Sagnac Experiment – the Factual Analysis

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Abstract. The article starts with a general introduction to the problem in modern physics about the constancy of the speed of light for all frames of reference. In the "General Introduction", besides presenting the used terms and definitions, the fundament of a real solution about all "unexpected" and "inexplicable" results of the experiments related to the measurement of the velocity of light in the time-spatial region "on the Earth surface" is given.

The "Sagnac experiment" was carried out by the French physicist Georges Sagnac in 1913. The presented analysis is based on the classical mechanics and Galilean relativity, which are indisputably valid and legitimate in our local time-spatial region "on the surface of the Earth". The experiment demonstrates that in relation to a moving system in the stationary space, the speed of the light differs depending on the speed and on the direction of movement of the system in the stationary space. However, the Sagnac experiment is considered as a paradox, because it demonstrates that the speed of light is not the same for all frames of reference – what is not convenient for modern physics, because the special theory of relativity is created on the basis of the claim that "the speed of light is the same for all frames of reference". As further evidence of the authenticity of the presented analysis, the derivation of the equation which is often used in the rotation analyses is shown.

Finally, we can underline that as early as 1913, the Sagnac experiment actually proved that "the speed of light is not the same in relation to all inertial frames of reference". This was even before the publishing of the general theory of relativity. Is it not surprising that Einstein never commented on this experiment, although certainly knew about its existence…

KEY WORDS: special theory of relativity; speed of light postulate; Sagnac experiment; æther; speed of light invariance.

1 General Introduction – Used Terms and Definitions

1.1 Concerning the used frames of reference and the speed of light

1.1.1 Frames of reference

The reference system (frame of reference) is a concept in physics (usually associated with the movement) to denote the point of view of the observer.

When we talk about a frame of reference (reference system), we usually imagine it as a coordinate system and we talk about an observer or an experimenter attached to it. When an observer is attached to a frame of reference, this frame is stationary for the observer.

Coordinate systems.

The reference frames used in dynamics are known as coordinate systems. The most widely used is the Cartesian coordinate system which consists of an origin and three axes. The axes are fixed lines, sized/dimensioned with numbers, corresponding to the same unit of length, perpendicular to one another and with direction for each axis. The common point where the axes cross is known as the origin of the coordinate system.

Using the Cartesian coordinate system, in a time-spatial region with constant measurement units (a region with a uniform intensity of the gravitational field), the location of any point in the space can be described, as well as the change into the time of the location of any point.

As a consequence, in the experiment, we distinguish two main frames of reference:

1) Reference system related to the Earth's surface. This is the frame of reference we usually use. In this frame of reference (for an observer, positioned at a point on the Earth's surface) – any object immovably fixed on the Earth's surface is stationary. This frame of reference is fixed to the moving surface of the Earth and it is moving in the stationary space due to the rotating of Earth around its axis in the stationary space.

2) Stationary reference system. Celestial bodies and space. Everything in the Universe possessing mass moves. The gravitation is the driving force. It is caused by the masses of celestial bodies and it sets them into motion. Therefore, a stationary reference system cannot actually exist because we cannot actually connect the "origin" of a stationary coordinate system to a stationary material point. Also, we cannot give exact directions to the axes because we cannot orient them to theoretically non-existing stationary points. However, for most of the cases under consideration, we can use the following approximately stationary frames of reference:

• *"Earth-centered inertial (ECI) coordinate system"* which can be considered in our time-spatial region as a stationary coordinate system in relation to the stationary space.

In other words, we can say that the "Earth-centered inertial (ECI) coordinate system" is related to the space itself where the Earth rotates…, where the photons are born and propagate. If an observer is positioned at a point in this coordinate system, he/she will be stationary in relation to the space near the Earth's surface and will see that the Earth's surface moves (as a result of the Earth's rotation around its axis) in the stationary space with a certain linear velocity (the velocity of a point of the Earth's surface in the stationary space, at the respective latitude). Every point of the Earth's surface always moves in the eastern direction. The magnitude of the linear velocity (i.e., the speed) of a particular point of the Earth's surface, depends on the latitude and is the speed at which the point is moving along its path in the stationary space. It is approximately 0.46 km/s for any point on the equatorial line and is zero at the points of intersection of the axis of rotation of the Earth with the Earth's surface, which points coincide with the north and south poles.

Therefore, when we are located in our local region "near the Earth's surface" and talk about the speed of light "in vacuum" or "in the empty space" – this will mean that the speed of light is measured in relation to the "Earth-centered inertial (ECI) coordinate system".

• *"Heliocentric Inertial (HCI) coordinate system"* also can be considered in certain cases as stationary in relation to the space. *The origin* of this coordinate system is at the center of the Sun (which is not stationary) and its *axes* are approximately stationary in the space (aimed at very distant astronomical objects). An observer positioned stationary in the HCI frame will see how the planets orbit around the Sun (the Earth moves in its orbit around the Sun at approximately 30 km/s); how the plasma of the Sun rotates (at the equator the solar plasma rotation period is about 24.5 days and is almost 38 days at the poles).

