BULETINUL Universităţii Petrol – Gaze din Ploieşti	Vol. LXII No. 1/2010	41 - 45	Seria Matematică - Informatică - Fizică

The Parameters of Vacuum Modeled as an e-p Plasma

Ion Simaciu, Zoltan Borsos

Petroleum – Gas University of Ploiesti, Physics Department, Bd. Bucuresti, 39, Ploiesti, Romania
email: isimaciu@yahoo.com, borsos.zoltan@gmail.com

Abstract

In this paper we evaluate the physical quantities characterizing the e-p (electron-positron) plasma: the components mass, m_a, $m_{e\upsilon} = m_{p\upsilon}$, *the positronium atoms proper frequency* ω_0, *the internal permittivity* ε_υ, *the internal permeability* μ_υ, *the temperature* T_0, *the degree of ionization* f_0 *and the pressure* p_0. *Although the thermal motion of the vacuum components is comparable with the light speed* c_0, *these speeds are much lower than the limit speed in vacuum -* $c = c_0\alpha_e^{-2} >> c_0$ *- and, consequently, the relativistic effects are negligible at the internal temperature* T_0.

Keywords: *e-p plasma, positronium atom, Maxwell distribution*

Introduction

In this paper, that is a second part of the paper „Optical Properties of Vacuum Modeled as e-p Plasma" [9], we propose to evaluate the physical quantities characterizing the e-p (electron-positron) plasma: the components mass, m_a, $m_{e\upsilon} = m_{p\upsilon}$, the positronium atoms proper frequency ω_0, the internal permittivity ε_υ, the internal permeability μ_υ, the temperature T_0, the degree of ionization f_0 and the pressure p_0.

To do this evaluation we use the relations among these fundamental physical quantities and sizes, using the proposed model from the first paper [9].

The Evaluation of the Vacuum Components Parameters

Since the ionization degree is small, the electrical and magnetic properties of the vacuum are determined by the positronium fluid, $N_a \cong N_0$.

The fundamental property of vacuum is determined by the equality between the relative permittivity and the relative permeability [9, 1, 2, 4, 5, 7, 8 and 10]. The relative permeability of fluid atoms is [3, p. 725]

$$\mu = \mu_0 g_a^2 j_a \left(j_a + 1 \right) \frac{\mu_{BP}^2 \mu_\upsilon N_0}{3kT_0}. \tag{1}$$

The positronium has two states, in terms of total angular momentum, on ground state ($l = 0$): the zero spin state (parapositronium) and the nonzero spin state ($s = 1$, orthopositronium) [6, p. 398]. At temperature T_0 the most atoms are in ortho state and therefore the total angular momentum is given by the spin moment. In the ground state ($l = 0$) for orthopositronium $j_a = 1$ and $g_a = 2$. If the Bohr - Procopiu magneton is $\mu_{BP} = q\hbar/(2m_{e\upsilon})$ according to the electrons mass from vacuum, $c = c_0(\varepsilon_\upsilon\mu_\upsilon)^{-1/2}$ is the electromagnetic waves speed through the vacuum components and using $q^2/(4\pi\varepsilon_\upsilon\varepsilon_0) = e^2/\varepsilon_\upsilon$ the equation (1) becomes

$$\mu = \frac{8\pi e^2\hbar^2 N_0}{3m_{e\upsilon}^2 c^2 kT_0\varepsilon_\upsilon}. \tag{2}$$

According to equation (9) from paper [9], the relative permittivity of vacuum is, for $\omega << \omega_0$ and $f_0 << 1$,

$$\varepsilon_{0r} = \frac{4\pi e^2 N_0}{m_{e\upsilon}\omega_0^2\varepsilon_\upsilon} = 1. \tag{3}$$

From the equality of the these relative permittivities, results

$$(\hbar\omega_0)^2 = \frac{3}{2}m_{e\upsilon}c^2 kT_0. \tag{4}$$

The equation (4), together with the proportionality condition of the plasma temperature with the components mass

$$kT_0 = \frac{m_a c_0^2}{2s}, \tag{5}$$

leads to the equality

$$(\hbar\omega_0)^2 = \frac{3}{4s}m_{e\upsilon}m_a c^2 c_0^2. \tag{6}$$

From the quantum model of positronium [6], results that: the energy in the ground state, neglecting the increase of energy by passing into the ortho state, $\Delta E = (7\alpha_e^2 E_0/3) << E_0$, is

$$E_0 = -\frac{e^4 m_{e\upsilon}}{4\hbar^2\varepsilon_\upsilon^2}; \tag{7}$$

the proper frequency is

$$\omega_0 = \frac{e^4 m_{e\upsilon}}{2\hbar^3\varepsilon_\upsilon^2} = -\frac{2E_0}{\hbar}; \tag{8}$$

the orbital radius is

$$a = \frac{\hbar^2\varepsilon_\upsilon}{e^2 m_{e\upsilon}} \tag{9}$$

and positronium atom mass, neglecting special relativistic effects, is

$$m_a = 2m_{e\upsilon} + \frac{E_c}{c^2} \cong 2m_{e\upsilon}. \tag{10}$$

The ionization energy of the positronium is

$$E_I = E_\infty - E_0 = \frac{e^4 m_{e\upsilon}}{4\hbar^2 \varepsilon_\upsilon^2}\,. \tag{11}$$

