Conjectured Transient Release Of Zero Point Vacuum Energy In Powerful Electric Discharges

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Abstract I present the hypothesis that the unexplained large longitudinal stresses observed along the path of powerful electric discharges are caused by the transient release of zero point vacuum energy, very much as in Schwinger's theory of sonoluminescence, but it may also explain the emission of multi-keV X-rays in exploding wires.

1 Introduction

Over the years a number of authors have made the claim that strong forces are acting in the direction of the current in powerful electric discharges. These forces are difficult to explain by the Biot-Savart law of classical electrodynamics, but can quite well be modeled with the Ampere force law of pre-Maxwell electrodynamics [1–3]. To support this claim forces observed in electric discharges through thin wires or fibers and non-conducting liquids are quoted. Experiments by Nasilowski [4], and by Lochte-Holtgreven [5], have shown that thin wires or fibers fracture into small solid pieces before they could have been vaporized by the electric current.

As shown (Fig. 1) in a photograph taken from a paper by Graneau and Graneau [6], and in Fig. 2 taken from the paper by Lochte-Holtgreven [5], the fracturing of the wires appears at irregular distances, suggesting that it occurs at the randomly distributed weak points of the wires.

Because the outcome of these experiments can be modeled by the Ampere force law, and because this law, unlike the Biot-Savart law (which can be derived from the Lorentz force law), is in violation of special relativity, Rambaut and Vigier [7, 8] have tried to derive the Ampere force law from

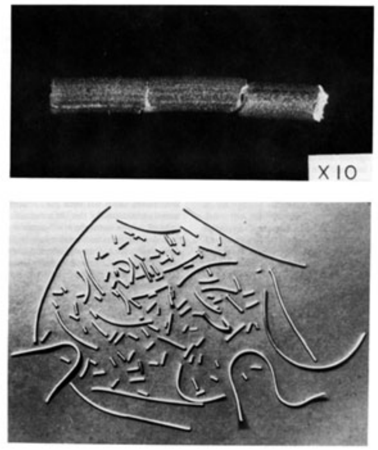

Figure 1:

Figure 2:

the Lorentz force law by a statistical average over the stochastically distributed electron trajectories inside the conductor. Unfortunately it seems, no experiments have been carried with superconductors where such an averaging procedure would not work, because the current carrying electrons are there highly correlated, moving parallel to each other in the direction of the current.

Longitudinal Ampere forces have also been claimed to occur in water arc explosions, where Früngel [9], and Graneau and Graneau [2], have observed a rapid rise of the water pressure up to 50,000 atm, with little water heating, difficult to explain with a hot steam model.

In this communication I propose a radically different explanation for these phenomena which takes a clue from Schwinger's [10] attempt to explain the poorly understood phenomenon of sonoluminescence as a "squeezing out" of zero point vacuum energy during the collapse of a bubble in a dielectric, in particular, in water.

2 Schwinger's theory of sonoluminescence and the equation of state for the zero point vacuum energy

Schwinger [10] had shown that the zero point energy density u in a dielectric relative to the zero point energy density of the vacuum is

$$u = -\int \frac{d\mathbf{k}}{(2\pi)^3} \frac{1}{2} (\hbar c)\, k \left(1 - \frac{1}{\sqrt{\varepsilon}}\right) \tag{1}$$

where ε is the dielectric constant.

The equation of state for the vacuum energy follows from the first law of thermodynamics for an adiabatic change

$$\mathrm{d}Q = \mathrm{d}\,(uV) + p\mathrm{d}V = 0 \tag{2}$$

where u is the energy density, V the volume and p the pressure, hence

$$u\mathrm{d}V + V\mathrm{d}u + p\mathrm{d}V = 0 \tag{3}$$

Because of Heisenberg's uncertainty principle the zero point vacuum energy density does not change with the volume V, which means that $\mathrm{d}u/\mathrm{d}V = 0$, whereby

$$p = -u \tag{4}$$

is the equation of state for the zero point vacuum energy. Hence, if in (1) u is negative, then $p = -u$ is positive and vice versa. The equation of state for the vacuum energy is of fundamental importance in cosmology for models of expanding universes described by the general theory of relativity [11]. While for $\varepsilon > 1$, as in water at optical frequencies, u is negative and p positive, it is the reverse for a bubble immersed in water.

In sonoluminescence intense sound waves in water create small bubbles by cavitation, which in the course of their collapse become the source of blue light. According to Schwinger [10] it is the sudden disappearance of the bubbles through their collapse that the positive zero point energy inside the bubbles is released as a flash of light.

