A New Form of Matter-Antimatter Transformation

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A new form of matter-antimatter transformation is described in this work. The transformation of matter into cold neutral antimatter (low-energy antimatter atoms) is achieved simply by means of the application of an ultra strong magnetic field upon the matter.

Key words: Antimatter, Cold neutral antimatter, Low-energy antimatter atoms, Imaginary mass.

1. Introduction

Antimatter in the form of individual anti-particles is usually produced by particle accelerators and in some types of radioactive decay. However, Antimatter in the form of anti-atoms is one of the most difficult substances to produce.

In 1995, CERN said that they had created 9 antihydrogen atoms. The experiment was performed using the Low Energy Antiproton Ring (LEAR). The Fermilab soon confirmed the CERN findings by producing 100 antihydrogen atoms at their laboratories. The antihydrogen atoms produced were extremely energetic ("hot") and were not well suited to experimental study. In 2002 the ATHENA project announced that they had created the world's first "cold" antihydrogen [1]. The ATRAP project produced similar results some time later [2].

In 2010, the ALPHA collaboration announced that they had so trapped 38 antihydrogen atoms for about 1/6 *s*. [3, 4]. This was the first time that *neutral antimatter* had been trapped. On 2011, ALPHA said that they had trapped 309 antihydrogen atoms during approximately 1,000 seconds. This was longer than neutral antimatter had ever been trapped before [5, 6]. ALPHA has used these trapped atoms to initiate research into the spectral properties of the antihydrogen [7].

In all these cases, it was required more energy for the generation of the antimatter than that it would be possible to obtain with the annihilation of the antimatter produced, in the annihilation antimatter/matter process.

Here we describe a new form of matter transformation into *cold neutral antimatter* (low-energy antimatter atoms).

2. Theory

In a previous paper, we have shown that *photons* have *non-null imaginary masses*, given by

$$m_{i(photon)} = \frac{2}{\sqrt{3}}\left(\frac{hf}{c^2}\right)i; \left(imaginary \;\; inertial \;\; mass\right)$$

$$m_{g(photon)} = \frac{4}{\sqrt{3}}\left(\frac{hf}{c^2}\right)i; \left(imaginary \; gravitational \;\; mass\right)$$

where f is the frequency of the photons and c the speed of light.

In the derivation of these expressions, it was assumed that the *momentum*, p, carried out by a photon is expressed by the well-known equation $p = h/\lambda = hf/c$. However, recently we have discovered that this equation is an *approximated expression*, valid only in the case of $f >> f_0$ (f_0 is a *limit frequency*, whose value is approximately equal to 10Hz). The complete expression for the *momentum* carried out by the *photon* is given by [8]

$$p = \left(1 - \frac{f_0}{2f}\right)\frac{hf}{c} = \left[1 - \frac{hf/V_{photon}}{2hf_0/V_{photon}}\left(\frac{f_0}{f}\right)^2\right]\frac{hf}{c} =$$

$$= \left[1 - \frac{W}{2W_0}\left(\frac{f_0}{f}\right)^2\right]\frac{hf}{c} \qquad (1)$$

where V_{photon} is the volume of the photon; W is the density of the electromagnetic energy inside the photon and W_0 is the density of electromagnetic energy correspondent to the energy hf_0 in the volume V_{photon}.

Starting from this new expression for p, the calculations shows (See ref. [8]) that the imaginary inertial mass and the imaginary gravitational mass of the photon are respectively expressed by

$$m_{i(photon)} = \frac{2}{\sqrt{3}}\left[1-\frac{W}{2W_0}\left(\frac{f_0}{f}\right)^2\right]\left(\frac{hf}{c^2}\right)i \qquad (2)$$

$$m_{g(photon)} = \frac{4}{\sqrt{3}}\left[1-\frac{W}{2W_0}\left(\frac{f_0}{f}\right)^2\right]\left(\frac{hf}{c^2}\right)i \qquad (3)$$

On the other hand, since $m_{i(photon)} = m_{i(photon)\ real} + m_{i(photon)\ imaginary}$ and $m_{i(photon)\ real} = 0$, we can conclude that $m_{i(photon)} = m_{i(photon)\ imaginary}$. Thus, Eq. (2) can be rewritten as follows

$$m_{i(photon)\ imaginary} = \frac{2}{\sqrt{3}}\left[1-\frac{W}{2W_0}\left(\frac{f_0}{f}\right)^2\right]\left(\frac{hf}{c^2}\right)i \qquad (4)$$

In the particular case of photons with frequency f_e produced by the annihilation of a par electron/positron, where we have $hf_e = m_{i0e\ real}\,c^2$ and $m_{i0e\ imaginary} = -m_{i(photon)\ imaginary}$ (See ref. [9]), we can write that

$$m_{i0e\ imaginary} = -\frac{2}{\sqrt{3}}\left[1-\frac{W}{2W_0}\left(\frac{f_0}{f}\right)^2\right]\left(\frac{hf_e}{c^2}\right)i =$$
$$= -\frac{2}{\sqrt{3}}\left[1-\frac{W}{2W_0}\left(\frac{f_0}{f}\right)^2\right]m_{i0e\ real}\ i \qquad (5)$$

where W is now the density of *external electromagnetic energy inside the electron*; W_0 is the density of energy correspondent to the energy hf_0 in the volume of the electron. Note that Eq. (5) can be generalized for protons, neutrons, etc.

