change can be compared with the red shifts of all the quanta (right and left polarized) in the main static field of the earth, measured by Pound and Rebka,

$$\frac{1}{\omega}\frac{d\omega}{dx} = \frac{g}{c^2} = 10^{-18}\ \mathrm{cm}^{-1}$$

For quanta with energy 14 keV and frequency $4 \times 10^{18}$ cps, the change in frequency is 4 cps/cm and the influence of the spin (circular polarization) of hard quanta is immeasurably small. For a proton the influence of the direction of the spin on its weight, due to the earth's rotation, is of the order of $10^{-28}$ of the weight of the proton.

[1] G. V. Skrotskii, DAN SSSR 114, 73 (1957), Soviet Phys. Doklady 2, 226 (1958).

[1)] The gyroscope axis lies in the horizontal plane and is perpendicular to the line drawn through the center of the body, the pole, and the observer, i.e., to the beam direction.

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# ACCELERATION OF PARTICLES BY THE EDGE FIELD OF A MOVING PLASMA POINT THAT INTENSIFIES AN ELECTRIC FIELD

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It is usually assumed that quasistatic electric fields are incapable of accelerating particles to energies above the potentials employed. In this paper is shown that by means of a moving inhomogeneity, which intensifies a quasistatic electric field, it is possible under certain conditions to obtain acceleration equivalent to potentials exceeding by many times the employed potential difference.

Let us consider a very simple example of intensification of an electric field by a specially produced inhomogeneity in the medium. We assume that two plane electrodes, between which a potential difference $U_0$ is applied, produce a field of intensity $E_0$. If a conducting projection is placed on one of the electrodes, in the form of half a prolate spheroid directed along the field, then the intensity of the field reaches a maximum value in the region of the maximum curvature in an area of radius $\rho \sim b^2/a$ on the top of the spheroid

$$E_m = E_0 \frac{2e^2}{(1 - e^2)(\ln \frac{1+e}{1-e} - 2e)} = \frac{E_0}{n^{(x)}}$$

where $e = (1 - b^2/a^2)^{1/2}$ is the eccentricity of the spheroid, a and b are the major and minor semiaxes, and $n^{(x)}$ is the depolarization coefficient. In the case of a very prolate ellipsoid ($a \gg b$, $e \to 1$), we have

$$E_m \approx E_0 \frac{a^2}{b^2(\ln \frac{2a}{b} - 1)} \sim \left(\frac{a}{b}\right)^2 E_0$$

(this follows directly from the condition for the potential accumulation $E_m \rho \sim E_0 a$).

This edge intensification of the field by means of a point, a phenomenon dating back to the theories of the lightning arrester, of streamer propagation, etc., can be used effectively to accelerate particles or matter only if the front of formation of propagation of the peak of the inhomogeneity ("point") moves together with the accelerated particles. This can occur in those cases when the accelerated particles themselves constitute part of the inhomogeneity or produce it, or when the accelerated particles themselves initiate the creation of the inhomogeneities by the field itself.

Let us consider these cases in greater detail.

1. Acceleration of the particles themselves in the edge of the inhomogeneity. The inhomogeneity itself can be produced by a thin plasma jet escaping from one of the electrodes (plasma gun, spark source, laser beam focused on the electrode, etc.). Layers of matter will be detached and accelerated from the vertex of the jet, and the succeeding layer will intensify the field acting on the layer moving in front of it. The effective accelerated charge of the layer is

$$Q_{eff} \sim \sigma_{eff} \pi \rho^2 \sim E_m \rho^2$$

The equivalent potential of the particles on the path $\ell$ on which there is still no detachment of the inhomogeneity leader from the bulk mass is $U_m \approx E_m \ell \gg E_0 a$ for $\ell \gg p$.

