ENERGY PROBLEM. ATOM AS A SOURCE OF ECOLOGICALLY PURE ENERGY

V.P. Oleinik and V.P. Prokofjev

Department of General and Theoretical Physics, National Technical University of Ukraine "Kiev Polytechnic Institute", 37, Pobedy ave., 03056, Kiev, Ukraine
http://SuperluminalElectron.org/en; e-mail: valoleinik@gmail.com
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Abstract

The fundamentally new approach to the energy problem based on the excitation of electronic quantum transitions in atom responsible for the increase in the mass defect of atom is put forward. The logically consistent quantum theory of hydrogen atom as a system of two particles interacting with each other - electron and proton - is constructed on the basis of the Dirac model of electron. It is indicated that the motion of nucleus in the hydrogen atom significantly influences the physical properties of the atom. The energy spectrum of the atom contains two regions of bound states of electron and nucleus separated from each other by energy on the order of $2m_2c^2$ (m_2 is the mass of proton, c is the velocity of light). As a consequence, there exist such states of the atom in which the mass defect of atom reaches the value of $2m_1$ (m_1 is the mass of electron). The existence of quantum states of atom with abnormally high mass defect and the ability of atom to make transitions from states with smaller value of mass defect to states with greater value open the prospect of creation of active thermal machines (TM) producing excess energy, i.e., transforming the energy of environment into an active one. From the conceptual point of view, the idea of production of excess energy in active TM does not differ from the physical one, which is carried out in the thoroughly studied reactions of thermonuclear synthesis. In both cases, the question is the organization and maintenance, in a system of interacting particles, of physical processes in which the state of system changes in such a manner that the mass defect of system eventually increases in comparison with the initial mass defect. Distinction between active TM and thermonuclear reactor lies only in the fact that physical processes of various types are used in them: in the first case - electronic processes in atoms, and in the second one - the processes going on at collision of nucleons and nuclei. The fact that both phenomena – the production of excess energy in active TM and the energy release in reaction of thermonuclear synthesis – are of the same physical nature and are described by the same parameter - the mass defect, means that production of excess energy is as real as thermonuclear synthesis. As the energy release in active TM occurs due to electronic processes in atoms instead of synthesis or splitting of atomic nuclei, active TM will be ecologically pure energy sources. As fuel for active thermal machine, any substance can serve, the atoms of which can be in the states with various values of the mass defect. The results of the present work do not contradict the laws of thermodynamics. The principles of action of TM described in textbooks on thermodynamics refer only to such TM, which are isolated from the environment (such TM can be called passive ones). The idea that it is impossible to transform energy of the environment into an active form, deeply rooted in consciousness, is the deepest and the most tragic mistake of the last century resulted in the orientation of the planet economy exclusively towards passive TM. Consequences are known: researches of the transformation of environment energy into active form (N. Tesla, K.E. Tsiolkovsky, P.K. Oshchepkov) have

been stopped and declared as pseudo science; that is why, by the end of the century, the mankind turned to be on the verge of ecological catastrophe. The real way to the energy problem solution, as the results of the paper show, passes through the research directed to the creation of active thermal machines, qualitatively new ecologically pure sources of energy. Production of excess energy in active TM is not in conflict with energy conservation. As a matter of fact, an active TM merely converts the poor-quality-energy of surrounding medium into the high-quality-energy capable of performing useful work. The total energy in nature remains constant, and only some part of it becomes active.

1. Introduction. From thermonuclear reactor to active thermal machine

The paper is concerned with the new approach to the energy problem consisting in creation of qualitatively new, ecologically pure energy sources capable to satisfy escalating human requirements on energy and to provide ecological safety of our planet. Presently, when the world has closely come nearer to eco-catastrophe, the energy problem becomes one of the most important problems of the XXI century facing science and engineering.

The purpose of the present work is to draw attention to the fact that quantum electrodynamics opens up new lines of attack on the energy problem.

Let us remind that, according to quantum mechanics, any microsystem in the ground state (i.e., in the state with the least energy) does not stay at rest and makes so-called zero oscillations [1]. For example, quantum oscillator, its zero oscillation energy makes $\hbar\omega/2$ (ω is the oscillator frequency, $\hbar$ is the Planck constant). Further, any quantum particle with nonzero rest mass makes a special oscillatory motion named Zitterbewegung [2] whose energy increases with increasing mass of the particle. Obviously, the world around us consists of different kinds of particles and physical fields corresponding to them and represents a huge reservoir filled with energy. This energy could fully satisfy the human requirements for energy. And the problem is to work out simple and effective technologies of extracting the energy from environment and to transform it into the form suitable for practical use.