> ***Note****: In this paper, the designation "frame of reference related to the space itself" is used as a generalized designation of "stationary in relation to the space coordinate system". For the sake of precision, the term "velocity" is used when referring to the vector* $\vec{V}$ *(with its magnitude and direction); and the term "speed" is used when referring to only the scalar magnitude* $|\vec{V}|$ *of the vector.*

Difference between the mechanical and the optical experiments carried out on the surface of the Earth

• In the mechanical experiments, due to the force of gravity, the material bodies in the atmosphere are involved in the rotation of the Earth around its axis.

• In the optical experiments, however, the photons are not involved in the Earth's rotation around its axis, because they do not have a mass and the gravitational force of attraction for the photons is equal to zero – (see Newton's law of universal gravitation). Therefore, the speed of the photons is constant in empty space (in vacuum, in the frame of reference related to the space itself /in ECI frame of reference/). The measured speed of light in the reference system related to the moving surface of the Earth in the stationary space, however, is not equal to the speed of light in the empty space and this was proven by the experiments. The stationary space is actually the medium of the electromagnetic and gravitational fields.

1.1.2 On the speed of light in different frames of reference

The two major frames of reference, where we will consider the measurement of the speed of light (of the electromagnetic radiation), are "the frame of reference related to the Earth's surface" and the "Earth-centered inertial (ECI) frame of reference" – the system that, in the considered case, is stationary relative to the space itself.

> *For the contemporary physics, there is no difference between "the speed of light in the frame of reference related to the Earth's surface" and "the speed of light in the Earth-centered inertial (ECI) frame of reference, which is the speed of light in vacuum". This is because the modern physics wrongly has accepted that the speed of light is the same in all inertial frames of reference. The factual analysis of all experiments will convince anyone that this claim is a big blunder.*

Anyone would ascertain the following fact – that all experiments undoubtedly prove that there is a difference between the measured velocity of light in the "frame of reference related to the Earth's surface" and the speed of light "in the empty space" (in the "Earth-centered inertial (ECI) frame of reference"). The only exception is the conceptually incorrectly designed Michelson-Morley experiment, in which, due to the inappropriate idea (the two-way measurement of the speed of light), used in the Michelson's interferometer, this difference is completely compensated, which fact is presented in a separate manuscript.

1.1.3 Two important statements as a consequence of Newton's law of universal gravitation

The electromagnetic field exists on the space. The hypothetical "luminiferous aether" (the medium for the propagation of the electromagnetic radiation) turns out to be the warped space-time by the celestial bodies themselves.

Newton's law of universal gravitation states that in the Universe any particle or body with a mass m_1 attracts any other particle or body (with a mass m_2) with a force that is directly proportional to the product of their masses (m_1 and m_2), and inversely proportional to the square of the distance between their centers (r), where G is the gravitational constant:

$$F = G\frac{m_1 m_2}{r^2} \qquad (1)$$

We have to be aware that space cannot be affected by the gravitational forces (cannot be attracted, because space has no mass. Therefore, Newton's law of universal gravitation has another important meaning:

First statement:

From this law, it becomes clear that the space is stationary – that means "the vacuum is stationary". This is undeniable, because space has no mass, and the gravitational forces do not attract it (the space does not rotate along with the Earth, but only the material bodies and the molecules in the atmosphere).

Second Statement:

The gravitational force affects the space by contracting it.

Experiments show that the propagation of the electromagnetic radiation and the electromagnetic properties of the atoms depend on the intensity of the gravitational field (on the density of this medium/on the contraction of the space/).

• In the regions with weaker gravitation, the energy density of the medium of the propagation of the photons (the vacuum) is lower. This means that the wavelength and frequency of any electromagnetic radiation are higher (photons will jump easier – farther and faster). This means that the "meter" becomes longer, and the "second" is shortened. Therefore, the speed of propagation of the photons (of the electromagnetic quanta) is higher $(c=\lambda\nu)$. And vice-versa:

• In the regions with stronger gravitation, the energy density of the medium of the propagation of the photons (the vacuum) is higher. This means that the wavelength and frequency of any electromagnetic radiation are lower (which means that the "meter" becomes shorter, and the "second" becomes longer). Therefore, the speed of propagation of the photons (of the electromagnetic quanta) is lower $(c=\lambda\nu)$.

In his article *"On the Influence of Gravitation on the Propagation of Light"* (see the reference number [1]), Einstein discussed the change of the speed of light in vacuum (proposing a formula without deriving it), when the light enters the regions with a different gravitational potential which actually are regions with different intensity of the gravitational field:

> *"If we call the speed of light at the origin of co-ordinates co, then the speed of light c at a place with the gravitation potential Φ will be given by the relation:*
>
> $$c = c_0\left(1 + \frac{\Phi}{c^2}\right) \qquad (2)$$
>
> *The principle of the constancy of the speed of light holds good according to this theory in a different form from the one that usually underlies the ordinary theory of relativity."* [1]

In the same article Einstein also points out that the frequency of any electromagnetic radiation changes depending on the gravitational potential:

$$\nu = \nu_0\left(1 + \frac{\Phi}{c^2}\right) \qquad (3)$$

This equation, however, was deduced on the basis of the acceptance that the photons (quanta) have mass and consequently the conclusions are wrong. For example, if the photon is losing energy when overcoming the star's gravity (as Einstein "proves"), then the photon will lose a different amount of energy depending on the mass of the star – i. e. the "redshift" will be different and the spectral series of the emission spectrum of the hydrogen atom will be shifted depending on the mass of the star! But there is no such dependence… and no astronomer has observed it!