Without dispersion ε is constant, and with $\mathrm{d}\mathbf{k} = 4\pi k^2 \, \mathrm{d}k$ one obtains from (1) that inside a bubble

$$\begin{aligned} u &= \frac{\hbar c}{2\pi^2} \int_0^{k_{\max}} k^3 \left[1 - \frac{1}{\sqrt{\varepsilon}}\right] \mathrm{d}k \\ &= \frac{\hbar c k_{\max}^4}{8\pi^2} \left[1 - \frac{1}{\sqrt{\varepsilon}}\right] > 0 \end{aligned} \tag{5}$$

Making the choice $\sqrt{\varepsilon} = 4/3$ for the refractive index of water, and for $k_{\max} \simeq 3 \times 10^5 \ \mathrm{cm}^{-1}$, with the cut-off frequency in water $\omega_{\max} = c k_{\max} \simeq 10^{16} \ \mathrm{s}^{-1}$, about equal to the water plasma frequency, but also about equal the frequency above which light in water is absorbed, one obtains $u \simeq 10^3 \ \mathrm{erg/cm}^3$, sufficient to explain sonoluminescence.

The difference between the static (Casimir effect) zero point energy, and the dynamic release of zero point energy conjectured by Schwinger [10] must here be emphasized. Whereas the static (Casimir) effect is small, this would not be true for the dynamic effect, lasting though only for a short moment.

In sonoluminescence mechanical energy on a macroscopic scale is transformed into electromagnetic energy on a microscopic scale. As Schwinger [10] has conjectured, the opposite might be possible as well: The conversion of electromagnetic energy in the small into mechanical energy on a macroscopic scale.

3 The occurrence of negative zero point energy pressure in electric discharges

We now turn to the above quoted experiments by Nasilowski [4] and Lochte-Holtgreven [5], which show the fragmentation of thin wires or fibers into small solid segments, as if a negative pressure had acted on the wires or fibers.

For frequencies above the electron plasma frequency one has $\varepsilon < 1$, with ε given through the dispersion relation of electromagnetic waves by

$$\varepsilon = \left(1 + \frac{\omega_p^2}{c^2 k^2}\right)^{-1} , \tag{6}$$

where ω_p is the plasma frequency. Inserting (6) into (5) one obtains in the moment of the current pause, the moment where the current is interrupted by the depletion of the conduction electrons,

$$u = \frac{\hbar c}{2\pi^2} \int_0^{k_{\max}} k^3 \left[\sqrt{1 + \frac{\omega_p^2}{c^2 k^2}} - 1\right] \mathrm{d}k \, . \tag{7}$$

The overwhelming contribution from this integral comes from regions where $ck \to \omega_p$, and one can with sufficient accuracy expand the square root in (7), obtaining

$$\begin{aligned} u &= \frac{\hbar c}{2\pi^2} \int_0^{k_{\max}} k^3 \frac{1}{2} \frac{\omega_p^2}{c^2 k^2} \, dk \\ &= \frac{1}{4\pi^2} \frac{\hbar \omega_p^2}{c} \int_0^{k_{\max}} k \, \mathrm{d}k \\ &= \frac{\hbar \omega_p^2}{8\pi^2 c} k_{\max}^2 \end{aligned} \tag{8}$$

Because u is here positive, $p = -u$ is negative. For $k_{\max}$ we set

$$k_{\max} \simeq \frac{Z}{r_B} , \qquad r_B = \frac{\hbar^2}{mc^2} = 0.5 \times 10^{-8} \text{ cm} \tag{9}$$

which means that the smallest wave length for which (6) is valid, is by order magnitude equal to the radius of the innermost electron orbit around a Z times charged atomic nucleus.

We remark, that the assumed transparency with regard to the X-rays is especially true for thin wires and the large wave numbers towards which u peaks. For iron wires $Z = 26$, and $k_{\max} \simeq 5 \times 10^9$ cm^{-1}. With $\omega_p \simeq 10^{16}$ s^{-1}, one finds that $u \simeq 10^{12}$ erg/cm^3 and $p \simeq -10^{12}$ dyn/cm^2 $\simeq -10^6$ atmospheres, sufficiently strong to break iron which has a tensile strength of

$\sigma \simeq 10^{10}$ dyn/cm^2. For uranium with $Z = 92$, the energy density is $u \simeq 10^{13}$ erg/cm^3, and the pressure $p \simeq -10^{13}$ dyn/cm^2 $\simeq -10^7$ atmospheres.

This then might be an example for the conjectured conversion of electromagnetic energy into mechanical energy, conjectured by Schwinger [10] through the intermediate transient conversion of the electromagnetic energy into zero point vacuum energy.

4 Water arc explosions

A phenomenon conceivably related to the mechanical breakup of wires may be the observed large pressures in water arc explosions. As we had mentioned above, these pressures are difficult to explain with a hot steam model.

In water arc explosions breakdown begins in a small channel by the streamer mechanism, which resembles the discharge through a thin wire or fiber. Therefore here too, the same transformation of electromagnetic energy into zero point energy, and from there into mechanical energy seems plausible. Applying the equations (8-9) for water with $Z = 8$ one obtains $u \simeq -10^{11}$ dyn/cm^2, which is here negative because the discharge channel acts like a cylindrical bubble, therefore $p \simeq 10^{11}$ dyn/cm^2 $\simeq 100,000$ atmospheres, of the same order of magnitude as the 50,000 atmospheres measured by Früngel [9].