As early as 1891, N. Tesla, delivering a lecture at the American institute of electrical engineers, underlined that the space surrounding us is an energy source: “Nature has stored up in the universe infinite energy… We are whirling through endless space with an inconceivable speed, all around us everything is spinning, everything is moving, everywhere is energy. There might be some way of availing ourselves of this energy more directly. Then, with the light obtained from the medium, with the power derived from it, with every form of energy obtained without effort, from the store forever inexhaustible, humanity will advance with giant strides. The mere contemplation of these magnificent possibilities expands our minds, strengthens our hopes and fills our hearts with supreme delight” [3].

K.E. Tsiolkovskii, analyzing the known conclusion made by Clausius about the inevitability of thermal death of the Universe, noticed that this conclusion is incorrect as Clausius has not considered the processes occurring in nature with reduction of entropy (for example, the processes of self-organization in living organisms) [4, 5]. According to Tsiolkovskii, nature development occurs cyclically and represents the circulation of energy having general, universal character. In each cycle of development, along with the processes of energy dissipation, accompanied by increase of entropy and degradation of physical systems, there inevitably take place the processes of energy concentration, accompanied by reduction of entropy and resulting in creation of internal structures. The processes of energy concentration provide new cycles of development and support “an eternal youth of the Universe” [4]. The challenge is to establish conditions at which the energy disseminated in environment can be concen-

trated again for active action. If we know the conditions and meet them, we can scoop energy from the boundless stocks of energy in environment.

P.K. Oshchepkov, developing Tsiolkovsky's ideas, has come to a conclusion that "the law of energy concentration is the fundamental law of nature". As Oshchepkov writes, "there is little doubt that to master the processes of natural circulation of energy in nature is the most daring dream of mankind"[6].

It should be noted that the standard formulation of the problem in the theory of thermal machines (TM), being outlined in standard textbooks on thermodynamics, suffers from a grave disadvantage. This formulation is based on the assumption that, in energy transformations, environment can play only passive role. Therefore, the processes of transforming the energy, extracted, for example, from coal at its firing, instead of the energy of environment are considered. Such statement of the problem in the TM theory quite satisfied the requirements of development of society in the XIX century. However, the time of such TM (it is natural to name them passive) has passed for a long time.

At present, it is necessary to create qualitatively new TM whose action is based on physical principles which essentially differ from the ones that underlie passive TM. In the latter, the energy received by user before the beginning of each running cycle at the cost, for example, of coal burning (we denote this energy by E_0) is transformed into energy, which goes for needs of consumer. Instead of this, all one needs to do is to extract energy from environment and to transform it from passive form, unsuitable for practical use, into the active one, capable of doing work. Energy E_0 should be spent only for excitation and organization in TM of such physical processes in which the energy of environment is redistributed in space and, concentrating inside TM, passes to the active form. That part of energy of environment, which passes to the active form in TM, becoming energy of high quality, and can be used by consumer to solve practical problems, we will name excess energy. In what follows, the thermal machines capable to receive excess energy will be called active TM in contrast with the passive TM described in textbooks on thermodynamics.

Extended investigations are now underway to construct TM of special kind named vortex thermal generators (VTG) (see survey paper [7]). The efficiency of VTG (the ratio of output power to energy consumption) is reported to exceed 1, unlike usual TM, at the expense of generation of excess energy [8, 9]. In our opinion, the case in point is an active TM that converts the energy of environment into active energy.

Judging from the literature available now, the state of the VTG problem is characterized by the fact that nowadays there is no theory explaining the physical reasons of excess energy occurrence. Moreover, from the viewpoint of thermodynamics, release of excess energy is forbidden by laws of physics and, hence, creation of active TM is impossible in principle. It is not surprising that the majority of physicists denies the possibility itself of transformation of environment energy into active form and considers investigation in this field to be pseudo science.

In this paper it is shown that the phenomenon of environment energy transition from the passive form to the active one really exists, the physical nature of this phenomenon is established, and conditions, at which release of excess energy becomes possible, are found. The idea that it is impossible to transform energy of environment into an active form, deeply rooted in consciousness, is the deepest and the most tragic mistake of the last century resulted in orientation of the planet economy exclusively towards passive TM.

Real physical systems consist of electrically charged particles – electrons and nuclei combined into atoms, molecules, ions. Electric charges, inseparable from real particles, generate in surrounding space long-range electric and magnetic fields, which appear to be as inseparable from particles as the electric charges. Special role in nature is played by potential

fields (for example, the Coulomb field), the sources and sinks of which are electrically charged particles. The main feature of these fields is that they cannot break in any bounded area of space as their field lines go from one charged particle (source) to another particle (sink) or to infinity. This means that any real particle represents an open system capable to interact with the material objects lying far outside of its spatial localization. An important point is that real electrically charged particles represent physical feedback systems, as self-fields created by particles are capable of exerting return influence on particles. Hence, the particles existing in nature are open, self-organizing systems [10-13].

