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Project AWAKE and the Maxwell's Electrodynamics

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ABSTRACT

The article proposes to increase the efficiency of the project AWAKE on the basis of Maxwell's corrected electrodynamics, which will allow scientists to sharply reduce drastically the sizes, and therefore the costs, of the accelerators needed to achieve the high-energy collisions of particles. Unfortunately, the authors of the project AWAKE are guided in their calculations by the classical Maxwell's electrodynamics and do not take into account the additional longitudinal force generated by the scalar magnetic field arising during the motion of relativistic protons.

Keywords: *proton, electron, vector field, scalar field, longitudinal force, transverse force.*

INTRODUCTION

At CERN, for the first time in the world, it has been experimentally proved that the acceleration of an electron beam in the plasma by means of a proton driver is possible. The team behind the Advanced Proton Driven Plasma Wakefield Acceleration Experiment (AWAKE) at CERN in Geneva has been working since 5 years after CERN approved the project in 2013. In an interview with the project manager AWAKE Edda Gshwendtner "This is the fantastic: the new method of particle acceleration works " explains the essence of the experiment "In the classical scheme, the electron beam in the collider accelerates under the influence of the electromagnetic field. In our experiment, a beam of protons flies in the plasma it creates a wave and thereby ensures the acceleration of the electron beam that follows. The beam of electrons with an the energy of 19 MeV flew in the plasma ten meters and increased energy to 2 GeV, that is, more than 100 times. This means that the average acceleration rate was 200 MeV / m." [1]. The experiment was carried out by the AWAKE collaboration and scientists from the Budker Institute of Nuclear Physics, Siberian Branch of the RAS (INP SB RAS). Traditional accelerators use what are known as radio-frequency (RF) cavities to kick the particle beams to higher energies. This involves alternating the electrical polarity of positively and negatively charged zones within the RF cavity, with the combination of attraction and repulsion accelerating the particles within the cavity. By contrast, in Wakefield accelerators, the particles get accelerated by "surfing" on top of the plasma wave (or Wakefield) that contains similar zones of positive and negative charges. Allen Caldwell, spokesperson of the AWAKE collaboration said, "Wakefield accelerators have two different beams: the beam of particles that is the target for the acceleration is known as a 'witness beam', while the beam that generates the Wakefield itself is known as the 'drive beam'. AWAKE is the first experiment to use protons for the drive beam, and CERN provides the perfect opportunity to try the concept. Drive beams of protons penetrate deeper into the plasma than drive beams of electrons and lasers. Therefore, Wakefield accelerators relying on protons for their drive beams can accelerate their witness beams for a greater distance, consequently allowing them to attain higher energies." However, the use of charged protons as a driver for electron acceleration, in comparison with photons, has one more advantage. It consists in the appearance of an electrodynamics longitudinal force that effectively accelerates the flow of electrons during the motion of the proton beam. This longitudinal force cannot be described by the transverse Lorentz forces or of effect Wakefield. To explain its nature, it is necessary to reconsider Maxwell's electrodynamics [2]. Maxwell made the mistake of applying the Gauss theorem (the Gauss theorem is one of Maxwell's equations) not only for resting charges, but also for moving ones. As a result of this arbitrary assumption, the dynamic state of moving electric charges is simply replaced by their static state. The

Coulomb's law is valid only for stationary charges. In the framework of known concepts in electrodynamics, the magnetic interaction between two charges moving in the same direction is eliminated altogether, although interesting dependences for interacting charges moving along one straight line were experimentally obtained and it would be erroneous to limit the explanation of this interaction only by the wake acceleration of charges thanks to the effect Wakefield [1,2,3,4,5,6].

