gradient (EFG) with polycrystalline samples. It is known that in the presence of hyperfine magnetic interaction the quadrupole shift of the excited levels of the iron nuclei is determined by the expression

$$\Delta E_m = (-1)^{|m_I|+1/2} \frac{e^2qQ}{4} \frac{3\cos^2\theta - 1}{2},$$

where m_I is the magnetic quantum number, e the electron charge, q the gradient of the electric field acting on the nucleus, Q the quadrupole moment of the nucleus, and θ the angle between the direction of the magnetic field and the EFG axis. The change of the measured quadrupole shift of the lines in the case of spin reorientation is due to the angle multiplier. From the values of the quadrupole shift before and after the reorientation and from the value of the quadrupole splitting in the paramagnetic region, it is possible to determine, apart from the sign, the angles θ between the EFG axis and the two crystallographic directions, under the assumption that the quadrupole interaction has a weak temperature dependence. This calculation determines, in addition, the sign of the quadrupole interaction constant, since

$$3\cos^2\theta > 0. \quad (1)$$

The calculation of the angles of the EFG axis, performed from the obtained experimental data, has shown that for the ions Fe(I) the EFG axis makes an angle 49° with the [001] direction and an angle 33.5° with the [100] direction. Condition (1) is satisfied here for $e^2qQ > 0$. For the ions Fe(II) the EFG axis makes an angle of 81° with the direction [001] and an angle 29° with [100]. The condition (1) is satisfied in this case for $e^2qQ < 0$. Such a difference between the directions of the axes and magnitudes of the EFG is apparently connected mainly with the nonequivalence of the surrounding of the Fe(I) and Fe(II) ions in the second coordination sphere.

Figure 2b shows the dependence, normalized to 77°K, of a quantity proportional to the probability of the resonant absorption, estimated from the areas of the first lines of the spectra. In spite of the qualitative character of the estimate, it is seen from the figure that the probability experiences a jump in the region of the spin-reorientation temperature. Since the probability of the resonant absorption characterizes the connection between the resonant nucleus and the crystal lattice, the dependence shown in Fig. 2b offers evidence of a change of the elastic properties of the crystal lattice Fe_3BO_6 on going through the spin-orientation temperature.

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MECHANISM OF ACCELERATION OF IONS ON THE FRONT OF IONIZATION OF A GAS BY A RELATIVISTIC ELECTRON BEAM

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It was reported recently that when strong-current relativistic electron beams are injected in a gas the ions are captured and accelerated on the gas ionization front [1]. This phenomenon is of interest as one of the promising methods of producing strong-current ion accelerators in the energy region $\varepsilon_i \approx 1 - 100$ MeV and with a total number of accelerated ions in the pulse $N_i \approx 10^{14} - 10^{16}$. In a number of papers [2 - 4] there were proposed different mechanisms for accelerating ions with electron beams, claiming a qualitative description of the observed phenomena. Thus, in [2] the acceleration of the ions was attributed to their capture in a potential well on the front of the ionization of the gas by the electron beam[1]. However, the conditions that limit the ultimate vacuum current of the beam were not made concrete, making it impossible for the authors to describe correctly the dependence of the energy and of the number of accelerated ions on the electron energy. In [3] the ion acceleration is attributed to the inverse Cerenkov effect or to the "blowing-out" of the ions by the beam electrons. Such a mechanism, however, gives much too low a value of the number of accelerated ions. In [4] there was considered an induction mechanism of capture and acceleration of ions during the process of self-compression of an electron beam (pinch effect) with partial compensation of its charge by ionization of the gas. Such a mechanism is predominant in the absence of an external magnetic field and at ultrarelativistic energies of the electron beam. It is possible that this explains the good agreement between the results of [4] and certain experimental measurements [1].

We propose below a mechanism for acceleration of the ions on the front of the ionization of the gas in the presence of a strong external longitudinal magnetic field greatly exceeding the magnetic field of the beam current, and for arbitrary relativism of the electrons. We determine the conditions under which this acceleration mechanism can appear effectively.

We consider a plane ionization front moving with velocity V at a sufficiently large distance from the electron-beam injector, such that all the transient processes (including the capture of the ions on the gas ionization front) can be regarded as complete. An electron beam with current density $j_0 = en_0u$ in the ionized part of the gas moves without deceleration; the magnetic neutralization of the beam is ensured by the return current flowing in the plasma [5]. On emerging from the surface of the ionization front in the gas under the influence of the potential of the beam space charge, the electrons begin to slow down, and under conditions $u \gg V$ the slowing-down length of the electrons is equal to [6]

$$Z_0 = \sqrt{\frac{mc^3}{8\pi e j_0}} \int_1^{\gamma} \frac{dx}{(x^2 - 1)^{1/4}} \approx \sqrt{\frac{mc^3}{2\pi e j_0}} (\gamma^{2/3} - 1)^{3/4}, \tag{1}$$

where $\gamma = (1 - u^2/c^2)^{-1/2}$.

