A favorable situation for the observation of the indicated effects is one in which the electron-phonon interaction in the impurity center is not too small, but at the same time it is not large enough to hide the phononless line by the vibrational structure. Such objects, for example, are the phononless line of the U-band of ruby ($Cr^{3+}:Al_2O_3$) and also the phononless line and its vibrational replicas of the $4f \to 5d$ transitions in $Ce^{3+}:CaF_2$ [4]. For numerical estimates we shall use the procedure for calculating the parameters of the electron-phonon interaction [5, 6]; this procedure results in good quantitative agreement with experiment. For the phononless line of the U band (the transition ${}^4A_{2g}(t_2^3) \to {}^4T_{2g}(t_2^3)$), we obtain the broadening δ:

$$\delta = (100\sqrt{2\ln 2}/3)D_q\sqrt{P/\rho v^3}, \qquad (6)$$

where D_q is the parameter of the theory of the crystalline field, ρ is the density of the crystal, D is the density of the ultrasonic energy flux. Using for ruby D_q = 1800 cm^{-1}, ρ = 4g/cm^3, v = 10^6 cm/sec, and P = 100 W/cm^2 (this power corresponds to a frequency $\nu \sim 10^6$ sec^{-1}), we get $\delta \sim 1$ cm^{-1}. For the highest attainable ultrasonic powers ($P \simeq 10^5$ W/cm^2, $\nu = 2 \times 10^4$ sec^{-1} [7]) we obtain $\delta \simeq 30$ cm^{-1}.

The proposed effect can be important for applications, since the width of the phononless line is one of the main parameters determining the operating conditions of a laser.

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MECHANISM OF EXCITATION AND CONTROL OF RELAXATION OSCILLATIONS IN A PLASMA-BEAM SYSTEM

S.M. Krivoruchko, A.S. Bakai, and E.A. Kornilov
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Relaxation oscillations in a beam-plasma system placed in a magnetic field (these were observed by many investigators and described in detail in [1]) are customarily called low-frequency (LF) oscillations, resulting from the rapid diffusion of the plasma from the region where the beam is located. The diffusion of the plasma is due to ionic oscillations. When the diffusion causes the plasma density in the region of the beam to become lower than a critical value, the interaction between the beam and the plasma stops, and the power of the high-frequency (HF) electronic oscillations excited by the beam decreases, and with them also the power of the ionic oscillations; the diffusion stops, the plasma density increases, reaches a critical value, the beam begins to excite electronic oscillations, followed by excitation of ionic oscillations that lead to enhanced diffusion of the plasma, etc. This is the character of the relaxation oscillations. Their study deserves special attention, since they limit significantly the power that the beam can transfer to the plasma via the electronic oscillations. Thus, we have observed that at fixed parameters of the beam and of the magnetic field, the power of the high-frequency oscillations, in the regime when the relaxation oscillations are excited, is several times smaller than in their absence. The reason is that when relaxation oscillations are excited the beam does not interact with the plasma for a long time. For these reasons, the relaxation oscillations are a serious obstacle to effective excitation of plasma by a beam. In [1], the hypothesis was advanced that excitation of ionic oscillations is the result of heating of electrons by a spatially inhomogeneous plasma by high frequency oscillations excited by the beam. We have investigated the mechanism of excitation of relaxation oscillations in a beam-plasma system, and methods of controlling this process. The experiments were carried out with a setup described in [2]. An electron beam with a current up to 100 mA and an energy 5 keV produced a plasma of density $\sim 10^{11}$ cm^{-3} in a constant uniform magnetic field of intensity 1 - 3 kG.