5 Anomalous X-Ray Emission By Exploding Wires

Electric pulse power driven metallic wire explosions are known to be the source of intense X-rays, but which are difficult to explain solely with resistive heating of the wires. Magnetically imploding an array of many wires has shown that the energy released as X-rays is there more than twice as large as the kinetic energy of the magnetically accelerated wires, upon mutual impact converting their kinetic energy into blackbody radiation [12]. Of course it is clear that the energy emitted as X-rays must come from the radially inward directed component of the Poynting vector, but a mechanism how this energy is converted into up to 100 keV X-rays is unknown. Ideas put forward suggesting that the conversion of electromagnetic energy into X-rays goes over turbulent magnetic reconnection can only give a partial explanation, with magnetohydrodynamics breaking down for wavelengths smaller than the Debye length, for an exploding wire plasma at a temperature of $T \sim 10^6$ °K, of the order $\sim 10^{-7}$ cm. Therefore, magnetic reconnection can explain keV X-ray energies, but not the much higher X-ray energies actually observed [13]. It is here where the transient release of zero point vacuum energy may offer perhaps at least a partial explanation.

Prior to the lateral disintegration of the wires into many solid fragments, the zero point energy in the wires relative to the zero point energy of the surrounding vacuum is positive. For tungsten wires, often used in these experiments, one has $Z = 74$, $k_{\max} \simeq 1.5 \times 10^{10}$ cm^{-1}, and $E_{\max} = hck_{\max} \simeq$ 100 keV, with $u \simeq 6 \times 10^{12}$ erg/cm^3. Immediately following the disintegration of the wires into solid fragments, the zero point energy positioned in the void between the suddenly created wire fragments remains unbalanced, where, as in Schwinger's theory, it is squeezed out of the vacuum and released in the form of X-rays, with a maximum energy of ~ 100 keV.

The situation is in fact quite similar to the squeezing out of vacuum energy in sonoluminescence where $\varepsilon > 1$, and where the squeezing out results from the sudden **disappearance** of a void inside a dielectric with $\varepsilon > 1$, while in exploding wires where $\varepsilon < 1$, the squeezing out results from the sudden **appearance** of a void in between unbroken segments of the wire.

6 Lowering the Coulomb barrier for nuclear fusion

The need for high temperatures in thermonuclear fusion is dictated by the height and width of the Coulomb barrier. In muon catalyzed fusion the width of the barrier is lowered by the smaller Bohr radius for the larger muon mass, reducing the width by the factor $m_\mu/m \simeq 200$ (m electron, m_μ muon mass), from $r_B \simeq 6 \times 10^{-9}$ cm (for hydrogen) to $r_B \simeq 3 \times 10^{-11}$ cm.

With Heisenberg's uncertainty principle determining both the magnitude of the zero point energy and the Bohr radius, a transient reduction of the zero point energy in a dielectric medium must be equivalent to a transient change of $\hbar$. With u given by (4) as the difference in the zero point energy in between the dielectric and its surrounding, this means that a negative value of u implies a reduction in the zero point energy, and with it a reduction of the Coulomb force. In classical electrodynamics this corresponds to a reduction of the Coulomb force from $F = e^2/r^2$ to $F' = e^2/\varepsilon r^2$, with $F' < F$ for $\varepsilon > 1$. In a bubble or void embedded in a medium with $\varepsilon > 1$, one has there $\varepsilon < 1$ and $F' > F$. For most substances $\varepsilon > 1$ if $\omega << \omega_p$, but if $\omega >> \omega_p$ one has $\varepsilon < 1$, with u positive, where in a void u is negative.

The foregoing suggests to enhance the nuclear fusion reaction rate by placing the fusion fuel in metallic capillars made up of high Z material. Choosing $Z = 92$, one finds a reduced Bohr radius equal to $r_B/Z = 6 \times 10^{-11}$ cm, about twice as large as the muon atom Bohr radius, reducing the width of the Coulomb barrier 100 fold, not 200 fold as for muon catalyzed fusion, but still large enough to greatly enhance the fusion reaction rate. However, since the change in the zero point energy is a transient phenomenon, it can only last a short fraction of the time the high current discharge lasts, prior to the transformation of the capillar containing the fusion fuel into a hot plasma.

There seems to be some experimental evidence for something like this to happen in electric discharges where nuclear reactions in heavy elements are reported to have been observed under conditions where such reactions are not expected to occur [14–16]. Finally, there is evidence for DD nuclear reactions in sonoluminescence [17], speaking in favor of Schwinger's original conjecture.

7 Conclusion

Sonoluminescence, explained by Schwinger as a transient release of zero point vacuum energy is a rather feeble effect, the main reason the limitation in the intensity of the stimulating sound waves. By contrast, the conjectured inverse of this effect, stimulated by powerful electric discharges should be by orders of magnitude larger, and could be verified or disproved by rather inexpensive experiments. If proved to be true, this would without any doubt be of great importance.

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