Consequently, the maximal interaction is observed at a plasma density such that the length of the excited plasma wave λ_p is equal to the difference between the bunches, i.e., when $\omega_p \sim \omega_{mod}$.

The interaction efficiency depends strongly on the beam current. Figure 3 shows the distribution function of the beam electron energies for a current 0.5 A and a plasma density $n_p \sim 10^{11}$ cm^{-3} (curve II). As seen from Fig. 3, when the beam current decreases, the interaction is greatly reduced even at the optimal value of the plasma density.

The large values of the energy lost and acquired by the particles, and the resonant character of the dependence of the loss on the plasma density (Fig. 2c), offer undisputed evidence of the coherent collective character of the interaction of the relativistic electron beams with the plasma.

We note that the negative result of [7] may be due to the fact that the condition for coherent interaction ($\omega_p \sim \omega_{mod}$) was not satisfied and the beam current was too small (~0.15 A).

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MAGNETOOPTICAL PROPERTIES OF THE BIELECTRON IN THE BiI_3 CRYSTAL

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The absorption spectrum of the BiI_3 crystal at 4.2°K revealed a number of sharp absorption lines with longer wavelengths than the intrinsic absorption edge, in the spectral interval 6150 - 6250 Å. These lines converge in the long-wave region of the spectrum (see Fig. 2a) and their position is well described by the hydrogen-like relation

Fig. 2. Absorption spectrum of inverse hydrogen-like series in a magnetic field perpendicular to the crystal axis: a - H = 0, b - H = 34 kG.

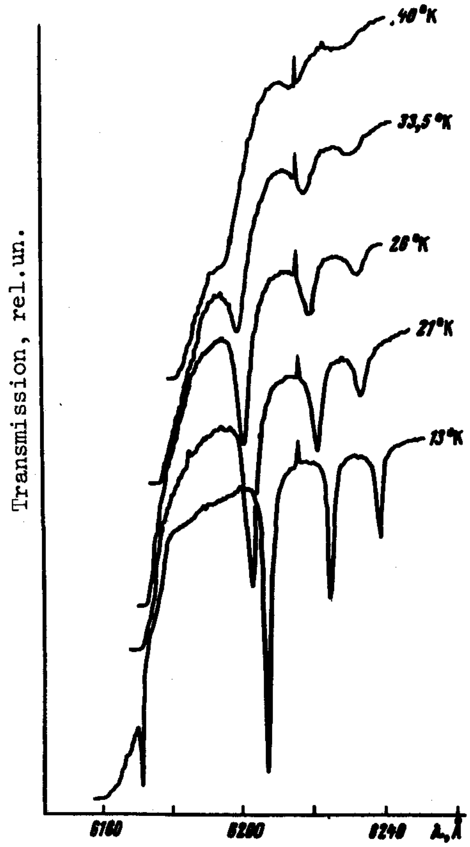

Fig. 1. Microphotographs of the absorption spectrum of the inverse series (n = 3, 4, 5, 6) at different temperatures.

$$\nu_n = \nu_\infty + \frac{R_1}{n^2} = 15978 + \frac{1995}{n^2}\ \mathrm{cm}^{-1}, \quad n = 3, 4, 5, 6, \qquad (1)$$

where n is the quantum number, R_1 the Rydberg constant, and ν_∞ the limit of the inverse series. We note that we have succeeded in observing only some of the lines of the series. We did not observe states with n = 1 and 2. According to (1), these lines should be located near λ = 5564 Å for n = 1 and λ = 6069 Å for n = 2. These wavelengths fall in the region of strong continuous absorption of the crystal, and therefore the states n = 1 and 2 are not observable. In addition, the series ends with the sixth term.

This raises the doubts whether the observed series is made up of lines having different natures, which fall in the hydrogen-like sequence only accidentally. To resolve this doubt, we investigated the behavior of this group of lines at different temperatures. The measurements have shown (see Fig. 1) that the following occurs with increasing temperature: 1) all the terms of the series move as a unit towards the short-wave region of the spectrum, whereas the absorption edge moves in the opposite direction, i.e., to the long-wave side; 2) a decrease of intensity, a broadening, and a gradual vanishing of the lines set in starting with the highest long-wave terms of the series; 3) the intensity ratios of lines with different quantum numbers remain constant.

These results lead us to the conclusion that these lines are due to a single physical phenomenon, and the serial relation (1) is not accidental. In addition, all the lines behave in the same manner in a magnetic field, as will be described below, thus confirming again their common origin.

How is one to imagine a hydrogen-like formation with inverse convergence in a crystal?

It was noted in [1] that the appearance of an inverse hydrogen-like series in the spectrum can be due to electron transitions to discrete levels of states with negative masses.

To explain the process of formation of a system producing an inverse hydrogen-like series in a crystal, we investigated the behavior of the series of absorption lines in a magnetic field, hoping to obtain the usual Zeeman effect for these lines.

The absorption spectra of BiI_3 crystals were photographed in polarized light with a DFS-13 spectrograph with a linear dispersion 1.9 A/mm. The investigation was carried out at 4.2°K in magnetic fields up to 34 kG. The experiment was performed in a geometry such that the magnetic field was perpendicular to the optical axis of the crystal, and the light propagated along this axis.