Investigations show that the ionic oscillations are excited in a threshold manner (relative to the power P of the HF oscillations) as the result of the development of decay instability [3]. With increasing P, the spectrum of the LF oscillations broadens. This means that P successively exceeds the thresholds of excitation of different modes of ionic oscillations. The plasma diffusion in the field of the ionic oscillations depends on the polarization of the latter and is maximal when they are polarized transversely to the magnetic field. This, naturally, indicates that plasma diffusion in crossed fields develops. Thus, enhanced diffusion of the plasma and the relaxation oscillations caused by it begin when P exceeds the threshold of excitation of the ionic oscillations polarized transversely to the magnetic field. Figure 1 shows the results of an investigation of low-frequency oscillations in a beam-plasma system as a function of the power of the high-frequency oscillations. One can see that intense excitation of transverse LF oscillations in the frequency region $\sim$10 - 100 kHz occurs at a definite level of the HF power, and gives rise to intense diffusion and to strong amplitude modulation of the HF oscillations (depth of modulation $\sim$1), and then to relaxation oscillations. The diffusion coefficient, according to estimates made, exceeds the Bohm value. We note that when the power of the HF oscillations increases by more than 10 times, the plasma temperature changes relatively little, by 2 - 3 times, whereas the changes in the spectrum of the LF oscillations are much

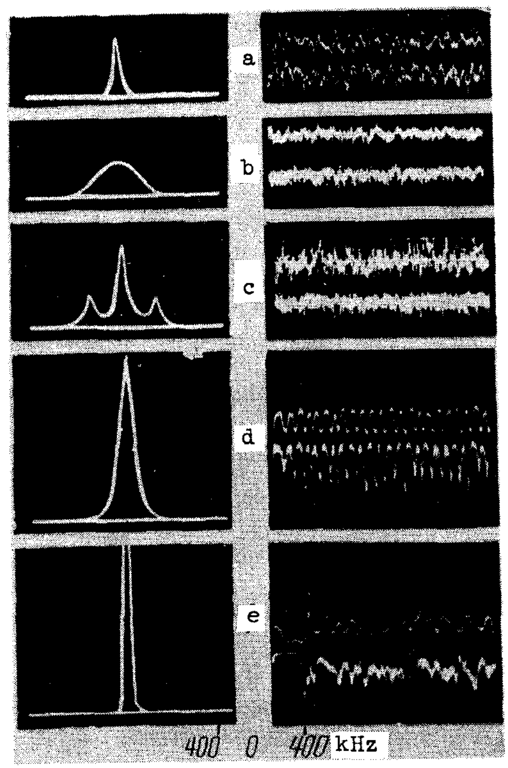

Fig. 1. Dependence of the form of the LF spectrum, the LF oscillations (upper trace), and the envelope of the HF oscillations (lower trace) on the HF power P, in relative units: a - P = 1, b - P = 3.3, c - P = 4.6, d - P = 10, e - P = 12. In cases (d, e), an attenuation of 10 dB was introduced in the analyzer of the LF spectrum, and the gain of the upper trace of the oscilloscope was decreased by a factor of 5. Oscilloscope beam sweep 2 msec.

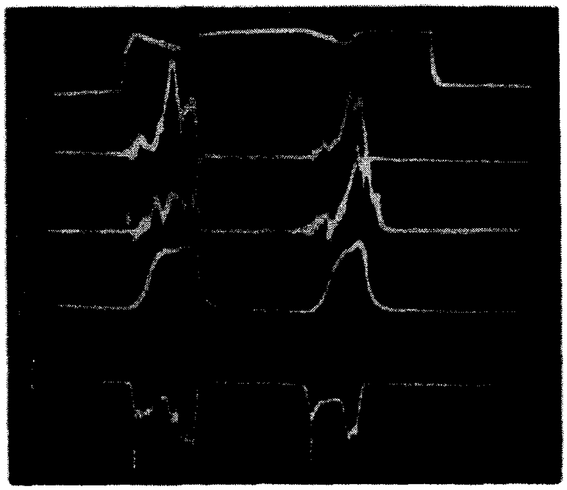

Fig. 2. Time sweep of relaxation oscillations: I - constant potential, II - oscillations from radial probe, III - oscillations from longitudinal probe, IV - current in transverse-diffusion meter, V - envelope of HF oscillations. Sweep 1.5 msec.

greater. This indicates that the interaction of the HF and LF oscillations plays a predominant role in the excitation of the relaxation oscillations.

