Space-time Engineering
with Lasetron Pulses

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Abstract
The LASETRO N project (Phys. Rev. Lett., 88, (2002), p. 074801-1) offers the possibility of the investigation of electron-positron structure of the space-time. Following our results (From Quarks to Bulk Matter, Hadronic Press, 2001) we analyze theoretically possibility of the penetration of zeptosecond laser pulses \(10^{-21}\) s through space-time.

Key words: Zeptosecond laser pulses; LASETRO N; Electron-positron pairs; Space-time.
1. Introduction

In the paper [1] the theoretical project of the LASERON was described. As was shown in paper [1] the $10^{-22}$ s (zeptosecond) laser pulses can be generated using petawatt lasers, while already available terawatt lasers may generate subattosecond laser pulses of $10^{-19}$ s. The pulses will be radiated by ultrarelativistic electrons driven by circularly polarized high-intensity laser fields. LASERON pulses can be achieved by placing a solid particle or a piece of wire of subwavelength cross section in the focal plane of a superpowerful laser.

In the book [2] it was shown that the lifetime of the electron-positron pair is of the order of $10^{-17}$ s. Strictly speaking the lifetime of the order of the relaxation time $\tau$

$$\tau = \frac{\hbar}{m_e \alpha^2 c^2} \approx 10^{-17} \text{s}.\quad (1)$$

In formula (1) $m_e = m_p$ is electron, positron mass, $\alpha$ is the fine structure constant and $c$ is the vacuum light velocity. As can be concluded from formula (1) the zitterbegung or tremor of space-time can be investigated with the LASERON pulses, for the latter are shorter than the characteristic relaxation time.

For the time period $\Delta t < \tau$, i.e. for LASERON pulse the vacuum of space-time is filled with the gas of electron-positron pairs with lifetime $\approx 10^{-17}$ s. In that case the propagation of LASERON pulse will be described by the Heaviside equation;

$$\frac{\partial^2 E}{\partial t^2} + \frac{\sigma}{\varepsilon_0} \frac{\partial E}{\partial t} = c_\gamma^2 \frac{\partial^2 E}{\partial x^2}.\quad (2)$$

In equation (1) $\varepsilon_0$—permittivity of free space-time, and $\sigma$ is the conductivity of free space-time, $c_\gamma$ is the photon velocity* in space-time and $E$ is electric field (in one dimension).

In the seminal paper [4] F. Calogero described the cosmic origin of quantization. In paper [4] the tremor of the cosmic particles is the origin of the quantization and the characteristic acceleration of these particles $a \approx 10^{-10}$ m/s$^2$ was calculated. In our earlier paper [5] the same value of the acceleration was obtained and compared to the experimental value of the measured space-time acceleration [6]. In this

* $c_\gamma$ is the photon speed in space-time filled with electron-positron pairs. The electron-positron fluctuations can change the $c$ to $c_\gamma$, i.e. $c_\gamma \neq c$ [3].
paper we define the cosmic force — Planck force, 
\[ F_{\text{Planck}} = M_p a_{\text{Planck}} \] (\(a_{\text{Planck}} \approx a\)) and study the history of Planck force as the function of the age of the Universe.

Masses introduce a curvature in space-time, light and matter are forced to move according to space-time metric. Since all the matter is in motion, the geometry of space is constantly changing. A Einstein relates the curvature of space to the mass/energy density:

\[ G = kT, \]

\(G\) is the Einstein curvature tensor and \(T\) the stress-energy tensor. The proportionality factor \(k\) follows by comparison with Newton’s theory of gravity: \(k = G/c^4\) where \(G\) is the Newton’s gravity constant and \(c\) is the vacuum velocity of light; it amounts to about \(2.10^{-43} \text{N}^{-1}\), expressing the rigidity of space-time.