Obviously, physical properties of real particles noted above are of primary importance in natural processes, and these properties must be taken into account when studying the general problems of energetics and analyzing the physical processes that lead to production of excess energy in TM.

To gain a more penetrating insight into physical processes leading to liberation of excess energy, it is natural to address the models of elementary physical systems and, in the first instance, electron. As is known, quantum electrodynamics (QED), describing interaction of electron with electromagnetic field, has serious difficulties which, according to Dirac, "in view of their fundamental character can be eliminated only by the radical change of the foundations of theory, probably, radical to the same extent as the transition from the Bohr orbits theory to modern quantum mechanics" ([1], p. 403).

The analysis of the problem of electron [10] shows that the main reason of the QED difficulties is the notion of electron as a structureless, point particle underlying the theory, and that the key to solve the problem of electron is the self-action of electron. As the electric charge is inseparable from electron, the Coulomb field created by the particle, owing to the existence of charge, should be included in particle definition at the initial stage of construction of the model of electron. Such an approach stated in a series of papers [10, 14, 15] has led to a generalization of the known Dirac equation for electron. The generalized quantum equation takes into account self-action of particle, i.e., back action of the Coulomb field created by the charged particle upon the same particle, and allows, due to this, to investigate physical properties of electron as an open self-organizing physical system.

Investigation of solutions to this equation shows that the distribution of electric charge of electron in the ground state consists of a region of basic localization with the linear sizes on the order of the Bohr radius a_0 $(a_0 \sim 10^{-10} m)$, a tail stretched infinitely in all directions, and a self-field. All these three components of electron are inseparable from each other, forming a single physical system. Thus, electron is a spatially extended object that occupies, in a sense, the whole space.

As evident from the notion of electron stated above, the idea of generation of excess energy inside TM is quite reasonable and theoretically grounded. Since electrons enter into atoms and molecules, any material body is an open system. The possibility in principle to generate excess energy in some bounded region of space, using the property of openness of electron and other charged particles, becomes obvious. With regard to the problem of interest to us, the challenge is to excite in TM, considering its openness as a physical system, such physical processes, which result in the concentration of energy inside TM by way of energy redistribution in environment and inside TM.

Leading role in the specified redistribution of energy should be certainly played by the microscopic processes that are the processes of interaction between electrons, ions, atoms, and molecules. Therefore, the physical explanation of the excess energy generation effect should be looked for in quantum electrodynamics by investigating the interaction between electrically charged particles considered as open spatially distributed systems.

To elucidate the physical nature of the phenomenon, it is natural to address the simplest system of two particles interacting with each other - the hydrogen atom. A preliminary research of the hydrogen atom carried out by us on the basis of relativistic equations of motion of mechanics, supplemented with the quantization condition $L = n\hbar$ (L is the total angular momentum of atom, $n = 1,2,\ldots$), has shown that if the nucleus of atom is considered as an independent degree of freedom, there are such states of atom, for which the distance between electron and nucleus can be significantly smaller than the Bohr radius a_0. From the physical point of view, this means that under certain conditions the value of binding energy of electron and proton in atom increases and, hence, the mass defect of atom increases too.

Let us remind that by the mass defect of a system of particles interacting with each other is meant the difference between the sum of rest masses of free particles, to which the system breaks up if the distance between particles beyond all bounds increases, and the mass of system as a whole at rest. Mass defect (it will be denoted by δm) characterizes the binding energy between the particles of the system: the quantity $\delta m c^2$ (c is the velocity of light in vacuum) is equal to the greatest energy, which can be released at formation of the coupled system from its constituent particles. Hence, having found a way of increase in mass defect of atoms, we thereby will open a way to excess energy generation. The value of energy release of atom, if the mass defect changes from initial value δm_1 to final δm_2 ($\delta m_2 - \delta m_1 > 0$), makes $(\delta m_2 - \delta m_1)c^2$.

According to quantum theory of hydrogen atom [16], constructed in the assumption that the nucleus is a motionless Coulomb centre, the mass defect of electron in atom is defined by the formula

$$\frac{\alpha^2}{2n^2} m_0 \equiv (\delta m)_n, \tag{1}$$

where α is the fine structure constant, m_0 is the rest mass of electron, $n = 1,2,\ldots$ is the main quantum number. As is seen from (1), mass defect decreases with increasing the main quantum number, assuming the greatest value in the ground state of atom (at $n = 1$). Notice that $(\delta m)_1 c^2 = I_0$, I_0 is the ionization energy of hydrogen atom.