Correction of Maxwell's Electrodynamics

Correction of Maxwell's equations electrodynamics based on the recognition of the additional scalar magnetic field, acting along the direction of the current, which creates the longitudinal force in addition to the transverse Lorentz forces. The presence of a scalar magnetic field and the longitudinal force generated by it confirm the Aharonov-Bohm effect [3], as well as the work of G. Nikolaev [4]. Researcher of the Tomsk Polytechnic University G.V. Nikolaev , using the single-valued magnitude of physical property of vector potential $\bar{\mathbf{A}}$ moving charge e_o at v < c ascertained existence of two types of magnetic fields in the space around moving charge [4]:

vector field $Hr = H^{\perp} = \text{rot}\bar{\mathbf{A}}$ (1)

scalar field $Hp = H\| = -\text{div}\bar{\mathbf{A}}$ (2)

and the longitudinal force of the magnetic interaction, which is different from the transverse Lorentz forces. Maxwell himself pointed out the difficulties with his the equations when unclosed electric currents and the individual elements of the current. These difficulties lie in the fact that for the open currents alone, non-zero spatial derivative $\text{rot}\bar{\mathbf{A}} = \mathbf{H}$ of vector potential $\bar{A}$ cannot determine it completely. It revealed the existence of yet another non-zero spatial derivative $\text{div}\bar{\mathbf{A}} \neq 0$ of the vector potential $\bar{\mathbf{A}}$. In general, the vector potential $\bar{\mathbf{A}}$ can be represented as the sum of the potential and the vortex components of $\bar{\mathbf{A}}r + \bar{\mathbf{A}}p$. It turns out that a rectilinear infinite current does not create a scalar magnetic field, and an element of a current of finite length creates both a vector magnetic field $Hr = \text{rot}\,\mathbf{A}r$ and a scalar magnetic field $Hp = -\text{div}\,\mathbf{A}p$ [5]. The expression for the electromagnetic energy flux density (Poynting's vector) has the form

$$\mathbf{S} = (\mathbf{E} \times \mathbf{H}r) + (\mathbf{E} \times \mathbf{H}p) \quad (3)$$

Changing the scalar magnetic field equivalent to the formation of electrical charges, which change in turn generates an electric potential field. The longitudinal wave propagates along the axis in the collider plasma column. Based on experimental results, it is proposed to abandon the Lorentz calibration, but instead take the expression for the electromagnetic energy density in the form [6]:

$$\mathbf{S} = -\text{div}\,\mathbf{A} - \lambda\varepsilon 0\mu 0\, d\varphi/dt \quad (4)$$

Obviously, potentials imposed thus allow great flexibility in the use of Maxwell's equations. In the classical case relies S = 0. When using the calibration (4) at $\lambda = 0$ we obtain the Coulomb's gauge, and at $\lambda = 1$ we have the Lorentz's gauge. If you do not assume the vanishing of the expression for S, then at $\lambda = 0$ the scalar field acquires the meaning of a longitudinal magnetic field. Further transformations are performed in the standard way, with the result that allows to obtain the following system of equations:

$$\frac{\partial E}{\partial t} - \text{rot}H - \text{grad}\,S = 0,$$
$$\frac{\partial H}{\partial t} + \text{rot}E = 0, \quad (5)$$
$$\text{div}\,E - \frac{\partial S}{\partial t} = 0,$$
$$\text{div}\,H = 0$$

For ease of reference the equations (5) consider the case of absence of currents and charges and accepted $\varepsilon 0 = \mu 0 = 1$.

For clear separation of the concept of a longitudinal wave in a vacuum, and of the electromagnetic longitudinal waves that exist in material media, in proposed to call the longitudinal electromagnetic E-wave of a wave, in which the magnetic field is zero, and the vector of the electric field is directed along the propagation direction energy flux density. This is scalar function $\mathbf{S}E// = \alpha\mathbf{E}$, where $\alpha = \alpha$ (x, y, z, t). Similarly, is determined by the longitudinal H-wave, generating energy flow $\mathbf{S}H// = b\mathbf{H}$.

Differential equations for the generalized electromagnetic field can be derived from the concept of the Poynting's vector. Poynting's vector for electromagnetic waves of general view, including both conventional transverse modes and longitudinally polarized modes, can be represented as:

$$\mathbf{S} = \mathbf{E} \times \mathbf{H} + \alpha\mathbf{E} + b\mathbf{H} \quad (6)$$

The corresponding energy density of this vector is expressed as:

$W = \frac{1}{2}(\mathbf{E}^2 + \mathbf{H}^2) + WE/\!/ + WH/\!/$ (7),

where $WE/\!/$ and $WH/\!/$ - extra energy.