The frequency of certain electromagnetic radiation defines the base unit of time "second". Therefore, the base unit of time "second" also changes in places with different gravitation potential (with different intensity of the gravitational field) because the duration of the same number 9,192,631,770 time-periods of the used particular electromagnetic radiation will change (see the definition of the "second" since 1967, Ref. [2]). This means that in regions with weaker gravitation (where the frequency increases) the base unit of time "second" becomes shorter (with shorter duration). In this paper, Einstein does not discuss the change in the wavelength of electromagnetic radiation. However, in other articles related to the general theory of relativity it is discussed that in regions with higher gravitation the base unit of length "metre" is contracted (the wavelength of any electromagnetic radiation is shortened) – see the definition of the "metre" in SI accepted in 1960, Ref. [3].

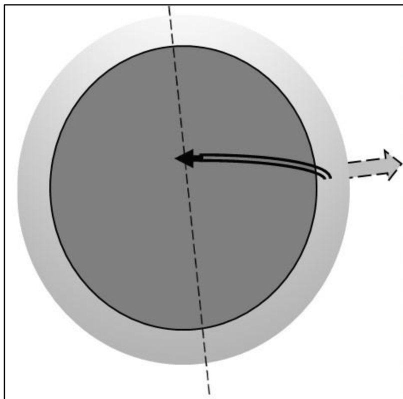
It is clear, however, that the space is stationary but the contraction of the space (changed density of the medium of propagation of the electromagnetic radiation) is moving along with the celestial bodies. All celestial bodies (as well as the Earth) are traveling through the space-time of the Universe along with the distortion (contraction) of the contiguous, warped by the bodies themselves (and belonging to them) time-spatial domains, which we can name *"near the surface of the celestial bodies"*.

The misunderstanding of the dominant part of the physical society consists in the fact that the contraction of space moves along with the celestial bodies, but the space remains stationary!

The intensity of the gravitational field *"near the surface of the celestial body"* remains practically the same during the travel of the celestial body through the space, because the intensity of the gravitational field is determined (dominated) by the mass of the celestial body. The speed of light in vacuum (in the stationary empty space), in any particular time-spatial domain, corresponds to the intensity of the gravitational field in this time-spatial domain.

Therefore, during the travel of the celestial body through the space the constant intensity of the gravitational field "near the surface of the celestial body" determines the constant "speed of light in vacuum" there.

Therefore, that is the reason why there is no variation in "the speed of light in vacuum" when the Earth moves in its orbit around the Sun and together with the Solar System in the Galaxy.



All celestial bodies (as well as the Earth) are traveling through the space-time of the Universe **together with the distortion of the stationary space**, warped by the body itself.
The speed of light in vacuum (in the reference system related to the space itself) depends on the intensity of the gravitational field.

That is why, **the speed of light in vacuum on the surface of the celestial body remains always the** same (constant) during the travel, because the intensity of the gravitational field on the surface of the celestial body remains the same, dominated by the mass of the celestial body.

Figure 1. Movement of the celestial bodies together with the distortion of their "own time-spatial domain"

As a consequence, we have to be aware that the behavior of the electromagnetic radiation in vacuum must be considered in two aspects:

- in regions with different intensity of the gravitational field.
- in regions (local time-spatial domains) with a uniform intensity of the gravitational field;

The local physical reality is a "local time-spatial domain". It is any time-spatial domain with a practically uniform (the same) intensity of the gravitational field in the vicinity of any celestial body which remains constant in the general motion of the celestial bodies in the Universe and where the base units of time and of space (length) can be considered to be constant. Our local physical reality can be named "near the Earth's surface".

1.2 The speed of light in regions with different intensity of the gravitational field

The speed of light in vacuum depends on the intensity of the gravitational field. In regions with different intensity of the gravitational field, the speed of light in vacuum (in relation to the stationary space) is different and this has been proven by experiments:

1) The speed of light in vacuum is higher in regions with weaker gravitation.

In the regions with a weaker intensity of the gravitational field, the electromagnetic waves will not be so suppressed by the gravity – they will oscillate more freely (easier). This means that they will oscillate with a higher frequency v – the "time period" of the electromagnetic oscillations will be of shorter duration. This means that the "spatial period" (the wavelength λ) of the electromagnetic oscillations will also be greater (they will "jump" with larger wavelength). Therefore, the increased frequency and the increased wavelength of each electromagnetic radiation determine not only the shortening of the "second" and the lengthening of the "meter" but also increase in the speed of light in vacuum ($c=v\lambda$). That was proven by the registered anomalies in the accelerations of the space-probes "Pioneer 10", "Pioneer 11", "Galileo", "Ulysses" …

> *"The expected travel time of the communicational electromagnetic signals (based on the constancy of the speed of electromagnetic radiation) between the spacecraft and the Earth, turns out to be much more than the real travel time. So we register backward attraction (acceleration) of the ship to the Sun."* [**4**].

The new higher speed will be valid again for the entire electromagnetic spectrum – it will be again a local physical constant. This logic coincides with the idea of the general theory of relativity.

2) The speed of light in vacuum is lower in regions with stronger gravitation.

