Influence of field potential on the speed of light
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Abstract—The paper discusses the affection of the scalar potential on the speed of light in the electromagnetic field, by means of the characteristics of octonion. In the octonion space, the radius vector is combined with the integral of field potentials to become one new radius vector. When the field potentials can not be neglected, the new radius vector will cause the prediction to departure slightly from the theoretical value of the speed of light. The results explain why the speed of light varies in diversiform optical waveguide. And there exist negative refractive indexes due to different scalar potentials in the gravitational field and electromagnetic field.

1. INTRODUCTION
The invariable speed of light is being doubted all the time. And this question remains as puzzling as ever. But the existing theories do not clarify why the speed of light has to keep unchanged, and then do not offer reasonable explain for this empirical fact. The paper attempts to reason out why the speed of light keeps the same in most cases, even in the electromagnetic field.

The invariable speed of light is being doubted all the time. The existing theories do not clarify why the speed of light has to keep unchanged, and then do not offer reasonable explain for this empirical fact. The paper attempts to reason out why the speed of light keeps the same in most cases, even in the electromagnetic field.

The invariable speed of light has not been validated in strong electromagnetic field, although the optical field potential is switched from positive to negative. This inference is coincided with that in the negative index materials [7]. In optical waveguide materials, when the electromagnetic field potential is switched from positive to negative. This inference is coincided with that in the negative index materials [7].

2. OCTONION TRANSFORMATION
In the octonion space, the basis vector \( \mathbf{E} \) consists of the quaternion basis vectors \( \mathbf{E}_g \) and \( \mathbf{E}_e \). The basis vector \( \mathbf{E}_g = (1, \mathbf{i}_1, \mathbf{i}_2, \mathbf{i}_3) \) is the basis vector of the quaternion space for the gravitational field, and \( \mathbf{E}_e = (\mathbf{I}_0, \mathbf{I}_1, \mathbf{I}_2, \mathbf{I}_3) \) for the electromagnetic field. And that the basis vector \( \mathbf{E}_e \) is independent of the \( \mathbf{E}_g \), with \( \mathbf{E}_e = \mathbf{E}_g \circ \mathbf{I}_0 \).

\[
\mathbf{E} = (1, \mathbf{i}_1, \mathbf{i}_2, \mathbf{i}_3, \mathbf{I}_0, \mathbf{I}_1, \mathbf{I}_2, \mathbf{I}_3)
\]

The octonion physical quantity \( \mathbb{D}(d_0, d_1, d_2, d_3, D_0, D_1, D_2, D_3) \) is defined as follows.

\[
\mathbb{D} = d_0 + \Sigma(d_j \mathbf{i}_j) + \Sigma(D_i \mathbf{I}_i)
\]

where, \( d_i \) and \( D_i \) are all real; \( i = 0, 1, 2, 3; j, k = 1, 2, 3 \).

When the octonion coordinate system is transformed into the other, the physical quantity \( \mathbb{D} \) will be transformed into the octonion \( \mathbb{D}'(d'_0, d'_1, d'_2, d'_3, D'_0, D'_1, D'_2, D'_3) \).

\[
\mathbb{D}' = \mathbb{K}^* \circ \mathbb{D} \circ \mathbb{K}
\]

where, \( \mathbb{K} \) is the octonion, and \( \mathbb{K}^* \circ \mathbb{K} = 1 \); * denotes the conjugate of octonion; \( \circ \) is the octonion multiplication.

When the spatial coordinates \( d_1, d_2, d_3, D_0, D_1, D_2, D_3 \) take part in the rotation, the octonion \( \mathbb{D} \) satisfies the following relation.

\[
d_0 = d'_0
\]

In the above equation, the scalar part \( d_0 \) is preserved during the octonion spatial coordinates are transforming. Some invariants of electromagnetic field will be obtained from the characteristics of the octonion physical quantity.
### 3. Speed of Gravitational Intermediate Boson

In the case for coexistence of the electromagnetic field and the gravitational field, the algebra of octonions can be used to describe the property of electromagnetic field and gravitational field.

According to the viewpoint of field theories, each fundamental interaction is mediated by the exchange of electromagnetic intermediate bosons between charges. Meanwhile the electromagnetic interaction is mediated by the exchange of gravitational intermediate bosons between masses. And that the gravitational intermediate boson and the electromagnetic intermediate boson can be combined together to become the photon. The latter can be interacted with either gravitational field or electromagnetic field.