The result mentioned above concerning hydrogen atom and obtained by us in terms of classical relativistic mechanics testifies that, with allowance for the motion of nucleus in atom, there appear special states of the atom characterized by abnormally high mass defect, i.e., by abnormally strong coupling between electron and proton. Calculation shows that the mass defect of electron can reach several tenths of rest mass of electron; thus, electron comes nearer to nucleus to distances on the order of $10^{-15}\,m$.

This result seems to be a little unexpected: till now it has been considered that the account of nucleus motion as independent degree of freedom of the atom cannot significantly affect the behavior of hydrogen atom. It seemed obvious that, in view of huge distinction in masses of electron and proton, the latter can be considered motionless, having replaced its action by an external field and having reduced thus the problem of atom motion to an one-particle problem of motion of electron in a given external field.

As is evident from the results obtained in the paper, this point of view is erroneous: electron in real atom can essentially differ in its physical properties from electron in atom with fixed nucleus. In quantum relativistic theory of atom with fixed nucleus, some features of energy spectrum of atom, caused by the presence of proton states with negative energy and Zitterbewegung of proton as well, drop out of the field of vision [2]. The calculation shows that it is intolerable not to take into account the motion of nucleus since the influence of pro-

ton motion on the behavior of atom can be considerable. It is illustrated by the example of hydrogen atom that there are such states of atom, in which the mass defect of atom considerably surpasses in magnitude the mass defect in the stationary state defined in the standard theory by formula (1). In going from the state with mass defect (1) to the state with abnormally high mass defect, the energy may be released that considerably exceeds the energy of initial stationary state.

Let us underline that fundamentally the idea of excess energy production in active TM does not differ from the physical idea which is carried out in well studied exothermal nuclear reactions and, in particular, in reactions of thermonuclear synthesis. In both cases it is a question of organization and maintenance, in the system of interacting particles, of physical processes, in which the state of the system changes in such a manner that mass defect of system increases eventually in comparison with mass defect in initial state. In both cases the energy release is equal to the increase in the coupling energy between interacting particles. Distinction between active TM and thermonuclear reactor consists only in the fact that physical processes of various types are used in them - in the first case the electronic processes that occur in atoms, and in the second - the processes that proceed at collision of nucleons and nuclei. From here, one more distinction follows - in scales of energy release: in the first case, the value of released energy per one act of interaction does not exceed several tenths of MeV, and in the second - it can make tens MeV. On the basis of analogy with thermonuclear reactor, the active TM can be naturally called a thermoatomic reactor. Really, in this device of the future there are induced such quantum transitions of atom from one state to another, accompanied by energy release, at which the state of nucleus does not change.

Stated above allows us to draw a conclusion of basic importance, which can be formulated as follows. The establishment of the fact that both phenomena discussed (production of excess energy in active TM and energy release in reaction of thermonuclear synthesis) are of the same physical nature and are described by the same quantity – the mass defect removes all objections which were put forward by experts within two centuries against the basic possibility of transformation of environment energy to the active form. Moreover, we have the right to assert that, having proved identity of the phenomena discussed from the physical point of view, we thereby have obtained the proof of reality of the excess energy production phenomenon: the latter exists with necessity just as the reactions of thermonuclear synthesis well studied in experiments on collision of nuclei exist. Having established that there exist the states of hydrogen atom, in which mass defect of atom considerably exceeds mass defect in stationary state, we thereby have obtained a telling argument in favor of practical possibility of active TM creation.

It is necessary to underline that the processes occurring in atom are obviously of quantum nature and, consequently, their quantitative description is made possible only on the basis of quantum equations of motion.

2. Hydrogen atom with allowance for the motion of nucleus. Quantum equations of motion and energy spectrum

Let us construct the relativistic quantum theory of hydrogen atom, taking into account the motion of nucleus, as a direct generalization of non-relativistic theory [17], the relativistic theory in which the atomic nucleus is supposed to be motionless [16], and the theory offered by Breit for the description of quantum system, consisting of two electrons interacting with each other [18, 19].

We start with the Lagrangian function

$$L = \int d\vec{r}_1 d\vec{r}_2 \; \Psi^* \left\{ i\frac{\partial}{\partial t} - \sum_{s=1,2} H_s - U(\vec{r}_1, \vec{r}_2) \right\} \Psi, \tag{2}$$

where subscripts $s = 1$ and $s = 2$ refer to electron and nucleus, respectively,

$$H_s = \vec{\alpha}_s \hat{\vec{p}}_s + \gamma_{0s} m_s = \begin{bmatrix} m_s & \vec{\sigma}_s \hat{\vec{p}}_s \\ \vec{\sigma}_s \hat{\vec{p}}_s & -m_s \end{bmatrix}, \quad \hat{\vec{p}}_s = -i\vec{\nabla}_s, \quad U(\vec{r}_1, \vec{r}_2) = -\frac{e^2}{|\vec{r}_1 - \vec{r}_2|},$$