Experimentally, using the units of measurement defined on the Earth's surface, a slower speed of radar electromagnetic signals has been experimentally measured in the region with strong gravitation (near the Sun) by the American astrophysicist Dr. Irwin I. Shapiro (Shapiro time delay effect), reported in 1964 (see Ref. [5]). The result of this experiment was confirmed later much more precisely using controlled transponders aboard the "Mariner-6" and "Mariner-7" spacecrafts as they orbited the planet Mars.

1.3 The speed of light in regions with a uniform intensity of the gravitational field

In regions with a uniform intensity of the gravitational field, the speed of light in vacuum (in relation to the stationary space) is a local constant in any local time-spatial domain with a uniform intensity of the gravitational field, and this concerns the whole spectrum of electromagnetic radiation.

> *"The "speed of light in empty space" is the correlation between the frequency and the wavelength for the whole electromagnetic spectrum, which is a local constant for our and for any other local time-spatial domain, where the intensity of the gravitational field is uniform."* [**6**].

However, in regions with a uniform intensity of the gravitational field (as in the region "near the Earth' surface"), the experiments register different velocity of light in relation to the moving frames of reference in the stationary space. This reality is confirmed by:

• the experiments "One-way measurement of the speed of light", (see Ref. [**7**] and Ref. [**8**]);

• the "Sagnac experiment" (Ref. [**9**];

• the experiment "Michelson-Gale-Pearson" (Ref. [**10**, **11**].

All of the experiments related to the speed of light measurement have their real explanation (see Ref. [**12**]) in accordance with the classical mechanics and the Galilean relativity (which are indisputably valid and lawful in our local time-spatial domain "on the Earth's surface").

The exception is only the Michelson-Morley experiment… The analysis of the Michelson-Morley experiment shows (see Ref. [12]) that the inappropriate conceptual design, used in the construction of the Michelson interferometer (the advanced version of which is used in the famous Michelson-Morley experiment, held in 1887) is actually the primary root cause for the great delusion that "the speed of light is the same in all inertial frames of reference", which is the core of the special theory of relativity. The difference in the velocity of light (in the frame of reference related to the moving Earth's surface in the stationary space) between the two light beams, traveling in two opposite directions on the same arm, is completely compensated if the "two-way light beam interferometer" is used.

> *"Actually, if even the "ether wind" exists (caused by the Earth's motion through the stationary luminiferous ether) – the difference in the speed of light between the two light beams, traveling in two opposite directions on the same arm, is completely compensated. It is true for any arm in any direction! In other words, if the projection of the velocity of the "ether wind" on the direction of one of the light beams is (+V), then the projection of the velocity of the "ether wind" on the direction of the reflected light beam (traveling in opposite), will be exactly (-V)."* [**6**].

The "unexplained anisotropy of the light velocity", depending on the direction of the light beam in the "one-way measurement of the speed of light" experiments performed using the GPS system, has its explanation that corresponds to the physical reality. The results of the experiments "One-way measurement of the speed of light", of the "Sagnac experiment", of the "Michelson-Gale-Pearson experiment", of the "Michelson-Morley experiment" and of the Fizeau experiment are analyzed in detail in the monograph [Ref. **12**]. Moreover, the essence of the so-called "fundamental tests of the special theory of relativity", which have been considered as three major types, is revealed there. This monograph includes the analysis of the article *"On the Electrodynamics of Moving Bodies"* (see Ref. [**13**]), presenting the special theory of relativity and **shows exactly where and how** the claim *"the speed of light is the same in all inertial frames of reference"* was applied. It is also presented in *"Thesis on the behavior of the electromagnetic radiation in the gravitational field of the Universe"* (in 10 Statements), which actually rejects the postulate of the constancy of the speed of light for all frames of reference and shows a solution of other big problems in physics today, such as: *"the accelerated expansion of the Universe"* and *"the dark matter and the dark energy in the Universe"*.

2 Analysis of the "Sagnac Experiment"

2.1 The idea and the description of the experiment

Georges Sagnac, a French physicist, constructed a device "ring interferometer" (rotating interferometer with two light beams on closed-loop), also called "Sagnac interferometer". The interferometer consists of a light source, collimator (transforming light or other radiation from a point source into a parallel beam), beam-splitter (splitting the beam in two directions), photographic plate and 4 mirrors of the interferometer, which are all mounted on a spinning disc (0.5m in diameter). In this way, they are all stationary with respect to the disc but they are actually spinning in the stationary empty space – in the reference system related to the space itself, (*Figure 2*).