With the feature of octonions, we find that the gravitational field potential has an influence on the speed of gravitational intermediate boson in the gravitational field. It means that the speed of gravitational intermediate boson is variable in the case for coexistence of the electromagnetic field and gravitational field, under the octonion coordinate transformation.

#### 3.1. Radius vector

In the octonion space for gravitational field and electromagnetic field, the octonion radius vector \( \mathbf{R} = \Sigma(r_i \mathbf{i}_i) + \Sigma(R_i \mathbf{I}_i) \). And that it can be combined with the octonion \( \mathbf{X} = \Sigma(x_i \mathbf{i}_i) + \Sigma(X_i \mathbf{I}_i) \) to become one new radius vector \( \mathbf{R} = \Sigma(\bar{r}_i \mathbf{i}_i) + \Sigma(\bar{R}_i \mathbf{I}_i) \). The \( \mathbf{X} \) is the integral of field potentials.

\[
\mathbf{R} = \mathbb{R} + k_{eg} \mathbf{X} \tag{4}
\]

where, \( \mathbf{i}_0 = 1; \bar{r}_i = r_i + k_{eg}k_{rx}x_i; \bar{R}_i = R_i + k_{eg}k_{rx}X_i; r_0 = v_0t; \bar{R}_0 = V_0T; k_{rx} = 1. \) \( t \) denotes the time, \( T \) is a time-like quantity. \( v_0 \) is the speed of gravitational intermediate boson; \( V_0 \) is the speed of electromagnetic intermediate boson. \( \mu_e \) and \( \mu_g \) are the coefficients for the electromagnetic field and gravitational field respectively. \( k_{eg} \) is a coefficient, and \( k_{eg} = \frac{\mu_g}{\mu_e} \).

In other words, the \( \mathbb{R} \) can be considered as the radius vector in the octonion space, with the basis vector \((1, \mathbf{i}_1, \mathbf{i}_2, \mathbf{i}_3, \mathbf{I}_0, \mathbf{I}_1, \mathbf{I}_2, \mathbf{I}_3)\). When the octonion coordinate system is rotated, we obtain the radius vector \( \mathbb{R}'(\bar{r}_0', \bar{r}_1', \bar{r}_2', \bar{r}_3', \bar{R}_0', \bar{R}_1', \bar{R}_2', \bar{R}_3') \). From Eqs.(3) and (4), we have

\[
\bar{r}_0 = \bar{r}_0'. \tag{5}
\]

The above states that the scalar \( \bar{r}_0 \) remains unchanged when the coordinate system rotates in the octonion space. And that there may exist the special case of the \( x_i \neq 0 \) when \( r_i = R_i = 0 \).

#### 3.2. Velocity

The velocity \( \mathbb{V} = \Sigma(v_i \mathbf{i}_i) + \Sigma(V_i \mathbf{I}_i) \) and the field potential \( \mathbb{A} = \Sigma(a_i \mathbf{i}_i) + k_{eg} \Sigma(A_i \mathbf{I}_i) \) can be combined together to become one new velocity \( \bar{\mathbb{V}} = \Sigma(\bar{v}_i \mathbf{i}_i) + \Sigma(\bar{V}_i \mathbf{I}_i) \) in the octonion space.

\[
\bar{\mathbb{V}} = \mathbb{V} + k_{eg} \mathbb{A} \tag{6}
\]

where, \( \bar{v}_i = v_i + k_{rx}a_i; \bar{V}_i = V_i + k_{eg}k_{rx}A_i; a_0 \) and \( A_0 \) are the gravitational scalar potential and electromagnetic scalar potential respectively.

In the above, the field potential \( \mathbb{A} \) consists of the gravitational field potential \( \mathbb{A}_g = \Sigma(a_i \mathbf{i}_i) \), and the electromagnetic field potential \( \mathbb{A}_e = \Sigma(A_i \mathbf{I}_i) \).

\[
\mathbb{A} = \mathbb{A}_g + k_{eg} \mathbb{A}_e \tag{7}
\]
When the coordinate system is rotated, we have one velocity \( \vec{v}_0 = \vec{v}_0' \) (8)

The above means that the speed of gravitational intermediate boson, \( v_0 \), will be variable, due to the existence of the scalar potential, \( a_0 \), of the gravitational field. Obviously, it is not associated with the field potential of electromagnetic field.

4. SPEED OF ELECTROMAGNETIC INTERMEDIATE BOSON

In the octonion space for the electromagnetic field and gravitational field, with the property of the algebra of octonions, we find that the electromagnetic field potential has an effect on the speed of electromagnetic intermediate boson in the electromagnetic field. It states that the speed of electromagnetic intermediate boson is variable in the case for coexistence of the electromagnetic field and gravitational field, under the octonion coordinate transformation.