In paper [5] the model for the acceleration of space-time was developed. Prescribing the \(-G\) for space-time and \(+G\) for matter the acceleration of space-time was obtained:

\[ a_{\text{Planck}} = -\frac{1}{2} \left( \frac{\pi}{4} \right)^{\frac{3}{4}} \left( \frac{N + \frac{1}{2}}{M} \right)^{\frac{3}{2}} A_p \]

where \(A_p\), Planck acceleration equal, viz.: \(A_p = \left( \frac{c}{\hbar G} \right)^{\frac{3}{2}} = \frac{c}{\tau_p} \equiv 10^{51} \text{ms}^{-2}\).

As was shown in paper [5] the \(a_{\text{Planck}}\) for \(N = M = 10^{60}\) is of the order of the acceleration detected by Pioneer spacecrafts [6].

Considering \(A_p\) it is quite natural to define the Planck force \(F_{\text{Planck}}\),

\[ F_{\text{Planck}} = M_p A_p = \frac{c^4}{G} = k^{-1}, \]

where

\[ M_p = \left( \frac{\hbar c}{G} \right)^{\frac{1}{2}}. \]

From formula (6) we conclude that \(F_{\text{Planck}}^{-1}\) = rigidity of the space-time. The Planck force, \(F_{\text{Planck}} = c^4/G = 1.2 \cdot 10^{44} \text{N}\) can be written in units which characterize the microspace-time, i.e. GeV and fm. In that units

\[ k^{-1} = F_{\text{Planck}} = 7.6 \cdot 10^{38} \text{GeV/fm}. \]
2. The Planck, Yukawa and Bohr forces

As was shown in paper [5] the present value of Planck force equal
\[ F_{\text{Planck}}^{\text{Now}} (N = M = 10^{60}) \equiv -\frac{1}{2} \left( \frac{\pi}{4} \right) 10^{-60} \frac{c^4}{G} \approx 10^{-22} \text{GeV/fm}. \] (7)

In papers [7, 8] the Planck time \( \tau_p \) was defined as the relaxation time for space-time
\[ \tau_p = \frac{\hbar}{M_p c^2}. \] (8)

Considering formulae (6) and (8) \( F_{\text{Planck}} \) can be written as
\[ F_{\text{Planck}} = \frac{M_p c}{\tau_p}, \] (9)

where \( c \) is the velocity for gravitation propagation. In papers [7, 8] the velocities and relaxation times for thermal energy propagation in atomic and nuclear matter were calculated:
\[ v_{\text{atomic}} = \alpha_{\text{em}} c, \]
\[ v_{\text{nuclear}} = c, \] (10)

where \( \alpha_{\text{em}} = e^2 / (\hbar c) = 1/137, \alpha_\gamma = 0.15 \). In the subsequent we define atomic and nuclear accelerations:
\[ a_{\text{atomic}} = \frac{\alpha_{\text{em}} c}{\tau_{\text{atomic}}}, \] (11)
\[ a_{\text{nuclear}} = \frac{\alpha c}{\tau_{\text{nuclear}}}. \]

Considering that \( \tau_{\text{atomic}} = \hbar / (m_e \alpha_{\text{em}}^2 c^2), \) \( \tau_{\text{nuclear}} = \hbar / (m_n \alpha^2 c^2) \) one obtains from formula (11)
\[ a_{\text{atomic}} = \frac{m_e c^3 \alpha_{\text{em}}^3}{\hbar}, \] (12)
\[ a_{\text{nuclear}} = \frac{m_n c^3 \alpha^3}{\hbar}. \]