H_s is the Hamiltonian operator of particle s; $\Psi = \Psi(\vec{r}_1, \vec{r}_2, t) = \begin{bmatrix} \Psi_{11} & \Psi_{12} \\ \Psi_{21} & \Psi_{22} \end{bmatrix}$ is the wave function of hydrogen atom, components of which have two subscripts: $\Psi_{\nu_1 \nu_2}$; $\vec{\alpha}_1, \gamma_{01}$ and $\vec{\alpha}_2, \gamma_{02}$ are the usual Dirac matrices, with matrices $\vec{\alpha}_1, \gamma_{01}$ pertaining to electron and acting on the first subscript (ν_1) in the wave function, and $\vec{\alpha}_2, \gamma_{02}$ pertaining to nucleus and acting on the second subscript (ν_2); $\vec{\sigma}_1$ and $\vec{\sigma}_2$ are the Pauli matrices. The Dirac matrices with different subscripts commute with each other: $\alpha_{1x}\alpha_{2y} = \alpha_{2y}\alpha_{1x}$, $\gamma_{01}\gamma_{02} = \gamma_{02}\gamma_{01}$ and so on. In more detail, Lagrangian function (2) may be written as follows

$$L = \sum_{\mu_1, \mu_2 = 1,2} \int d\vec{r}_1 d\vec{r}_2 \; \Psi^*_{\mu_1 \mu_2} \left\{ i\frac{\partial}{\partial t} \Psi_{\mu_1 \mu_2} - \sum_{\alpha} (H_1)_{\mu_1 \alpha} \Psi_{\alpha \mu_2} - \sum_{\alpha} (H_2)_{\mu_2 \alpha} \Psi_{\mu_1 \alpha} - U(\vec{r}_1, \vec{r}_2) \Psi_{\mu_1 \mu_2} \right\}. \tag{3}$$

The action principle with Lagrangian function (3) leads to the following equation

$$i\frac{\partial}{\partial t} \Psi_{\mu\nu} = \sum_{\alpha=1,2} (H_1)_{\mu\alpha} \Psi_{\alpha\nu} + \sum_{\alpha=1,2} (H_2)_{\nu\alpha} \Psi_{\mu\alpha} + U\Psi_{\mu\nu}. \tag{4}$$

Equation (4) is an obvious generalization of the Schrödinger equation for hydrogen atom to relativistic case.

If we make up "bispinors" $\begin{pmatrix} \Psi_{11} \\ \Psi_{21} \end{pmatrix} = \Phi_1$, $\begin{pmatrix} \Psi_{12} \\ \Psi_{22} \end{pmatrix} = \Phi_2$ and introduce the following denotation

$$\Lambda_\mu = \begin{bmatrix} D^{(-,\mu)} & -\vec{\sigma}_1 \vec{p}_1 \\ -\vec{\sigma}_1 \vec{p}_1 & D^{(+,\mu)} \end{bmatrix}, \quad \mu = +, -,$$

$$D^{(\pm,+)} = p_0 \pm m_1 + m_2 - U, \quad D^{(\pm,-)} = p_0 \pm m_1 - m_2 - U, \quad i\frac{\partial}{\partial t} = p_0,$$

equation of motion (4) can be represented in the compact form

$$\Lambda_- \Phi_1 = (\vec{\sigma}_2 \vec{p}_2)\Phi_2, \quad \Lambda_+ \Phi_2 = (\vec{\sigma}_2 \vec{p}_2)\Phi_1.$$

If we omit the second subscript pertaining to proton in the wave function components $\Psi_{\mu\nu}$ and put $m_2 = 0$ and $\vec{\sigma}_2 = 0$ in equation (4), we come to the set of two coupled equations

$$(p_0 - m_1 - U)\Psi_1 = (\vec{\sigma}_1 \vec{p}_1)\Psi_2, \quad (p_0 + m_1 - U)\Psi_2 = (\vec{\sigma}_1 \vec{p}_1)\Psi_1,$$

which coincide with the Dirac equation for electron in the Coulomb field considered as a given external field.

Euations of motion (4) allow one to define the energy spectrum of hydrogen atom considered as a single quantum system, which consists of electron and nucleus interacting with each other. The qualitative picture of energy spectrum can be obtained without using equations of motion on the basis of simple reasoning. We deal with the system of two particles, each of them has two regions of states named top and bottom continua and separated by a forbidden band. Due to the presence of proton, the energy spectrum of electron in atom should be split into two regions, one of them should be connected with the low border of the top con-

tinuum for proton, and the second - with the top border of the bottom continuum, i.e., with energies $+m_2$ and $-m_2$. It is natural to expect that the forbidden regions of electron in atom correspond to intervals $(m_2 - m_1, m_2 + m_1)$ and $(-m_2 - m_1, -m_2 + m_1)$. This means that the energy spectrum of atom should consist of four allowed energy bands. Analysis of equations of motion (4) completely confirms this conclusion.