4.1. Radius vector

In the octonion space, one new octonion quantity \( \bar{R}_q = \bar{R} \circ I_0 \) can be defined from Eq.(4).

\[
\bar{R}_q = \Sigma(\bar{R}_i \bar{k}_i) - \Sigma(\bar{r}_i I_i)
\] (9)

When the coordinate system is rotated, we have the radius vector \( \bar{R}_q' = (\bar{R}_0', \bar{R}_1', \bar{R}_2', \bar{R}_3', \bar{r}_0', \bar{r}_1', \bar{r}_2', \bar{r}_3') \). From Eqs.(3) and (9), we have

\[
\bar{R}_0 = \bar{R}_0'.
\] (10)

The above states that the scalar \( \bar{R}_0 \) remains unchanged when the coordinate system rotates in the octonion space. And it is easy to find Eq.(5) and Eq.(10) can not be established simultaneously.

4.2. Velocity

In the octonion space, one new octonion quantity \( \bar{V}_q = \bar{V} \circ I_0 \) can be defined from Eq.(6).

\[
\bar{V}_q = \Sigma(\bar{V}_i \bar{k}_i) - \Sigma(\bar{v}_i I_i)
\] (11)

When the coordinate system is rotated, we have the velocity \( \bar{V}_q' = (\bar{V}_0', \bar{V}_1', \bar{V}_2', \bar{V}_3', \bar{v}_0', \bar{v}_1', \bar{v}_2', \bar{v}_3') \). From Eqs.(3) and (11), we have the invariant about the speed of electromagnetic intermediate boson in the octonion space.

\[
\bar{V}_0 = \bar{V}_0'.
\] (12)

The above means that the speed of electromagnetic intermediate boson, \( V_0 \), will be variable, due to the existence of the scalar potential, \( A_0 \), of the electromagnetic field. Correspondingly, it is not dealt with the field potential of gravitational field. And Eq.(8) and Eq.(12) can not be established simultaneously also.

5. SPEED OF LIGHT

In some cases, the electric charge is combined with the mass to become the electron or proton etc., therefore we have the condition \( \bar{R}_i I_i = \bar{r}_i \bar{k}_i \circ I_0 \) and \( \bar{V}_i I_i = \bar{v}_i \bar{k}_i \circ I_0 \). It means that the gravitational field as well as the electromagnetic field has an influence on the movement of the electric charge with the mass. In other words, those electric charges with the masses take part in either gravitational interaction or electromagnetic interaction.

Similarly, the gravitational intermediate boson and the electromagnetic intermediate boson can be combined together to become the photon. While, these photons participate not only gravitational interaction but also electromagnetic interaction. As a result, the gravitational field potential and electromagnetic field potential both can impact the speed of light from Eqs.(8) and (12).

In the gravitational theory, the gravitational field potential has an effect on the speed of light. The inference is similar to the shift of spectral-line in Einstein’s general relativity. In Maxwell’s electromagnetic theory, the electromagnetic field potential has an influence on the speed of light in the glass etc. Therefore we have the concept of refractivity in the optics theory.

According to the viewpoint about the affection of field potentials on the speed of light, there may exist the negative refractive index due to different field potential. The conclusion may explain why there exist negative index materials or left-handed materials in a different way.
6. CONCLUSION

In the octonion space, the inferences about speed of light depend on the combinations of physical definitions. By means of definition combination of radius vector and velocity, the gravitational field potential as well as electromagnetic field potential are found to have the influence on the speed of light, in the case for coexistence of the gravitational field and electromagnetic field.

The speed of light changes with the gravitational field potential as well as electromagnetic field potential, and has a deviation from its theoretical value. The light speed variation has a limited effect on the movement of light, because the variation is quite small. Therefore the invariable speed of light is believed to be correct in most cases. However, when there is a very high potential of electromagnetic field, the light speed variation will become huge enough to impact the refractive index of materials obviously. There exist negative refractive indexes in optical waveguide materials, when the electromagnetic field potential is switched from positive to negative, or otherwise. This result is coincided with that in the negative index materials.

It should be noted that the study for influence of field potentials on the speed of light examined only one simple case with very weak field potentials in the gravitational field and electromagnetic field. Despite its preliminary characteristics, this study can clearly indicate that the field potentials in the gravitational field and electromagnetic field have an influence on the scalar invariants. For the future studies, the related investigation will concentrate on only the predictions of light speed variation due to the huge field potentials in the gravitational field and electromagnetic field.

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