A rigorous derivation of the additional energy and differential equations for generalized electromagnetic field are given in the work [5].

Aharonov-Bohm Effect

It is generally accepted that if the magnetic field H is known, there is no need to refer to "formal" vector potential $\bar{\mathbf{A}}$. However, the mere fact that the Schrödinger in wave equation appears only vector potential was obvious since the inception of this equation. Unsuccessful attempts to replace the vector potential $\bar{\mathbf{A}}$ in the equations of quantum mechanics "physical" magnetic field H is said that the wave function of any moving charge in the field of the vector potential $\bar{\mathbf{A}}$, should reflect the existence of a quite tangible interaction between a moving charge with this field. This interaction can be characterized by the magnitude of potential $\bar{\mathbf{A}}$ change and the wave function. In 1956 in quantum physics has been demonstrated simple experiment, the result of which is known as the Aharonov –Bohm experiment [3]. When an electron moves along the long solenoid with a current, the electron trajectory is changing, although the magnetic field outside the solenoid is zero ($\mathbf{B} = 0$). Aharonov-Bohm effect has several explanations [3,4,7]. R.Feynman explains the effect of the interaction of the particles with the vector potential $\bar{\mathbf{A}}$ [3], while G. Nikolaev and V.Aksenov suggest that the particle interacts with the scalar magnetic field. In the G. Nikolaev's electrodynamics the particle interacts with a new longitudinal scalar magnetic field H‖ [4], in of the V.Aksenov's theory of the toroidal magnetic fields the particle interacts with the non-force toroidal magnetic field Hr [7]. In the Nikolaev's theory the scalar magnetic field is generated by currents of displacement, in the Aksenov's theory non-force magnetic field is generated by the displacement currents occurring between the plates of the capacitor and conduction currents. The experimentally observed phenomenon of the new longitudinal force in interact of moving electrons with the field of the vector potential $\bar{\mathbf{A}}$ in the experiments of the Aharonov-Bohm effect, was confirmed in later experiments by Japanese scientists (1984) [8]. During experiments, it was found change in the phase of the wave function of a moving charge in the absence and presence in the test area of the vector potential field $\bar{\mathbf{A}}$, in the complete absence in this area of the magnetic field $\mathbf{H}$. The positive results of experiments matched only unique value of the vector potential $\bar{\mathbf{A}}$, is compared with the same parameters unambiguous longitudinal force. Changing the phase of the wave function of the vector potential $\bar{\mathbf{A}}$ is given by:

$$\Delta\varphi = q / \hbar \int \bar{\mathbf{A}} ds, \quad (8)$$

where the integral is taken along the particle's trajectory. Experimental discovery of the phenomenon of longitudinal force effect of interaction along the axis of toroid of electrons with the field of vector potential $\bar{\mathbf{A}}$ in the Aharonov-Bohm experiments make one revise the well-established view about the transverse magnetic forces alone and accept the presence of longitudinal forces of magnetic interaction.

The Cathode-Ray Tube with the Toroidal Winding (A. Kostin's Experiment)

Figure 1 demonstrates the phenomenon the moving charge interaction with the field of vector potential $\bar{\mathbf{A}}$**.** At the cathode-ray tube (1), at the location of the deflecting plates (2), a toroidal winding is placed (3) . Toroidal winding is made of outer and inner layers of wound copper wire of 0.62 mm with a total of 500 turns. The need for double-layer winding is caused by eliminating the magnetic fields of the ring current (one winding is left-screw, the other is right). The windings are connected so that their magnetic fluxes summed.

The electrons are accelerated in the tube potential difference 400V. On the vertical plate was fed a constant deflection voltage to set the basic displacement of the electron beam on the screen (5-20 mm). The current in the coil was varied 0-5A. The results of the experiment are shown in the graph (Figure 1). As the current increases in one direction of the electron beam deflection angle increases in magnitude relative to the reference deviation. Increasing the angle of deflection of the electron beam at a constant voltage across the deflection plates is due to a decrease in the electron beam velocity due to their interaction with the field of the vector potential $\bar{\mathbf{A}}$ of the toroidal winding. When the current in the winding changes to reverse current, the electron beam deflection angle decreases its value in relation to its baseline deviation, registering the effect of increasing the speed of the electron beam in their interaction with the field of the vector potential $\bar{\mathbf{A}}$ toroidal winding.