The ionization energy must be equal to the energy generation of e-p pairs

$$E_I = 2 m_{e0} c_0^2 = \frac{e^4 m_{e\upsilon}}{4\hbar^2 \varepsilon_\upsilon^2}\,. \tag{12}$$

From relations (11, 12) and (8) yields a frequency proportional with the Compton frequency ω_C

$$\omega_0 = \frac{4 m_{e0} c_0^2}{\hbar} = 4\omega_C\,. \tag{13}$$

From relations (6, 10) and (13), results

$$m_{e\upsilon} = 4\left(\frac{2s}{3}\right)^{1/2} m_{e0}\varepsilon_\upsilon\,. \tag{14}$$

From relations (12) and (14), results

$$\varepsilon_\upsilon = \left(\frac{s}{6}\right)^{1/2}\left(\frac{e^2}{\hbar c_0}\right)^2 = \left(\frac{s}{6}\right)^{1/2}\alpha_e^2 << 1\,,\ \text{so}\ c = \frac{c_0}{\varepsilon_\upsilon} >> c_0\,. \tag{15}$$

Substituting equation (15) in (14), results

$$m_{e\upsilon} = \left(\frac{4s}{3}\right)\alpha_e^2 m_{e0} << m_{e0} \tag{16}$$

and

$$m_a \cong 2 m_{e\upsilon} = \frac{8s}{3}\alpha_e^2 m_{e0} << m_{e0}\,, \tag{17}$$

i.e. the positronium mass is much smaller than the electron rest mass.

The Evaluation of the e-p Plasma Parameters

Knowing that the vacuum electron mass given by (16), from relations (5) and (10) results the vacuum equivalent temperature away from substance

$$T_0 = \frac{m_{e\upsilon} c_0^2}{sk} = \frac{4}{3}\alpha_e^2 \frac{m_{e0} c_0^2}{k} \cong 10^6\,\mathrm{K}\,. \tag{18}$$

To evaluate the plasma e-p concentration N_0 and the ionization coefficient f_0 the following steps can be used.

From relations (3), (13), (15) and (16) with $\varepsilon_{0r} = 1$, results

$$N_0 = \frac{m_{e\upsilon}\omega_0^2 \varepsilon_\upsilon}{4\pi e^2} = \left(\frac{128 s^3}{27\pi^2}\right)^{1/2}\alpha_e^3 \left(\frac{m_{e0} c_0}{\hbar}\right)^3\,. \tag{19}$$

For both, isothermal compression ($s = 1$) and adiabatic ($s = 5/3$), results a high value for the components concentration

$$N_0 \cong 10^{32}\,\mathrm{m}^{-3}\,. \tag{20}$$

The ionization degree expression for plasma, away from the substance f_0, is deduced using equation (17) from [9], where the following quantities: $m_{e\upsilon}$, T_0, N_0 and E_I are replaced

$$f_0 \cong \left(\frac{m_{e\upsilon}}{2\pi\hbar^2}\right)^{3/4} \left(kT_0\right)^{3/4} \left(\frac{kT_0}{p_0}\right)^{1/2} \exp\left(\frac{-E_I}{kT_0}\right) = \\ \left(\frac{m_{e\upsilon}kT_0}{2\pi\hbar^2}\right)^{3/4} N_0^{-1/2} \exp\left(\frac{-E_I}{kT_0}\right) = \frac{1}{2^{1/2}3^{3/4}\pi^{1/4}} \alpha_e^{3/2} \exp\left(-\frac{3}{4\alpha_e^2}\right) << 1. \tag{21}$$

The expression and the amount of vacuum pressure, away from substance, for this very low degree of ionization, it follows to be, using equation (14) of paper [9],

$$p_0 = N_0 kT_0 = \frac{32s}{9\pi} \alpha_e^5 \frac{m_{e\upsilon}^4 c_0^5}{\hbar} \cong 10^{15} \ \mathrm{Nm}^{-2}. \tag{22}$$

The parameters values for positronium fluid maintain the original assumptions. Thus, at temperature T_0 and pressure p_0, the ionization coefficient f_0 is very small because E_I is higher than the energy kT_0. The fluid is found predominantly in the ortho state because the difference between ortho state and para state energy $\Delta E = \left(7\alpha_e^2 E_0\right)/3 = \left(14\alpha_e^2 m_{e0} c_0^2\right)/3$, is comparable with the average energy per degree of freedom, $\left(kT_0\right)/2 = \left(2\alpha_e^2 m_{e0} c_0^2\right)/3$.

