$$(\gamma_0/\omega_0) >> \sqrt{1-\phi}(kr_{De})^{-3}\exp\left[-\frac{1}{2}k^{-2}r_{De}^{-2}\right]$$

and by relation (11). In the case $E \ll E_T$ this is possible, for example when $\Delta\omega_0 \approx \omega_s$. We note that in order to satisfy these conditions the plasma must be strongly non-isothermal ($T_e \gg T_i$).

We note in conclusion that particularly favorable conditions for the appearance of the instability in question occur in the presence of a constant magnetic field, similar to the case of the ordinary plasma instability under conditions of anomalous dispersion [3]. It must be assumed that a similar phenomenon can take place also in condensed media.

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AMPLIFICATION OF SHORT-WAVE RADIATION IN A PLASMA OF MULTIPLY CHARGED IONS

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Submitted 22 January 1968
ZhETF Pis'ma 7, No. 7, 246-248 (5 April 1968)

For media that amplify effectively in the vacuum ultraviolet or the soft x-ray band, the requirements of absolute level population inversion are much more stringent than in the visible spectrum. This is due to the weaker reflection from the "mirrors" and to the drop in the probability ratio of the stimulated and spontaneous transitions. When speaking of the use of a plasma as such a medium, mention must be made of the remarks made in [1,2]. In [1] we considered pulsed recombination of nuclei into multiply charged hydrogenlike ions; [2] dealt with conditions created by charge exchange of ions passing through a specially chosen material. The main difficulty in the procedure discussed in [1] is the need for rapidly shutting off the heating field, since the relaxation times of a dense plasma of multiply charged or hydrogen-like ions are quite short. In the scheme proposed by Smirnov in [2], the smallness of the ion relaxation time also leads to a technical problem, where competition sets in between the relaxation times and the times of passage of the ion through the substance. In addition, it is impossible to attain a sufficiently high density in a pure ion beam; on the other hand, in a multiply charged ion plasma beam the high temperature of the free electrons leads rapidly to ionization of the "charge exchanging" substance and to deceleration of the beam.

Unlike the cooling scheme [1] and the beam scheme [2], we shall discuss here the conditions arising when a plasma of two chemical elements is rapidly heated. During the time Δt when the heating field is applied, the atoms B_1 and B_2 are essentially ionized to different ion multiplicities n_1 and n_2. Let us denote by E_1 the ionization energy $B_1^{(n_1-1)+}$ of the ion of multiplicity $n_1 - 1$ and by E_2 the ionization energy $B_2^{(n_2-1)+}$ of the ion of multiplicity $n_2 - 1$; let $E_1 > E_2$. The values of E_1 and E_2 depend strongly, besides on Δt and on the heating-field intensity, also on the structure of the external electron shells of B_1 and

B_2, and $E_1 - E_2$ can be quite large. Let us consider separately two situations that are convenient for our problem: 1) the ion $B_1^{(n_1-1)+}$ has a level with ionization energy $E_1' \simeq E_2$; 2) the ion $B_2^{n'+}$ has an internal electron whose binding energy with the ion is $E_2' \simeq E_1$.

If $|E_1' - E_2|$ is sufficiently small and the density of the ions $B_2^{(n_2-1)+}$ in the ground state is high, then the charge exchange

$$B_2^{(n_2-1)+} + B_1^{n_1+} \rightarrow B_2^{n_2+} + B_1^{(n_1-1)+}(E_1') \tag{1}$$

leads to selective population of the level E_1' of the ion $B_1^{(n_1-1)+}$. Computer calculations, made at the Physics Institute of the Academy of Sciences, of the relaxation of the plasmas of hydrogen, hydrogenlike ions, helium, and lithium point that the conditions for appreciable inversion become much more favorable with increasing number of "relaxation channels." This leads us to expect amplification by the ions $B_1^{(n_1-1)+}$ in situation (1). From the point of view of the analysis of the relaxation, situation (1) is close to that discussed in [2]; only calculation for a plasma with a specified chemical composition can show the extent of the harm done by the filling of the levels of the $B_1^{(n_1-1)+}$ ion in the case of ionization in a heating field.

Of particular interest is the situation when the energy defect* $\Delta E \simeq |E_1 - E_2'|$ is sufficiently small and the concentration N of the $B_1^{n_1+}$ ions is sufficiently large, and intense charge exchange takes place in the ground state:

$$B_1^{n_1+} + B_2^{n'+} \rightarrow B_1^{(n_1-1)+} + B_2^{(n'+1)+}(E_2'). \tag{2}$$