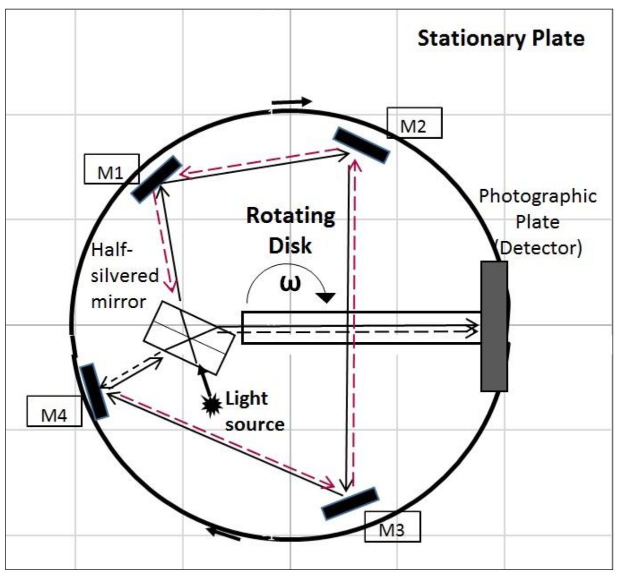


Figure 2. Schematic representation of the Sagnac's interferometer

Description of the experiment: A monochrome light beam is split and the resulting two beams follow (in the reference system related to the spinning disk), exactly the same path reflected by the four mirrors. The trajectories of the two beams, however, are in opposite directions, which is actually the brilliant idea of the experiment of Georges Sagnac. The two recombined light beams (unified again after one full cycle), are then focused on a photographic plate, creating a **fringe pattern *(a series of bright and dark bands caused by light rays that are either in phase or out of phase relative to each other*)**, permitting measurement of the interference fringe displacement with a high accuracy, as Georges Sagnac described in his article *"On the proof of the reality of the luminiferous aether by the experiment with a rotating interferometer"* [**9**].

The idea *is to demonstrate the different speeds of the two light beams in the* ***frame of reference related to the spinning disk***. In this frame of reference, the speed of the beam, moving in the direction of rotation of the disk decreases, and the speed of the other beam, moving in the opposite direction of rotation of the disk increases, when the speed of rotation of the disk increases. The experiment demonstrates that the picture of the **interference fringes** (the bright or dark bands caused by beams of light that are in phase or out of phase relative to each other) changes when the speed of rotation of the disk changes.

The results of the experiment are precisely fixed. **The observed effect** is that the displacement of the interference fringes (the bright and dark bands), is changing with the change of the velocity of the disk rotation.

The reported result by Georges Sagnac is:

"The result of these measurements shows that, in ambient space, light propagates with a velocity V_0, independent of the collective motion of the source of light O and the optical system. This property of space experimentally characterizes the luminiferous aether. The interferometer measures, according to the expression (according to the presented equation), the relative circulation of the luminiferous aether in the closed circuit." [**9**].

It is understandable that the result of the experiment has been explained a century ago with a relative circulation of the luminiferous aether in a closed circuit. It is according to the supposition of Christiaan Huygens (Dutch physicist), that the light travels in a hypothetical medium called "luminiferous aether" – a space-filling substance, thought to be necessary as a transmission medium for spreading of the electromagnetic radiation.

In fact, **the conclusion is** not that the space has a property that characterizes the "luminiferous aether", but:

"the "ether" turns out to be the "warped space-time of the Universe" itself." [**4**].

2.2. Explanation of the experiment in accordance with the classical mechanics and the Galilean relativity

The Earth rotates in the surrounding stationary space *with a constant angular velocity*. The linear velocity of the Earth's surface, at the latitude where the experiment is carrying out, *is constant*. The plate (the table on which the rotating disk is mounted), is fixed stationary on the Earth's surface. *Therefore, the influence of Earth's rotation on the speeds of the two light beams (the* *displacement of the interference fringes due to the Earth's rotation),* ***is constant***.

> ***Note****: The displacement of interference fringes due to the Earth's rotation around its axis is discussed in the analysis of the "Michelson-Gail-Pearson experiment".*

According to the experiment, however, the light source, the collimator (transforming the light beam from a point source into a parallel beam), the beam-splitter (splitting the beam in two opposite directions), the photographic plate and the four mirrors mounted on the disk, are rotating all together in the stationary space at the speed of the disk. As a result, the different rotational speeds of the disc create different displacements of the interference fringes.

The two frames of reference, which we are considering in the theoretical explanation of the experiment, are:

1) The first one is related to the rotating disk, where the light source, the collimator, the beam-splitter, the photographic plate, and the four mirrors are mounted.

When the observer is on the disk, all devices (the collimator, the beam splitter, the photographic plate, and the four mirrors) mounted on the disk are stationary for the observer (regardless of whether the disc is spinning or not).

2) The second one is related to the stationary space itself.

Appropriate for the explanation of the experiment is, to consider it in a *"Disk-Centered Inertial coordinate system"* (DCI frame).

The description of this frame of reference is:

• **The origin** of the "DCI coordinate system" is the center of the disk. If we ignore the displacement of the interference fringes due to the Earth's rotation (which is constant regardless of the disk rotation), we actually accept that the origin of the "DCI coordinate system" (the center of the disk which is a fixed point on the Earth's surface), **is stationary in relation to the surrounding space**. Similarly, the North and South poles are stationary in the stationary space when the Earth rotates around its axis.

• The plane of the disk represents the (x,y) plane and the axes of the "DCI coordinate system" are stationary in relation to the surrounding stationary space.

It means that the "Disk-Centered Inertial coordinate system" (DCI frame), can be considered as a stationary frame of reference in relation to the surrounding stationary space. In other words, the observer situated in the DCI frame will see how the light source, the collimator, the beam splitter, the photographic plate, and the four mirrors of the interferometer are rotating together with the disc.

Before the examination of the experiment, we can recall that every mechanical or optical experiment actually takes place in the common space of the considered frames of reference.