We define, analogously to Planck force the new forces: \( F_{\text{Bohr}}, F_{\text{Yukawa}} \)
\[ F_{\text{Bohr}} = m_e a_{\text{atomic}} = \frac{(m_e c^2)^3}{\hbar c} \alpha_{\text{em}}^3 = 5 \cdot 10^{-13} \text{GeV/fm}, \]
\[ F_{\text{Yukawa}} = m_n a_{\text{nuclear}} = \frac{(m_n c^2)^3}{\hbar c} \alpha^3 = 1.6 \cdot 10^{-2} \text{GeV/fm}. \] (13)
Comparing formulae (7) and (13) we conclude that gradients of Bohr and Yukawa forces are much large than $\frac{F_{\text{Bohr}}}{F_{\text{Planck}}}$, i.e.:

$$\frac{F_{\text{Bohr}}}{F_{\text{Planck}}} = \frac{5 \cdot 10^{-13}}{10^{-23}} \approx 10^9,$$

$$\frac{F_{\text{Yukawa}}}{F_{\text{Planck}}} = \frac{10^{-2}}{10^{-23}} \approx 10^{20}. \quad (14)$$

The formulae (14) guarantee present day stability of matter on the nuclear and atomic levels.

As the time dependence of $F_{\text{Bohr}}$ and $F_{\text{Yukawa}}$ are not well established, in the subsequent we will assumed that $\alpha_s$ and $\alpha_{em}$ [9] do not dependent on time. Considering formulae (9) and (12) we obtain

$$\frac{F_{\text{Yukawa}}}{F_{\text{Planck}}} = \frac{1}{\left(\frac{\pi^2}{4}\right)^2 \frac{m_e}{M_p \alpha^3 \text{T}}}, \quad (15)$$

$$\frac{F_{\text{Bohr}}}{F_{\text{Planck}}} = \frac{1}{\left(\frac{\pi^2}{4}\right)^2 \frac{m_e}{M_p \alpha^3 \text{em} \text{T}}} \quad (16).$$

As can be realized from formulae (15), (16) in the past $F_{\text{Planck}} \approx F_{\text{Yukawa}}$ (for $T = 0.002$ s) and $F_{\text{Planck}} \approx F_{\text{Bohr}}$ (for $T = 10^8$ s), $T$ = age of universe. The calculated ages define the limits for instability of the nuclei and atoms.

3. The Planck, Yukawa and Bohr particles

In 1900 M. Planck [10] introduced the notion of the universal mass, later on called the Planck mass

$$M_p = \left(\frac{\hbar c}{G}\right)^{\frac{1}{2}}. \quad (17)$$

Considering the definition of the Yukawa force (13)

$$F_{\text{Yukawa}} = \frac{m_N v_N}{\tau_N} = \frac{m_N \alpha_{\text{strong}} c}{\tau_N}, \quad (18)$$

the formula (18) can be written as:

$$F_{\text{Yukawa}} = \frac{m_{\text{Yukawa}} c}{\tau_N}, \quad (19)$$

where
\[ m_{\text{Yukawa}} = m_N \alpha_{\text{strong}} \equiv 147 \frac{\text{MeV}}{c^2} \sim m_\pi. \]  

(20)

From the definition of the Yukawa force we deduced the mass of the particle which mediates the strong interaction – pion mass postulated by Yukawa in [11].

Accordingly for Bohr force:

\[
F_{\text{Bohr}} = \frac{m_\pi \alpha_{\text{em}} c}{\tau_{\text{Bohr}}} = \frac{m_{\text{Bohr}} c}{\tau_{\text{Bohr}}},
\]

(21)

\[ m_{\text{Bohr}} = m_\pi \alpha_{\text{em}} = 3.7 \frac{\text{keV}}{c^2}. \]  

(22)

For the Bohr particle the range of interaction is

\[
\gamma_{\text{Bohr}} = \frac{\hbar}{m_{\text{Bohr}} c} = 0.1 \text{nm} ,
\]

(23)

which is of the order of atomic radius.

Considering the electromagnetic origin of the mass of the Bohr particle, the planned sources of hard electromagnetic field LASERTRON [1] are best suited to the investigation of the properties of the Bohr particles.