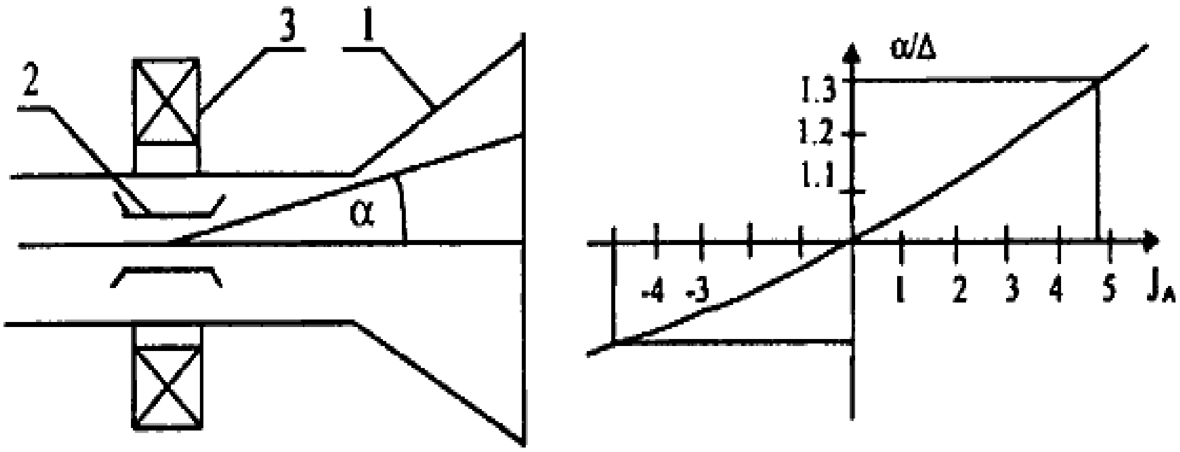

Figure1. *Cathode-ray tube with a toroidal winding*

Thus, the results clearly prove the existence of a conventional classical analogue of the well-known experience of the Aharonov-Bohm and confirm the existence of a previously unknown phenomenon in the science of the longitudinal magnetic interaction (fifth interaction). Not paying attention to the new scalar magnetic field $H_{\|} = -\ \mathrm{div}\bar{A}$ and related new longitudinal magnetic interactions ((fifth interaction) science cannot provide a sufficiently of reliable theory electrodynamics tokamak, charged particle accelerators. The phenomenon of longitudinal magnetic interaction present in the accelerator in the form effect of longitudinal instability of accelerated charged particles, it is the experimentally proven fact. An example of this can serve as the spurious "edge effects" the longitudinal induction currents in the conductive medium in the MHD- generator [4].

Conclusion

Today, before the physicists there is of question: "Which project them choose for the new collider?" If the LHC had discovered the new particle outside the Standard Model or reliably pointed some fundamentally new effect, of physicists would know how to build a collider to study this phenomenon. This would be a reasonable of choice. Now of physicists are forced to make a choice almost blindly, trying to find an option that would be optimal in terms of time, financial investments, and the expected scientific impact. In September 2017, at the 186th session of the CERN Council, the secretariat of the European Strategic Group (ESG) was established, a new body to coordinate the preparation of the updated European Strategy. The key task of the European Strategic Group is to draw up a final program plan and submit it for consideration at CERN. Installing a Large Hadron Collider (LHC) particle accelerator require a concrete tunnel about 27 kilometers (nearly 17 miles) long and US$5 billion in spare change. Project AWAKE uses something known as plasma Wakefield acceleration – and it takes up just 10 meters or 33 feet of space. Scientists noted that the discovery could drastically reduce the sizes, and therefore the costs, of the accelerators needed to achieve the high-energy collisions. Unfortunately, the authors of the project AWAKE are guided in their calculations by the classical Maxwell's electrodynamics and do not take into account the additional longitudinal force generated by the scalar magnetic field arising during the motion of relativistic protons. Allowance for longitudinal force other than the Lorentz's transverse forces can significantly improve the efficiency of the project AWAKE.

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