2.2.1 Examination of the Sagnac's experiment in the reference system related to the surrounding stationary space – in the "Disk-Centered Inertial coordinate system"

In our time-spatial region *"in the vicinity of the Earth's surface"*, the intensity of the gravitational field is uniform (the same). According to the abovementioned initial conditions of the experiments (which conditions do not, in fact, contradict the standpoint of the contemporary physics): *the electromagnetic radiation propagates in vacuum (in the stationary space), with a constant speed equal to* ***c.*** This is actually *the speed of light* in the stationary in relation to the space *DCI frame of reference*.

However, everything mounted on the spinning disc is rotating (moving) in the stationary space (which means: in relation to the stationary in the space *DCI frame of reference)*. Therefore, in this frame of reference, the length of the path that the two light beams actually travel in the space is different.

This is due to the movement of each mirror in the stationary space (at the rotation of the disk) during the travel of the light beams towards the mirrors.

The two light beams travel in opposite directions. Thus, the path length in the stationary space of one of the light beams (which travels in the opposite direction of the disk rotation) is shortened, and the path length in the stationary space of the other light beam (which travels in the direction of the disk rotation) is extended. As a result of the change of the path lengths of the two light beams (due to different velocities of the disk rotation) – different displacements of the interference fringes are created.

Therefore, the conclusion of the observer, located in the stationary in relation to the space "DCI coordinate system" (where the speed of light is constant and equal to c), is *that the displacement of the interference fringes is due to the change of the path lengths travelled by the two light beams, which in turn depends on the velocity of the disk rotation*.

2.2.2 Examination of the Sagnac's experiment in the frame of reference related to the spinning disk

Positioned on the spinning disk, the observer will see that all devices (the collimator, the beam splitter, the photographic plate, and the four mirrors) mounted on the disk do not move – that they are stationary. Therefore, the path lengths of the two beams (the distances among the mirrors) are not changing when the disk is spinning, either. As a result, the speeds of the two light beams (measured by the observer), in the reference system related to the spinning disk, turn out to be different. This difference depends on the velocity of the disk rotation: the speed of the beam which travels in the direction of the disk rotation decreases to $(c\text{-}V)$, where V is the linear velocity of the mirrors, while the speed of the other light beam, which travels opposite to the direction of the disk rotation – increases to $(c+V)$. In fact, the *"light velocity anisotropy"* observed in the Sagnac's experiment is similar to *"light velocity anisotropy"* in the experiments *"One-way determination of the speed light"* (see the described cases "Eastward Transmission" and the "Westward Transmission" in *chapter 4* of the book [**12**].

Therefore, the conclusion made by the observer positioned in the frame of reference related to the spinning disk is that the displacement of the interference fringes is *due to the difference between the speeds of the two light* *beams*. In turn, that difference (respectively the displacement of the interference fringes) changes with the change of speed of the disk rotation.

Finally, we can underline that as early as 1913, Georges Sagnac's experiment [9] actually proved that ***"the speed of light is not the same in relation to all frames of reference"***. This was even before the publishing of the general theory of relativity. Is it not surprising that Einstein never commented on this experiment, although certainly knew about its existence…

Georges Sagnac's experiment is unofficially considered mystical, because so far, none of its explanations have been officially accepted. Of course, there are many "modern scientific explanations" which, however, are based on unscientifically proven hypotheses – or on "scientific" references to false theories (see Part IV of this book [12]: *"What is the Truth and the Proof in the Science?")*. Although Sagnac's experiment proves that the speed of light is not the same in all inertial reference frames, many modern physics journals publish *"scientific" explanations based on the special theory of relativity*... which is based on the false claim that *"the speed of light is the same in all inertial frames" ...* In other words, this is ***a classical "circular reference"***! Such an example of a published "scientific" comparison of different explanations is that of Malykin, G.B. *"The Sagnac effect: correct and incorrect explanations"* [14]. There are other such examples in the scientific literature.

Despite all this mystification, although there is no valid scientific explanation to this day, nowadays, the result of this experiment has many significant applications in the practice. A wide-ranging application is found in the space navigation, aviation (optical gyroscope) as well as in daily Earth positioning needs, where no one has observed any "anisotropy" of the "meter" as a unit of measurement (which is a claim of the special theory of relativity).

Additional proof of the credibility of the above-mentioned explanation of the Sagnac experiment is given in the next subsection. This theoretical explanation demonstrates the derivation and the origin of the most commonly used equation in the rotational analyses.

2.3 Derivation of the equation, which is often used in the rotation analyzes

The Sagnac effect is manifested itself in a setup called a ring interferometer. It is the basis of the widely used high-sensitivity fiber-optic gyroscope that fixes the changes in the spatial orientation of the object (airplane, satellite, ...).

In general, the fiber-optic gyroscope consists of a rotating coil with a number of optical fiber turns.

The optical fibre is a flexible, transparent fiber, made of glass (silica) or plastic. It consists of two separate parts. The middle part of the fiber is called *core* and that is *the fiber optic medium* the light travels through. Wrapped around the outside of the core is another layer of glass called the *cladding*. The cladding's task is to keep the light beams inside the core. It can do this because it is made of a different type of glass to the core – *the cladding* has a lower refractive index and acts as countless small mirrors. Each tiny particle of light (photon) propagates down the optical fibre by bouncing repeatedly off the cladding, as though the cladding is really a mirror – it reflects back in again and again. This phenomenon is called total internal reflection, which causes the fiber to act as a waveguide.