For $W = 0$, Eq. (5) reduces to

$$m_{i0e\ imaginary} = -\frac{2}{\sqrt{3}}m_{i0e\ real}\ i \qquad (6)$$

Substitution of the well-known expression: $W = \frac{1}{2}\varepsilon_0 E^2 + \frac{1}{2}\mu_0 H^2 = B^2/\mu_0$ into Eq. (5) gives

$$m_{i0e\ imaginary} = -\frac{2}{\sqrt{3}}\left[1-\frac{B^2}{2\mu_0 W_0}\left(\frac{f_0}{f}\right)^2\right]m_{i0e\ real}\ i \qquad (7)$$

where B (in Tesla) is the intensity of the magnetic field inside the electron.

Previously, it was shown that the electric charge, q, can be expressed by the following equation

$$q = \sqrt{4\pi\varepsilon_0 G}\ m_{g\ imaginary}\ i =$$
$$= \sqrt{4\pi\varepsilon_0 G}\ \chi\ m_{i0\ imaginary}\ i \qquad (8)$$

where χ is the correlation factor between gravitational mass and inertial mass [9].

In the particular case of the electron, we have

$$q_e = \sqrt{4\pi\varepsilon_0 G}\ \chi_e m_{i0e\ imaginary}\ i \qquad (9)$$

where $\chi_e = -1.8\times10^{21}$ [9].

Substitution of Eq. (6) into Eq. (9) yields

$$q_e = \sqrt{4\pi\varepsilon_0 G}\ \chi_e\left(-\frac{2}{\sqrt{3}}m_{i0e\ real}\ i\right)i =$$
$$= \sqrt{4\pi\varepsilon_0 G}\ \chi_e\left(\frac{2}{\sqrt{3}}\right)m_{i0e\ real} = -1.6\times10^{-19}C \qquad (10)$$

Substitution of Eq. (7) into Eq. (8) gives

$$q_e = \sqrt{4\pi\varepsilon_0 G}\ \chi_e\left(\frac{2}{\sqrt{3}}\right)\left[1-\frac{B^2}{2\mu_0 W_0}\left(\frac{f_0}{f}\right)^2\right]m_{i0e\ real} \qquad (11)$$

Note that for $\left[1-\frac{B^2}{2\mu_0 W_0}\left(\frac{f_0}{f}\right)^2\right] = -1$ the electron charge becomes

$$q_e = -\sqrt{4\pi\varepsilon_0 G}\;\chi_e\left(\frac{2}{\sqrt{3}}\right)m_{i0e\ real} =$$

$$= +1.6\times10^{-19}C \qquad (13)$$

A possible interpretation for this fact is that, under these circumstances, *the electron becomes a positron*.

It is easy to show that, also for $\left[1-\frac{B^2}{2\mu_0 W_0}\left(\frac{f_0}{f}\right)^2\right] = -1$ the proton becomes an *anti-proton*, and the neutron becomes an *anti-neutron*.

Assuming that the electron is a sphere with radius r_e and surface charge $-e$, and that *at an atomic orbit* its total energy $E \cong m_{e0}c^2$ (m_{e0} is the rest inertial mass of the electron) is equal to the potential electrostatic energy of the surface charge, $E_{pot} = e^2/8\pi\varepsilon_0 r$ [10], then these conditions determine the radius $r \equiv r_e$: $r_e = e^2/2.4\pi\varepsilon_0\, m_{e0}c^2 \cong 1.4\times10^{-15}m$ *, which is equal to the radii of the protons and neutrons. Consequently, we can assume that electrons, protons and neutrons *in the atom* have the same value for W_0, i.e., $W_0 = hf_0/\frac{4}{3}\pi\; r_e^3 \cong 10^{12}\; joules.m^{-3}$. This means that, it is necessary by applying a magnetic field with intensity:

$$B = (2f/f_0)\sqrt{\mu_0 W_0} \cong 2{,}242(f/f_0)\;Tesla \qquad (14)$$

through the neutral matter in order to transform it into *neutral antimatter*. It is important to note that, for $B > (2f/f_0)\sqrt{\mu_0 W_0}$ the transformation does not occur. Therefore, $B = (2f/f_0)\sqrt{\mu_0 W_0}$ is a *critical value* in order to transform the matter into antimatter.

Note that for $f = 0.5Hz$ the value of B reduces to $\sim 112\;Tesla$.

In 1999, the National High Magnetic Field Laboratory (USA) announced that they had created a *45 tesla* magnet [13]. This is the strongest *continuous* magnetic field yet produced in a laboratory. Posteriorly, in 2010, they had created a *36 tesla* resistive magnet [14]. This is the strongest *continuous* magnetic field produced by *non-superconductive resistive magnet*. In 2012 Researchers of the National High Magnetic Field Laboratory and the Los Alamos National Laboratory, USA reach world-record 100.75 Tesla magnetic field (pulsed) [15].

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* The radius of the electron depends on the circumstances (energy, interaction, etc) in which it is measured. This is because its structure is easily deformable. For example, the radius of a *free electron* is of the order of $10^{-13}m$ [11], when accelerated to 1GeV total energy it has a radius of $0.9\times10^{-16}m$ [12].

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