According to the equations of motion, there are two regions of bound states of electron and nucleus located in forbidden energy bands of electron. One of them is located close to the energy level $p_0 = m_2 + m_1$; the second, close to the level $p_0 = -m_2 + m_1$. The dependence of total energy of the system of particles upon energies of separate particles has two branches: $p_{01} = \pm(\varepsilon_2 + \varepsilon_1)$, $p_{02} = \pm|\varepsilon_2 - \varepsilon_1|$, where $\varepsilon_1 = \sqrt{\vec{p}_1^{\,2} + m_1^2}$, $\varepsilon_2 = \sqrt{\vec{p}_2^{\,2} + m_2^2}$ ($\varepsilon_1, \varepsilon_2$ and $\vec{p}_1, \vec{p}_2$ are energies and momenta of particles). Hence, there exist two types of states of hydrogen atom: states with energies p_{01} and p_{02}. The states of the second type are characterized by the feature that the energy of the whole system in these states appears to be less than the sum of energies of all its constituent particles. We call attention to the fact that total energy of the system of two particles being in the second-type state can be equal to zero, though energies of separate particles making the system differ from zero.

Note that if $\vec{p}$ is the relative momentum of the system of two particles, $\vec{q}$ is the momentum of its centre of mass, and $\vec{q} = (0,0,q)$, $\vec{p} = (0,0,p)$, the borders of energy bands are described by curves $p_{01}^{(\pm)} = \pm E^{(+)}(p,q)$ and $p_{02}^{(\pm)} = \pm E^{(-)}(p,q)$, where $E^{(\pm)}(p,q) = \sqrt{m_2^2 + (p - cq)^2} \pm \sqrt{m_1^2 + (p + (1-c)q)^2}$, $c = m_2/(m_1 + m_2)$.

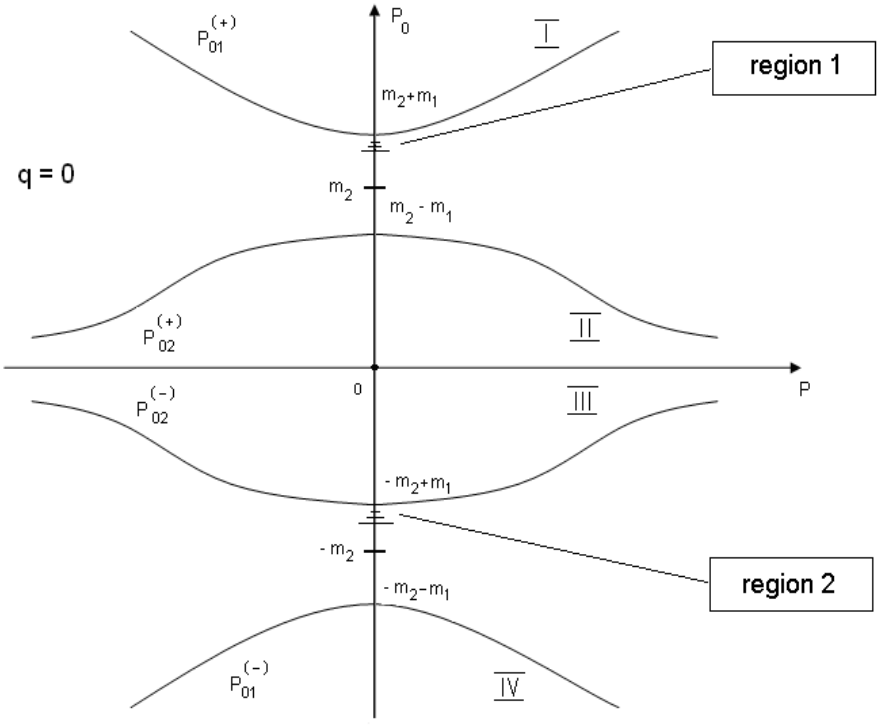

Fig. 1. Energy spectrum of hydrogen atom. Dependence of energy of atom p_0 upon momentum of relative motion of electron and nucleus $\vec{p}$ for fixed values of total momentum $\vec{q}$ of atom. It is assumed that $\vec{p} = (0,0,p)$, $\vec{q} = 0$. $I - IV$ are the allowed energy bands of continuum spectrum. Curves $p_{01}^{(+)} = E^{(+)}(p,q)$ and $p_{02}^{(+)} = E^{(-)}(p,q)$ represent the low boundary of band I and the upper boundary of band II; curves $p_{01}^{(-)} = -E^{(+)}(p,q)$ and $p_{02}^{(-)} = -E^{(-)}(p,q)$, the upper boundary of band IV and the low boundary of band III, respectively. Region 1 and region 2 are bound states of electron and nucleus. Energy regions $p_0 \in (m_2 - m_1, m_2 + m_1)$ and $p_0 \in (-m_2 - m_1, -m_2 + m_1)$ are forbidden bands.