We will examine a simple ring interferometer (a coil with only one fiber-optic turn) mounted on a rotating disk with an angular velocity ω radian/sec *(see below Figure 3)*.

Two laser beams propagate in the rotating coil: one of them in the direction of the coil rotation, and the other – in the opposite direction of the coil rotation. When the angular velocity of the rotating coil is changing at the turning of the object where it is mounted – and the displacement of the interference fringes changes.

The strength of the Sagnac effect is dependent on the effective area of the closed optical path. However, this is not simply the geometric area of the loop but is enhanced by the number of turns in the coil. The equation that we will derive on the basis of the aforementioned theoretical explanation of the Sagnac's experiment is often used in the analyses of rotation:

$$\left(\Delta t = \frac{4A\omega}{c_0^2}\right) \qquad (4)$$

, where *A* is the area of the circle bounded by the fiber-optic coil. The optical circuit (the "fiber-optic medium"), mounted on the rotating disc rotates along with the rotation of the disc at a linear speed equal to $(R\omega)$, where *R* is the radius of the optical circuit, ω is the angular velocity of the rotating disk. The speed of light inside the *"fiber-optic medium"* (where the speed of light is constant for the homogeneous optical medium) is c_0.

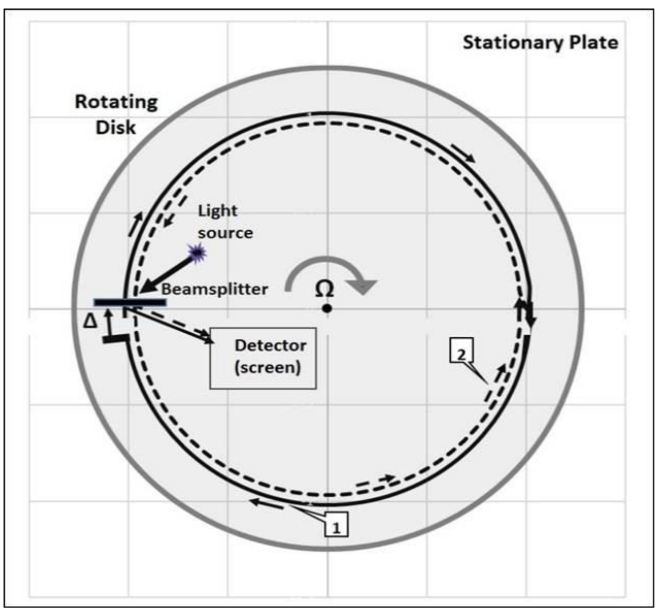


Figure 3. Schematic presentation of a circular interferometer with one optical coil

As is shown, the two light beams (beam 1 and beam 2) are traveling in opposite directions in the same fiber optic circle. Let us analyze one cycle of each of the two beams (from the moment of splitting – up to the moment of directing them to the screen-detector).

Here it must take into consideration two things:

• **the first** is that the space inside the optical fibre (the optical medium) is stationary, although each atom of the optical fiber moves at the rotation.

Since the space has no mass, no force can give it acceleration (to set it in motion). This is a consequence of Newton's second law of motion ***(F =ma)***. Neither the strength of the chemical bonds between atoms (in the micro-world) nor the gravitational forces (according to Newton's law of universal gravitation in the macro-world) can force the space to move because the space has no mass.

• **the second** is that at the microscopic level, the cladding of the optical fiber can be seen as a continuous series of millions of miniature mirrors in which electromagnetic waves are reflected in their propagation (in the case of the Sagnac's experiment, the mirrors are only four).

Similarly, to the Sagnac's interferometer, each of these "elementary mirrors" shifts at a definite angle from the previous photon reflection when the optical coil is rotated – (the mirrors are moved at a certain distance during the propagation time of the electromagnetic wave in the stationary "micro-space" of the optical medium). Thus, in the stationary space, the path of the photons (of the light beam), moving in the direction of rotation of the optical coil is extended, and the path of the light beam moving opposite to the rotation of the optical coil is shortened.

2.3.1 Analysis of one rotation cycle of the light beam "1" that travels in the direction of the disc rotation

2.3.1.1 In the stationary in relation to the surrounding space Disk-Centered Inertial (DCI) coordinate frame

After splitting, the light beam "1" makes one full cycle in the direction of the disk rotation, and reaches again the beam-splitter after time interval t_1 to redirect to the display-detector. For the stationary in the space observer (located in the DCI-coordinate system), the distance traveled by the beam "1" in the stationary space inside the optical medium is longer than the fiber optic coil circumference $(2\pi R)$ with $(\Delta = R\omega t_1)$. This is because, during the beam travel, the point of redirection to the detector display (as well as the entire optical loop) is moved, due to the disk rotation, at a distance Δ. Therefore, the distance traveled by the light beam "1" in the stationary surrounding space, is $(2\pi R + R\omega t_1)$, so for the time interval t_1, (the time for one turn of the light beam "1"), the observer in the "DCI frame of reference") will record:

$$t_1 = \frac{2\pi R + R\omega t_1}{c_o} \qquad (5)$$

, where $\boldsymbol{c_0}$ is the speed of light inside the "fiber-optic medium" (where the speed of light is a constant for the homogeneous optical medium).