Taking a Maxwell type distribution for positronium fluid, their thermal velocity is

$$\upsilon_{T_0} = \left(\overline{\upsilon^2}\right)^{1/2} = \left(\frac{3kT_0}{m_a}\right)^{1/2} = c_0 \left(\frac{3}{2s}\right)^{1/2} \tag{23}$$

and the most probable speed

$$\upsilon_{p_0} = \left(\frac{2kT_0}{m_a}\right)^{1/2} = c_0 \left(\frac{1}{s}\right)^{1/2}. \tag{24}$$

For both, isothermal compression ($s = 1$) and adiabatic ($s = 5/3$), these speeds are close to c_0.

Although the thermal motion speed of vacuum components is comparable with c_0, these speeds are much lower than the speed limit in vacuum - $c = c_0 \alpha_e^{-2} >> c_0$ - and so the internal relativistic effects are negligible at temperature T_0.

Conclusions

The e-p plasma model for physical vacuum involves both the dependencies of the vacuum parameters in interaction with microscopic and macroscopic systems and the correlation of the components parameters (positrons, electrons and bounded systems - positronium atoms) with the plasma parameters.

For this model, as results, three conditions are imposed: to establish the equality between the relative permittivity and the relative permeability (an observable fundamental property), the positronium atom ionization energy to be equal with the pairs generation energy and the theory must be non-relativistic, i.e., the components speeds are smaller than the maximum speed of the interactions propagation between the components of the plasma.

With these conditions are determined: the mass of free electron and free positron $m_{e\upsilon}$ that is much smaller than the electron mass m_{e0}, see equation (16), the positronium atom mass $m_{a\upsilon}$, the speed of interactions propagation between the plasma components c, see equation (15), that is higher than the speed light c_0 (the maximum speed of the interactions propagation between the components of the substance).

The same conditions lead to a very small ionization degree, according to equation (21), and a very high plasma density or pressure, according to relations (20) and (22). It is interesting to remark that the thermal speed and the most probable speed are close to c_0, but much smaller than c, as relations (23) and (24), i.e., the plasma is non-relativistic.

We believe that these results validate the model and it can be used to evaluate the optical parameters of vacuum modeled as e-p plasma for a compression in the gravitational field at high field intensities.

References

1. Dicke, R.H. - Gravitation without a Principle of Equivalance, *Reviews of Modern Physics* 29, p. 363, 1957
1. Evens, J., Nandi, K., Islam A. - The Optical-Mechanical Analogy in General Relativity: Exact Newtonian Forms for the Equations of Motion of Particles and Photons, *General Relativity and Gravitation,* 28, p. 413, 1996
2. Feynman, R. - *Fizica modernă, vol. II, Electromagnetism. Structura materiei*, Editura Tehnică, Bucureşti, 1970
3. Gordon, W. - Zur Lichtfortpflanzung nach der Relativitätstheorie, *Annalen der Physik,* 72, p. 421, 1923
4. Jackson, J.D. - *Electrodinamica Clasică*, v. I, II, Editura Tehnică, Bucureşti, 1991
5. Lifchitz, E., Pitayevski, L. - *Théorie quantique relativiste*, Prémier Partie, Éditions Mir, Moscou, 1973
6. Simaciu, I., Ionescu-Pallas, N. - A Covariant Approach to the Gravitational Refractive Index, *Anales de Fisica* 92, No. 2, pp. 66-70, 1996
7. Simaciu, I., Ciubotariu, C. - Radiation - medium - curvature - interaction, *Indian Journal of Theoretical Physics* 41, p. 129, 1993
8. Simaciu. I. - Optical proprieties of Vacuum Modelled as e-p Plasma, *Petroleum–Gas University of Ploieşti Bulletin, Mathematics – Informatics – Physics Series,* Vol. LXI, No. 2, pp. 99-105, 2009
9. Wilson, H.A. - An Electromagnetic Theory of Gravitation, *Physics Review* 17, p. 54, 1921

Parametrii vacuumului modelat ca o plasmă e-p

Rezumat

În această lucrare evaluăm mărimile fizice ce caracterizează plasma e-p: masa componentelor $m_a, m_{e\upsilon} = m_{p\upsilon}$, *pulsația proprie a atomilor de pozitroniul* ω_0, *permitivitatea internă* ε_υ, *permeabilitatea internă* μ_υ, *temperatura* T_0, *gradul de ionizare* f_0 *şi presiunea* p_0. *Deşi mişcarea termică a componentelor vacuumului se face cu viteze comparabile cu* c_0, *aceste viteze sunt mult mai mici decât viteza limită în vacuum -* $c = c_0\alpha_e^{-2} >> c_0$ *- şi deci efectele relativiste interne sunt neglijabile la temperatura* T_0.