The picture of energy spectrum at $q = 0$ is presented schematically in Fig. 1 (at $m_2 >> m_1$). The continuous part of spectrum consists of four bands - $I - IV$. There are two forbidden bands: one of them lies between curves $p_{01}^{(+)}$ and $p_{02}^{(+)}$; the second, between $p_{01}^{(-)}$ and $p_{02}^{(-)}$. The width of these bands makes $2m_1$ at $q = 0$; it decreases with increasing q. The bands II and III are adjacent to each other, not being crossed, if $q = 0$ (i.e., if the atom as a whole is at rest); their borders $p_{02}^{(+)}$ and $p_{02}^{(-)}$ intersect at $q \neq 0$. The bound states of electron and nucleus lie, as it should be, in forbidden bands; corresponding levels of energy are grouped in two regions (see Fig. 1). Each bound state of atom in region 1 corresponds to a state-twin located in region 2.

3. Discussion of results and main conclusions of the paper

As is seen from Fig. 1, the energy spectrum of hydrogen atom as a system of two quantum particles interacting with each other, electron and proton, significantly differs from the energy spectrum of hydrogen atom described in textbooks on quantum mechanics (see, for example, [17]). These differences are the following:

1) doubling of the number of allowed and forbidden energy bands,
2) occurrence of additional regions of the bound states of electron and nucleus characterized by abnormally great mass defect, and
3) existence of special quantum states of atom, in which the total energy of atom is equal to the difference of energies of its constituent particles.

According to our investigation, taking into consideration the nucleus motion leads to qualitatively new physical results. The standard model of hydrogen atom with the fixed nucleus appears to be a rather rough approximation to reality. The main point is the following: having released the nucleus of atom from fetters, we thereby have allowed the nucleus to make a trembling motion characteristic of micro-particles (Zitterbewegung) and have put into action the additional energy connected with this motion. As a consequence, in the energy spectrum of hydrogen atom, additional bands appear and additional region of bound states of electron and nucleus is formed. Note that results of the paper are a direct consequence of laws of quantum mechanics, which follow from the Dirac model of quantum particle.

Let us consider schematically those processes, which lead to energy liberation by atom.

In the ground state of atom, electron is on the lowest level of energy of region 1 (see Fig. 1). All other energy levels lying lower are filled with virtual particles according to the Pauli principle. As evident from Fig. 1, each energy level of electron in the model of atom with fixed nucleus corresponds, in the new model of atom presented here, to two levels; one of them lies in region 1, and the second lies in region 2 and has negative energy. Remind that in quantum electrodynamics to each virtual state with negative energy there corresponds a real state with energy of opposite sign. Hence, virtual bound states of electron and nucleus in region 2 (see Fig. 1) with negative energy $p_0 = -m_2 + m_1 + \widetilde{\varepsilon}$, $\left|\widetilde{\varepsilon}\right| << m_1$ correspond to the states with positive energy $m_2 - m_1 - \widetilde{\varepsilon} \equiv p_0'$. These states, the set of which we denote by region $2'$, are separated from the bound states in region 1 by the energy on the order of $2m_1$. If the states in region 2 are filled, the region $2'$ appears to be latent: owing to the Pauli principle, it is inaccessible to electron from region 1.

Under the action of some perturbation on atom there occurs a redistribution of virtual particles, the energy spectrum of system is deformed and, as a consequence of this, there can appear empty places (vacancies) in region 2 of bound states. The energy necessary for forma-

tion of such vacancies is drawn from the energy tank corresponding to Zitterbewegung of nucleus. Occurrence of vacancy in region 2 means that the state corresponding to this vacancy in region $2'$ turns from latent into real. There occurs a quantum transition of electron to this state from region 1, accompanied by energy release on the order of $2m_1$. The state of electron in region $2'$ is metastable. Electron occupies this state until there is a vacancy in corresponding state in region 2. As soon as vacancy disappears, there occurs a return transition - electron comes back to region 1 absorbing energy from environment.