2.3.1.2 In the frame of reference related to the rotating disk, where the fiber-optic coil is mounted

For the observer, positioned in this frame of reference (on the rotating disk), the distance traveled by the light beam "1" is $2\pi R$, because the fiber-optic coil does not move in this frame of reference (in relation to the rotating disc). He/she will measure that for the same time interval t_1 the speed of light beam "1" will be equal to $(c_0\text{-}R\omega)$, and for the time interval t_1 (the time for one turn of the light beam "1") the observer (in the frame of reference related to the rotating disk) will register:

$$t_1 = \frac{2\pi R}{c_o - R\omega} \qquad (6)$$

, which is actually equal to $\boldsymbol{t_1}$ from the expression (5) after its transformation.

2.3.2 Analysis of one rotation cycle of the light beam "2", which travels in the opposite direction to the disk rotation

2.3.2.1 In the stationary in relation to the surrounding space Disk-Centered Inertial (DCI) coordinate frame

After splitting, the light beam "2" makes one full cycle in opposite direction to the disk rotation and reaches again the beam splitter after time interval $\boldsymbol{t_2}$, to be redirected to the display-detector. Actually, the distance, traveled by the beam "2" in the stationary space inside the optical fibre, is shorter than the fiber optic coil circumference $(2\pi R)$ with $(\Delta = R\omega t_2)$. This is because, for the time of the beam travel, the point of redirection to the detector (as well as the entire fiber-optic coil) has come closer, due to the disk rotation against the direction of movement of the beam. Therefore, the distance traveled by the light beam "2" in the stationary space (in the "DCI coordinate frame"), is $(2\pi R - R\omega t_2)$; and for the time interval $\boldsymbol{t_2}$ (the travel time for one turn of the light beam "2"), the Observer in the stationary in relation to the surrounding stationary space "Disk-Centered Inertial (DCI) coordinate frame" will register:

$$t_2 = \frac{2\pi R - R\omega t_2}{c_o} \qquad (7)$$

where $\boldsymbol{c_0}$ is the speed of light in the "fiber optic medium" (where the speed of light for the homogeneous optical medium is constant).

2.3.2.2 In the frame of reference related to the rotating disk

For the observer, positioned in this frame of reference (on the rotating disk), the distance traveled by the light beam "2" is exactly $2\pi R$, because the fiber-optic coil does not move in relation to the rotating disc (in the observer's frame of reference). He/she will measure that for the same time interval t_2, the speed of light beam "2" will be equal to $(c_0 + R\omega)$; and for the travel time for one turn of the light beam "2", the observer in the frame of reference related to the rotating disk will register:

$$t_2 = \frac{2\pi R}{c_o + R\omega} \qquad (8)$$

, which is actually equal to $\boldsymbol{t_2}$ from the expression (7) after its transformation.

2.3.3. The results.

On the basis of the analysis, it was found that:

- the time t_2 for one complete tour of the light beam "2" is the same for both frames of reference;
- the time t_1 for one complete tour of the light beam "1" is the same for both frames of reference.
- However, the time for one complete tour of the light beam "1" (which moves in the direction of the rotation of the optical coil) is more than the time for one complete tour of the light beam "2" (which moves in the opposite direction of the rotation of the optical coil).

In the frame of reference related to the rotating disk, for the difference between the time for one tour of the light beam "1" and the time for one tour of the light beam "2", we get (after subtracting equation (8) from (6):

$$\Delta t = t_1 - t_2 = \frac{4\pi R^2 \omega}{c_0^2 - (R\omega)^2} \cong \frac{4A\omega}{c_0^2} \qquad (9)$$

, because

$$c_0^2 \gg (R\omega)^2 \qquad (10)$$

The equation (9) is actually the equation (4) we had to derive.

The result will be the same ***for the Disk-Centered Inertial (DCI) coordinate frame*** if we subtract the equation (7) from (5). So, **there is no "relativistic difference in time"...**

Therefore, the demonstrated derivation of the equation, which is often used in rotation analyzes, proves the veracity of the theoretical explanation of the Sagnac experiment (in accordance with classical mechanics and the Galilean relativity).

3. Conclusion

The moving reference system in the stationary space at the Sagnac experiment is the *"spinning disc"*. The moving reference system in the stationary space at the experiments "One-way measurement of the speed of light" is the *"moving/rotating Earth's surface"*.

The observed effects of displacement of the interference fringes in the case of *"Sagnac's ring interferometer"*, as well as "light speed anisotropy" (the difference in the speed depending on the direction of the light beam) in the case of *"one-way determination of the speed of light"*, clearly demonstrate that:

> *The speed of light in relation to the stationary space (in vacuum) is a constant in our local time-spatial region with the uniform intensity of the gravitational field (or in relation to the stationary space inside a homogeneous optical environment).*

However, it appears that in relation to a moving system in the stationary space, the speed of the light differs depending on the speed and the direction of motion of the system in the stationary space.

It is proven also by the experiments "One-way measurement of the speed of light" and the experiment "Michelson-Gale-Pearson" – that in the reference system related to the moving Earth's surface, the measured velocity of light is influenced by the rotation of the Earth (influenced by the motion of the Earth's surface in the stationary space), i.e. ***that the speed of light is not the same for all reference systems***.

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