Besides deceleration there occurs in a layer with thickness $\sim Z_0$ ionization of the gas, and after a time $\sim 1/\nu$, where ν is the frequency of the ionization (ν is considered constant), the space charge is completely neutralized. This restores in the layer free motion of the beam electrons with velocity u, and the ionization front is displaced by an amount Z_0. For the velocity of the ionization front we obtain as a result

$$V = Z_0 \nu \approx \sqrt{\frac{mc^3}{2\pi e j_0}} \nu (\gamma^{2/3} - 1)^{3/4}. \tag{2}$$

[1] Analogous considerations were advanced by N. Rostoker at the International Conference in Erevan in 1969.

The capture and acceleration of the ions to the velocity V occurs in a space-charge layer, on the leading edge of which the electron density reaches a value

$$n(Z_0) = \frac{n_0 u}{V} >> n_0,$$

and an electric field

$$E \approx 4\pi e n_0 Z_0 \approx \sqrt{\frac{8\pi m j_0 c^3}{e u^2}} \quad (\gamma^{2/3} - 1)^{3/4}. \tag{3}$$

The depth of the potential well on the ionization front is in this case of the order of the electron energy lost in the space-charge layer, i.e., $e\phi \lesssim mc^2(\gamma - 1)$. Therefore the relative energy spread of the accelerated ions is

$$\eta < \frac{2\bar{z}_i mc^2}{MV^2}(\gamma - 1), \tag{4}$$

where $\bar{z}_i$ is the average charge and M is the average mass of the ions. It is obvious that the ions most effectively accelerated are those with large ratio $\bar{z}_i/M$.

Finally, assuming that the electron charge is canceled out by the captured ions in the space-charge layer, we can estimate the total number of accelerated ions

$$N_i \approx \pi r_0^2 n_0 \frac{Z_0}{\bar{z}_i} \simeq 10^{12} \frac{r_0}{\bar{z}_i} \sqrt{I_0(\gamma^{2/3} - 1)^{3/2}}, \tag{5}$$

where r_0 is the radius of the beam and I_0 is the total current of the beam in kiloamperes.

The formulas presented above are valid only under conditions when $r_0 >> Z_0 \approx u\sqrt{\gamma}/\omega_L$, where ω_L is the Langmuir frequency of the beam electrons. Only under this condition can the ionization front be regarded as plane, and the return current in the plasma cancels the magnetic field of the beam current. In addition, it follows from this condition that the total current in the beam $I_0 = \pi r_0^2 j_0$ should be larger than the vacuum limiting current [6]. On the other hand, it is obvious that it should be smaller than the critical current in the compensated beam, for otherwise as a result of the development of the electrostatic instabilities the beam becomes "locked" in the plasma [6]. Therefore the proposed mechanism of ion acceleration is effective if the critical current in the compensated beam, for a given geometry of the system, greatly exceeds the limiting vacuum current. This is possible only for a relativistic electron beam in which the ratio of the critical current to the limiting vacuum current is

$$\approx \frac{u^3}{c^3} \frac{\gamma^3}{(\gamma^{2/3} - 1)^{3/2}} >> 1.$$

In a nonrelativistic beam, this ratio equals 5 - 6.

The proposed mechanism of ion acceleration explains well a number of experimental facts [1]. For typical values $\varepsilon \simeq 1$ MeV (i.e., $\gamma = 3$), $I_0 \simeq 100$ kA, $r_0 \simeq 1$ cm, and $V \simeq 0.06$ c we obtain from formula (2) $\nu \simeq 10^9$ sec^{-1}, which is likely for gas pressures $P_0 \simeq 1$ Torr. The linear dependence of the velocity V on the gas pressure, contained in (2), is also well confirmed experimentally (in the region $P_0 \simeq 0.2 - 1$ Torr). At the indicated beam parameters, according to (2) - (5), we obtain for the energy of the accelerated hydrogen ions $\varepsilon_H \simeq 4$ MeV, for deuterium $\varepsilon_D \simeq 8$ MeV, for carbon $\varepsilon_C = 25$ MeV; their relative scatter is $\eta \simeq 5 - 20\%$, and the intensity of the electric field on the ionization front is of the order of 5×10^6 V/cm. Finally, the total number of accelerated ions $N_i \simeq 10^{13}$ (at $z_i = 2$). These estimates agree well with the experimental data [1].

The comparison with experiment indicates that the proposed mechanism of ion acceleration is realistic, and at currents $I_0 \simeq 10^6$ A and electron energies $\varepsilon \simeq 10$ MeV it uncovers the possibility of accelerating $10^{15} - 10^{16}$ ions in a pulse to energies $\varepsilon_i \simeq 30 - 100$ MeV.

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CURIE TEMPERATURE AND SUSCEPTIBILITY OF AN AMORPHOUS HEISENBERG FERROMAGNET (HIGH-TEMPERATURE EXPANSION)

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1. The number of studies of properties of amorphous ferromagnets has increased recently. A review of work on this question can be found in [1 - 3]. Experiments show that ferromagnetism is possible also without crystalline order. Theoretically this question was first posed by Gubanov [4]. This was followed by calculation of the magnetization under definite assumptions [5 - 7]. The susceptibility was determined in the molecular-field approximation [5, 8] and also for an Ising ferromagnet with the aid of thermodynamic perturbation theory for small structure fluctuations [7].

2. In the present paper we calculate the susceptibility of an amorphous Heisenberg ferromagnet with the aid of a high-temperature expansion. To this end we use the so-called "lattice" model, in which the spins are at the lattice sites and the exchange integrals (between nearest neighbors) fluctuate