Let us note that the energy, released by atom as a result of the direct transition described above, differs in its quality from the energy absorbed in return transition. Direct transition is a transition to the state with greater coupling energy, and released energy is the energy of the ordered motion, i.e., the energy of high quality, whereas in return transition the energy of environment is absorbed (energy of vacuum fluctuations, of Zitterbewegung), and this energy is of poor quality.

As it follows from the arguments given in Introduction, any substance can serve a fuel for the active thermal machine. The only condition is that atoms be capable to transfer from a state with smaller mass defect to a state with greater one under the action of some perturbation and to come back to the state with initial value of mass defect after terminating the perturbation. In our opinion, the most effective way of production of fuel is the action of external electromagnetic fields, causing the rearrangement of energy spectrum of elementary excitations in system, on substance. As an example of the physical system, in which radical rearrangement of energy spectrum is observed, we can refer to electron in homogeneous magnetic field. Under the additional action of an electromagnetic wave on electron, there arise additional energy bands in the forbidden band separating electron and positron states [20, 21] (see Fig. 2). From the physical point of view, formation of additional allowed energy bands in the forbidden band means that under the influence of external field there occurs an ordering of elementary excitations of the system at hand and, accordingly, the coupling between them increases. It is of interest that rearrangement of energy spectrum of elementary excitation, caused by the action of electromagnetic field, is of universal character [22-24]. It can significantly change the physical properties of a system, resulting in a number of unusual physical effects. For example, electron-positron pair can be created by photon, the energy of which is much less, than $2mc^2$ (m is the free electron mass) [21].

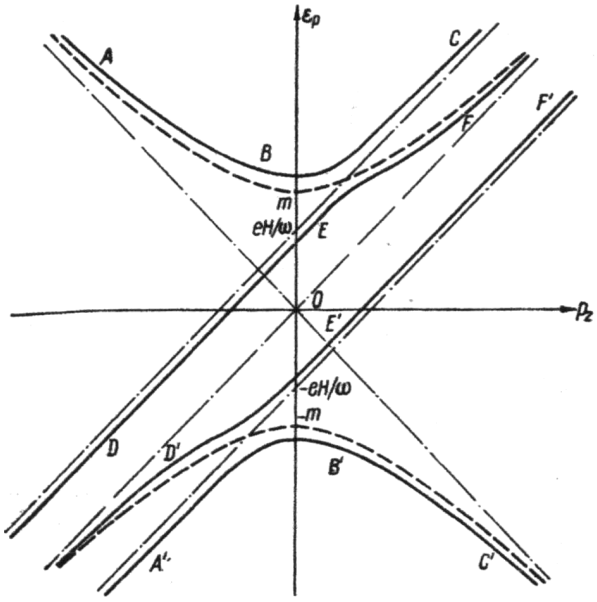

Fig. 2. Quasi-energy spectrum of electron in the field of electromagnetic wave and in the homogeneous magnetic field. Dependence of quasi-energy ε_p upon z-component of momentum p_z at fixed values of n and σ (n is the Landau level number, σ is the spin variable), e and m are the electric charge and mass of electron, H is the homogeneous magnetic field strength, ω is the electromagnetic wave frequency; ABC, DEF and $A'B'C'$, $D'E'F'$ are the electron and positron branches of spectrum. Dash curves represent electron branches of energy spectrum in homogeneous magnetic field in the absence of electromagnetic wave, dot-and-dash straight lines are asymptotes to spectrum branches.

Ordering under the influence of applied electromagnetic field can occur in electronic subsystem of atom as well, giving rise under certain conditions to increasing the mass defect of atom. By choosing the physical parameters characterizing the applied field and substance, it is possible to establish the conditions at which the mass defect of atoms of substance in applied field increases and to obtain, thereby, fuel for the active TM.

It is important to underline that in active TM the energy production occurs at the expense of electronic processes in atoms and not as a result of synthesis or splitting of atomic nuclei. This means that active TM will be ecologically safe energy source. As the world surrounding us is a boundless reservoir of energy, which can be transformed into active form by means of electronic transitions in atoms, we have the right to conclude that atom represents a source of ecologically pure energy.

One of the most important pressing tasks is to evaluate the probability of quantum transitions giving rise to the formation of atomic states with abnormally high mass defect and to elucidate the conditions under which such transitions can take place.

It should be emphasized that the production of excess energy in active TM is not in conflict with energy conservation. The gist of the matter is that the active TM merely converts the poor-quality-energy of surrounding medium into the high-quality-energy capable of performing useful work. The total energy in nature remains constant, and only some part of it becomes active.

In conclusion we should like to note that though in this paper only one special case is considered – the hydrogen atom, the obtained results are of general character: in electronic subsystem of any atom it is possible to cause the quantum transitions leading to increasing the mass defect of atom and, hence, accompanied by production of excess energy.

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