2. Acceleration of particles producing a plasma loop. Let us assume that a particle of matter moves from one of the electrodes, leaving behind it a plasma loop (for example, as a result of heating the particle with a laser beam or ionization of the residual air by fast motion of the particle). Such a particle will be situated at all times at the vertex of a plasma point, if the field on the particle is many times stronger than the field near it, and if the plasma moving behind the particle does not strongly screen the field in the region where the particle is situated (this occurs when the particle moves sufficiently rapidly, or else when the plasma overtaking the particle is drawn out rapidly and again admits the maximum field to the surface of the particle). Then the force accelerating the particle is $F \sim E_m^2{}^2$, where is the radius of the particle. If the radius of the plasma jet is not much larger than the radius of the particle, then the energy of the particle is $W \approx E_0^2(\ell^2/b_{av}^2)$, where $\ell$ is the acceleration path. The electric pressure on the particle is

$$P_{m\ el} \approx \frac{E_m^2}{4\pi} \sim \frac{E_0^2}{4\pi} \frac{a^4}{b^4} \gg \frac{E_0^2}{4\pi}$$

This pressure can reach many thousands of atmospheres (for example, at the feasible values $E_0 \sim 10^5$ V/cm and $a/b \approx 10^2$ we obtain $p_m \approx 10^6$ atm), which can exceed the recoil pressure of the evaporation reaction or the light pressure. The particle mass lost to produce the plasma loop can be small, because of the large difference between the densities of the loop and the particles (a difference by factors of tens and hundreds of millions is possible), making this method preferable to the reactive acceleration of particles [1].

3. Acceleration of particles in a breakdown leader. It is possible to accelerate particles by directional breakdown in a gas. Let us assume that a group of fast charged particles passing through a gas with an electric field close to breakdown value produces an ionized channel, in which the breakdown of the medium begins. Conditions can be realized under which the particles initiating the breakdown will be situated for a long time in the edge field of the breakdown cascade leader. Such a method of acceleration, in devices similar to spark chambers, can apparently be effective for particles which are first accelerated to velocities at which the dissipations of the directed velocities are small, but which do not differ greatly from the velocity of propagation of the breakdown through the ionized channel.

The quadratic dependence of the accelerating force on the field intensity in the first two variants in question, and the possibility of modification of the field of the point by the properties of the gas in the third variant, make it possible to make multiple use of alternating electrodes of one high-voltage source for through-acceleration. The acceleration mode is by its nature pulsed, since nonstationary processes are used.

We note that the described acceleration mechanism can appear when electric fields are used to draw out ions from a concentrated pulse-produced plasma. It is quite possible that this mechanism plays an essential role in the observed[2,3] effect of appearance of fast ions on application of an electric field to a plasma of a hot vacuum spark. The efficiency of appearance of the acceleration can depend strongly on the initial geometrical conditions, namely the dimension and the rate of spreading of the plasma jet, its compression, the limitation of the spark plasma by a dielectric tube, by magnetic fields, etc.

It must also be borne in mind that the appearance of a group of fast particles upon application of an electric field on a plasma inhomogeneity is not evidence of an initial high plasma temperature, and can be the result of electrostatic pressure of a large edge field (this will occur when $E_m^2 \gg 4\pi n_e kT_e$).

In conclusion I am grateful to Professor M. S. Rabinovich for a discussion and interest in the work.

[1] G. A. Askar'yan and E. M. Moroz, JETP 43, 2319 (1962), Soviet Phys. JETP 16, 1638 (1963).
[2] A. A. Plyuto, JETP 39, 1589 (1960), Soviet Phys. JETP 12, 1106 (1961).
[3] Plyuto, Karvalidze, and Kvartskhava, Atomnaya energiya 3, 153 (1957).

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# Q-MODULATION OF A NEODYMIUM-GLASS LASER WITH THE AID OF A PASSIVE SHUTTER

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Passive shutters, the action of which is based on the bleaching of the solutions of certain substances by a strong light field, have come recently into use for the production of giant laser radiation pulses. An advantage of a shutter of this type is the simplicity of its