Sagnac Effect on Inertial Motion

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Wang, Zheng, and Yao carried out an experiment in 2004 to determine if the Sagnac effect can be applied to the inertial motion. Their experiment showed that there was indeed phase difference between the two light beams passing through the same optical fiber in inertial motion. However, the focus of their experiment was on the rest frame of the light source. They did not realize that the time difference from the phase difference should exist in all reference frames. The difference in the elapsed time taken by two light beams to pass through the linear fiber segment in the rest frame of the segment effectively corresponds to the speed difference between two light beams. The Sagnac effect in inertial motion provides a precise experimental evidence that the speed of light is different in a different reference frame.

I. INTRODUCTION

In 1913, Georges Sagnac[1] constructed a ring interferometer to detect the effect of the relative motion of the ether. The interferometer produced an interference pattern if the ring was rotated. The phase difference in the interference indicated that the two split light beams arrived at the light detector at different times.

This time difference exists in all reference frames. There has been suggestion that the time difference in the rest frame of the ring corresponds to the speed difference between two light beams. However, the rest frame of the rotating ring is not an inertial reference frame. The physics community concludes that the Sagnac effect does not contradict the theory of special relativity[2].

In 2004, R. Wang, Y. Zheng, and A. Yao[3] made a breakthrough to add inertial motion to the ring interferometer. For example, two rings are connected with linear fiber and rotate in synchronization. All their experiments produced interference patterns similar to the pattern from Georges Sagnac's single ring interferometer. With a remarkable arrangement, the ring was eliminated completely in one experiment. The inertial motion became the main source of interference pattern.

However, no theoretical proof related to the speed of light beam was presented by any of the experimenters. No explanation was attempted to identify the speed difference between two light beams in the same inertial reference frame.

A rigorous proof will be derived in the following section.

II. PROOF

Consider one dimensional motion.

A. Elapsed Time

A linear segment of optical fiber is stationary in a reference frame F_1. The length of this segment is L_1 in F_1.

Let another reference frame F_2 move at a velocity of -v relative to F_1. The length of this segment is L_2 in F_2.

Let a light pulse pass through this segment of optical fiber in the direction of its inertial motion in F_2. The speed of the light pulse is C_2 in F_2. Let T_{2f} be the elapsed time for the light pulse to pass through this segment from end to end in F_2.

$$C_2 * T_{2f} = L_2 + v * T_{2f} \tag{1}$$

$$T_{2f} = \frac{L_2}{C_2 - v} \tag{2}$$

Let another light pulse pass through the sane segment of optic fiber in the opposite direction of its inertial motion in F_2. The speed of the light pulse is C_2 in F_2. Let T_{2b} be the elapsed time for the light pulse to pass through this segment from end to end in F_2.

$$C_2 * T_{2b} = L_2 - v * T_{2b} \tag{3}$$

$$T_{2b} = \frac{L_2}{C_2 + v} \tag{4}$$

From equations (2,4), there is a difference between two elapsed times in F_2.

$$T_{2f} \neq T_{2b} \tag{5}$$

B. Conservation of Elapsed Time

Let t_2 be the time of F_2. Let the segment be at the location of (r,0) in F_2. The segment moves at the velocity of (v,0) in F_2.

$$v = \frac{dr}{dt_2} \tag{6}$$

Let t_1 be the time of F_1. Let the segment be at the origin in F_1. The origin of F_2 is located at (-r,0) in F_1 and moves at the velocity of (-v,0) in F_1.

$$-v = \frac{d(-r)}{dt_1} \tag{7}$$

From equations (6,7),

$$dt_1 = dt_2 \tag{8}$$

The elapsed time is conserved in all inertial reference frames.

T_{2f} in F_2 is represented by T_{1f} in F_1.

$$T_{2f} = T_{1f} \tag{9}$$

T_{2b} in F_2 is represented by T_{1b} in F_1.

$$T_{2b} = T_{1b} \tag{10}$$

From equations (5,9,10),

$$T_{1f} \neq T_{1b} \tag{11}$$

There is also a difference between two elapsed times in F_1.

C. Speed of Light

Let C_{1f} be the speed of the forward light pulse in F_1.

$$C_{1f} = \frac{L_1}{T_{1f}} \tag{12}$$

Let C_{1b} be the speed of the backward light pulse in F_1.

$$C_{1b} = \frac{L_1}{T_{1b}} \tag{13}$$

From equations (11,12,13),

$$C_{1f} \neq C_{1b} \tag{14}$$

In the rest frame of the fiber segment, the speed of the forward light pulse is different from the speed of the backward light pulse.

D. Sagnac Effect

In 2004, R. Wang, Y. Zheng, and A. Yao added inertial motion to the original Sagnac interferometer. One of their experiments took the shape of parallelogram.

In figure 1, the top horizontal segment is in inertial motion while the bottom horizontal segment (including source, coupler, detector) is stationary.

They described this innovative arrangement with the following statement: "The light from a source is split into two beams that counterpropagate in the fiber which is wound onto a parallelogram."

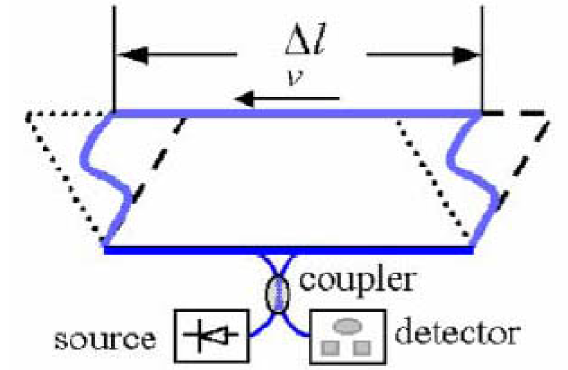

FIG. 1. Sagnac Interferometer

They measured the phase difference between the two light beams as $\Delta\phi$.

$$\Delta\phi = 4\pi \int \vec{v} * d\vec{l}/c\lambda \tag{15}$$

and related the difference in time to the difference in phase.

$$\Delta\phi = 2\pi * \Delta t * c/\lambda \tag{16}$$

The observed phase difference is proportional to the time difference Δt.

$$\Delta t = T_{2f} - T_{2b} \tag{17}$$

They concluded that there is a difference in the elapsed time for two light beams in the rest frame of the light source, F_2. This time difference in F_2 verifies that there is also a time difference in F_1, the rest frame of the linear segment in inerital motion. Therefore, two light beams take two different elapsed times to pass through the same length in F_1.

Based on the measurement of the phase difference, their experiment on Sagnac effect has provided an excellent experimental evidence that the speed of light beam in the rest frame of the fiber segment is different in a different direction.

III. CONCLUSION

The speed of light is constant in the rest frame of the light source. However, it is not constant in all inertial reference frames.

The inertial version of the Sagnac interferometer provides an excellent experimental evidence that the speed of light is different in a different inertial reference frame.

Any theory that assumes a single constant speed of light in all reference frames is proved to be false. For example, Lorentz transformation[4] and its related theories.

[1] Sagnac, Georges (1913). "The demonstration of the luminiferous aether by an interferometer in uniform rotation" . Comptes Rendus. 157: 708710.

[2] Reignier, J.: The birth of special relativity - "One more essay on the subject". arXiv:physics/0008229 (2000) Relativity, the FitzGerald-Lorentz Contraction, and Quantum Theory

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[4] B. J. Hunt (1988), The Origins of the FitzGerald Contraction, British Journal for the History of Science 21, 6176.

[5] Eric Su: List of Publications, http://vixra.org/author/eric_su