to face another contest.

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