Our experiments revealed a remarkable fact: The magnetic field up to 34 kG produced no changes whatever in the spectrum of the inverse hydrogen-like absorption series of the BiI_3 crystals, and no noticeable shift or splitting or change of the line contour was observed even in the strongest magnetic fields. It should be noted that our apparatus could detect a splitting with a g factor larger than 0.26 and a line shift of 0.2 cm^{-1}.

We then investigated the Zeeman effect in a different geometry, with the optical axis of the crystal inclined 30° to the magnetic field, and with the light propagating as before perpendicular to the field. No influence of the magnetic field on the series was observed in this geometry, too.

These experiments show that the inverse hydrogen-like series of lines exhibits neither the linear Zeeman effect nor the quadratic (diamagnetic) shift (see Fig. 2b).

The absence of the linear effect means that there is neither orbital splitting nor unpaired spins in the system.

The former indicates that such a formation consists of an even number of identical particles with compensated spins. We assume further that the good hydrogen-like relation between the lines of the inverse series demonstrates that this even number of particles is in our case equal to two. In other words, the system causing the appearance of an inverse hydrogen-like series in the spectrum of the BiI_3 crystals consists of two identical light components with negative masses and antiparallel spins.

The equality of the particle masses is confirmed by the absence of orbital splitting[1]. The reduced mass of these particles, calculated from the Rydberg constant of the inverse series, is $0.6m_0$. This is close to the value $0.5m_0$ obtained for the reduced mass of two identical particles with effective masses equal to m_0. We propose that the system consists of two electrons with antiparallel spins. It is natural to call this particle a bielectron.

We have established that the diamagnetic shift, even for the line n = 6, is at the very most smaller than 0.2 cm^{-1}. It can be estimated [2] that such a small diamagnetic shift occurs for a hydrogen-like system with reduced mass $0.6m_0$ if its effective radius does not exceed 280 Å. At the same time an estimate of the radius, based on the hydrogen-like formula (1), shows that for the states with quantum numbers n = 3, 4, and 5 the effective radius is even smaller. Thus, the absence of an experimentally-observed diamagnetic shift agrees with the dimensions of the hydrogen-like formation, as calculated from its energy spectrum.

We have observed that the line with n = 6 in the absorption spectrum vanishes at 45°K. The lines n = 5 and 4 vanish successively at higher temperatures. The observed dissociation of the states with increasing temperature, starting with higher terms, is customary for hydrogen-like systems. In our case, however, such a dissociation cannot be explained in the usual manner as being due to thermal destruction of the bound states. The point is that the state

[1]The absence of orbital splitting in the Zeeman effect may be due not only to the equality of the masses, which we postulate, but also to the symmetrical state of the system (S state). It seems to us, however, that the latter is less probable in our case, since orbital splitting is missing from all the terms of the series, and consequently it would be necessary to assume that we observe only S states at all quantum numbers (n = 3, 4, 5, 6).

n = 6 has a lower energy than the states with lower numbers, and should be the last to dissociate.

The dissociation of the bound states can occur as a result of screening of the Coulomb interaction by free carriers. Then the only stable states are those whose effective radius is smaller than the screening length of the Coulomb interaction. With increasing temperature, the screening length decreases as the result of the increased concentration of the free carriers. Since states with higher numbers have a larger effective radius, the screening will destroy them at a lower temperature. Thus, the observed successive dissociation of the states with increasing temperature is connected with the size of their effective radius and can be attributed to screening of the Coulomb interaction.

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PHYSICAL STATES ON DAUGHTER TRAJECTORIES IN THE DUAL AMPLITUDE UNDER THE CONDITION $\alpha(0) = 1$

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One of the difficulties encountered in the generalized Veneziano model [1, 2] is the presence of "ghost" states with negative norm in the spectrum of the particles arising in the dual amplitude [3, 4]. There have been grounds recently for hoping that there are no such states in the case $\alpha(0) = 1$ ($\alpha(q^2)$ is the Regge-pole trajectory) [5].

We consider in this paper the physical states on the first three daughter trajectories and show that "ghosts" remain also in this case on the third daughter trajectory at large masses ($m^2 > 22\alpha'^{-1}$).

In the generalized Veneziano model [1, 2], the scattering amplitude of N + M scalar particles has an explicitly factorized form for the pole with mass k^2, $\alpha(k^2) = j$ [3, 4]. This amplitude is given by the expression

$$\Sigma \frac{V^j_{n\{\mu_\ell\}} \bar{V}^j_{n\{\mu_\ell\}}}{j - \alpha(k^2)}, \tag{1}$$

where

$$V^j_{n\{\mu_\ell\}} \equiv \langle f | n \rangle = \langle 0 | \int \Pi dx_i \, \phi(x_i p_i) \exp\{\Sigma P^{(n)}_\mu a^{(n)}_\mu / \sqrt{n}\} | n \rangle$$

$$= \int \prod_i dx_i \, \phi(x_i p_i) \, \Pi [P^{(\ell)}_{\mu_\ell}]^{n_\ell} \equiv \langle \Pi P^{(\ell)}_{\mu_\ell} \rangle, \tag{2}$$

and

$$| n \rangle = \Pi \frac{(a^{(\ell)+}_{\mu_\ell})^{n_\ell}}{\sqrt{n_\ell !}} | 0 \rangle$$