Hardly any $B_2^{(n'+1)+}(E_2')$ ions, which lack besides the n' external electrons also one internal one, are produced during the course of the direct ionization by electron impact; the same is obviously true also for the relaxationally-close states of this ion. The maximum charge-exchange cross section σ corresponds to the following heavy-particle velocities v [3]: $v = v_m(\Delta E)$, $v_m(\Delta E) \simeq (a/h)(\Delta E)$, $a = 7 \times 10^{-8}$ cm; the values $\Delta E \simeq 10^{-2} - 10^{-1}$ eV correspond to relatively low velocities $v \sim 10^5 - 10^6$ cm/sec. The value of σ decreases rapidly with increasing $|v - v_m(\Delta E)|$, and therefore it is hardly possible for the charge-exchange cross section to be resonant for two transitions at the same time. At velocities somewhat lower than $v_m(\Delta E)$ $(v \simeq v_m/3)$, we can write $\sigma = \pi R_0^2$, $R_0 \simeq (4\gamma/\pi)(mv^2e^2/(\Delta E)^2)$, where $\gamma = (E_1/R_y)^{1/2}$, and m and e are the mass and charge of the electron. For the charge exchange probability $A_\sigma = \langle v\sigma\rangle N$ we have $A_\sigma \sim 10^7 - 10^9$ sec^{-1} for the foregoing values of the parameters and for $N \sim 10^{16} - 10^{18}$ cm^{-3}; these values compete successfully with the probabilities of the radiative and nonradiative transitions in the ion. Estimates show that the gain per centimeter of photon path in the plasma is

$$\kappa_{mp} = \frac{\lambda_{mp}^2}{4\Gamma_{mp}} A_{mp}\left(\frac{N_p}{g_p} - \frac{N_m}{g_m}\right)$$

(g_k is the statistical weight of the state), and is sufficient in principle to develop a generator in the soft x-ray band; the effect of the decrease of the wavelength λ_{mp} compared with lasers is fully compensated by the high probability A_{mp} of the spontaneous emission and by the values N_p of the level populations that are possible in the discussed case.**

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* The energy defect is determined not only by its value at large distances, but also by the Coulomb and polarization interaction of the ions.

** The values of the width of the spectral line Γ_{mp} are practically independent of the free-electron concentration, up to very high plasma densities, since the cross sections of the "collision" transitions of the external electron of the multiply charged ion B^{n+} decrease rapidly with increasing n; these cross sections are even smaller for the internal electrons of the ion.

INFLUENCE OF THE RELATIVE DISPLACEMENT OF THE MINIMA OF THE VALLEYS IN A MAGNETIC FIELD ON OSCILLATORY EFFECTS

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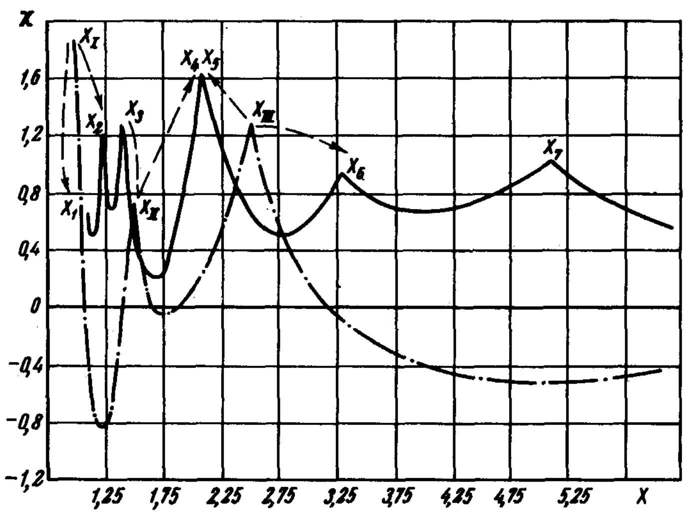
Submitted 23 January 1968
ZhETF Pis'ma 7, No. 7, 248-250 (5 April 1968)

The effective-mass Hamiltonian for crystals with low symmetry (for example, with lattice of the Te type [1,2]) can have terms of the form $\vec{H}\cdot\vec{B}(\vec{k})$ [3], which are proportional to the magnetic field;, it is necessary for this purpose that the wave-vector group admit of an invariant imaginary pseudo-vector $\vec{B}(\vec{k})$. The presence of such a term in the Hamiltonian gives rise to a relative displacement of the minima located at the points $\vec{k}$ and $-\vec{k}$ of the Brillouin zone, and leads to a certain singularity in all the oscillatory phenomena arising as a result of oscillations of the electron state density. By way of an example, we shall consider henceforth the de Haas - van Alphen effect.

1. The electron energy in a quantizing arbitrarily oriented magnetic field, for a



Oscillations of the magnetic susceptibility as a function of the dimensionless magnetic field:

$\eta_1 = (3 + b_1 + b_2)x_1,$
$\eta_2 = (3 + b_1 - b_2)x_2,$
$\eta_3 = (3 - b_1 + b_2)x_3,$
$\eta_4 = (3 - b_1 - b_2)x_4,$
$\eta_5 = (1 + b_1 + b_2)x_5,$
$\eta_6 = (1 + b_1 - b_2)x_6,$
$\eta_7 = (1 - b_1 + b_2)x_7,$
$\eta_I = (3 + b_1)x_I,$
$\eta_{II} = (3 - b_1)x_{II},$
$\eta_{III} = (1 + b_1)x_{III};$

the dash-dot curve denotes χ_1 and the solid curve χ_2.