4. Possible interpretation of \( F_{\text{Planck}} \), \( F_{\text{Yukawa}} \) and \( F_{\text{Bohr}} \)

In an important work, published already in 1951 J. Schwinger [12] demonstrated that in the background of a static uniform electric field, the QED space-time is unstable and decayed with spontaneous emission of \( e^+e^- \) pairs. In the paper [12] Schwinger calculated the critical field strengths \( E_s \):

\[
E_s = \frac{m_e^2 c^3}{\epsilon \hbar}.
\]

(24)

Considering formula (23) we define the Schwinger force:

\[
F_{\text{Schwinger}}^e = e E_s = \frac{m_e^2 c^3}{\hbar}.
\]

(25)

Formula (24) can be written as:

\[
F_{\text{Schwinger}}^e = \frac{m_e c}{\tau_{\text{Sch}}} ,
\]

(26)

where

\[
\tau_{\text{Sch}} = \frac{\hbar}{m_e c^2}.
\]

(27)

is Schwinger relaxation time for the creation of \( e^+e^- \) pair. Considering
formulae (13) the relation of $F_{\text{Yukawa}}$ and $F_{\text{Bohr}}$ to the Schwinger force can be established

$$F_{\text{Yukawa}} = \alpha_s \left(\frac{m_N}{m_e}\right)^2 F^{e}_{\text{Schwinger}}, \quad \alpha_s = 0.15,$$

and for Planck force

$$F_{\text{Planck}} = \left(\frac{M_p}{m_e}\right)^2 F^{e}_{\text{Schwinger}}. \quad (29)$$

In Table 1 the values of the $F^{e}_{\text{Schwinger}}$, $F_{\text{Planck}}$, $F_{\text{Yukawa}}$ and $F_{\text{Bohr}}$ are presented, all in the same units GeV/fm. As in those units the forces span the range $10^{-13}$ to $10^{38}$ it is valuable to recalculate the Yukawa and Bohr forces in the units natural to nuclear and atomic level. In that case one obtains:

$$F_{\text{Yukawa}} \approx \frac{16 \text{ MeV}}{\text{fm}}. \quad (30)$$

It is quite interesting that $a_s \approx 16 \text{ MeV}$ is the volume part of the binding energy of the nuclei (droplet model).

| $F^{e}_{\text{Schwinger}}$ [GeV/fm] | $F_{\text{Planck}}$ [GeV/fm] | $F_{\text{Yukawa}}$ [GeV/fm] | $F_{\text{Bohr}}$ [GeV/fm] |
|-----------------------------------|--------------------------------|-----------------------------|----------------------------|
| $\approx 10^{-6}$                 | $\approx 10^{38}$               | $\approx 10^{-2}$           | $\approx 10^{-13}$        |

For the Bohr force considering formula (13) one obtains:

$$F_{\text{Bohr}} \approx \frac{50\text{ eV}}{0.1\text{ nm}}. \quad (31)$$

Considering that the Rydberg energy $\approx 27 \text{ eV}$ and Bohr radius $\approx 0.1 \text{ nm}$ formula (31) can be written as

$$F_{\text{Bohr}} \approx \frac{\text{Rydberg energy}}{\text{Bohr radius}}. \quad (32)$$
5. Concluding remarks

In this paper the forces: Planck, Yukawa and Bohr were defined. It was shown that the present value of the Planck force (which is the source of the universe acceleration) $\approx 10^{-22}$ GeV/fm is much smaller than the Yukawa ($\approx 10^{-2}$ GeV/fm) and Bohr ($10^{-13}$ GeV/fm) forces respectively. This fact guarantees the stability of the matter in the present. However in the past for $T$ (age of the universe), $T < 0.002$ s, $F_{\text{Yukawa}} < F_{\text{Planck}} (0.002 \text{ s})$ and $F_{\text{Bohr}} < F_{\text{Planck}} (10^8 \text{ s})$. In this paper the relation of the Schwinger force (for the vacuum creation of the $e^+e^-$ pairs to the Planck, Yukawa and Bohr force was obtained. With the LASERTRON pulses the electron-positron structure of space-time can be investigated.
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