The time sweep of the relaxation oscillations is shown in Fig. 2. It makes it possible to trace the details of the dynamics of their excitation. In particular, it is seen that there is no beam-plasma interaction over relatively long time intervals.

We see that the threshold HF power for the excitation of transverse ionic oscillations is in practice the threshold power for the excitation of the relaxation oscillations and the maximum power that can be transferred from the beam to the plasma. Consequently, the efficiency of energy transfer from the beam to the plasma can be increased by increasing the threshold for the excitation of the transverse ionic oscillations. The threshold power [4] is proportional to the product of the damping coefficients of the electronic and ionic oscillations and is inversely proportional to the square of the coefficient of interaction between them: $P_c \sim \gamma_e \Gamma_i / V_{ei}^2$, and the damping coefficient of the transverse ionic oscillations in an inhomogeneous plasma situated in a magnetic field is determined, as is well known, not only by the ion-electron collision frequencies, but also by the gradients of the density and of the electric potential, etc. It is natural to expect therefore the changes of the latter to cause also a change in the threshold for the excitation of the relaxation oscillations. Experimental investigations have shown that the threshold of excitation of the relaxation oscillations is quite sensitive to the external potential applied to an electrode that is coaxial with the beam and placed in the plasma. Thus, for example, at a potential difference V - 45 V, the threshold power P_c is four times larger than the value of P_c at V = 0. However, the $P_c(V)$ dependence is nonmonotonic, for when V increases an appreciable change takes place in the modes of the low-frequency oscillations and in the character of their interaction with the HF oscillations.

Thus, our investigations have shown that the relaxation oscillations in a beam-plasma system are the result of threshold excitation of transverse ionic oscillations by HF oscillations. The excitation threshold is quite sensitive to the distribution of the external potential and can be altered with the aid of the latter in a wide range. This makes it possible to regulate the average power level of the HF oscillations excited by the beam.

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ELECTROMAGNETIC FORM FACTOR FOR THE PION IN THE DUAL RESONANT MODEL

G.S. Iroshnikov and A.S. Chernov
Moscow Engineering Physics Institute
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We show in the present paper that the form factors proposed in [1 - 4] can be obtained from the unitarity relation for the matrix element of the electromagnetic current

$$\mathrm{Im} < p_1, p_2 | J_\mu(0) | 0 > = \frac{(2\pi)^4}{2} \sum_n \delta^4(p_1 + p_2 - p_n) < p_1, p_2 | T^+ | n > < n | J_\mu(0) | 0 > \qquad (1)$$

if we neglect in it all the intermediate states except the two-pion one. Here T is the scattering matrix, and the pion isovector form factor is determined by the relation

$$< p_1, p_2 | J_\mu(0) | 0 > = (p_1 - p_2)_\mu F(s), \quad s = (p_1 + p_2)^2. \qquad (2)$$

Within the framework of this approximation, the form factor F(s) can be written in the form

$$F(s) = \Phi(s)\Omega(s), \qquad (3)$$

where $\Phi(s)$ is an entire function and $\Omega(s)$ is the Omnes function

$$\Omega(s) = \exp\left\{\frac{s}{\pi}\int_{4\mu^2}^{\infty} \frac{ds'\delta(s')}{s'(s' - s - i\epsilon)}\right\}. \qquad (4)$$

The equality follows from the fact that $\Phi(s) = F(s)/\Omega(s)$ is analytic in any finite part of the complex s plane. The function $\Omega(s)$ depends on the phase of the form factor $\delta(s)$, which is determined by the elastic-unitarity relation

$$\mathrm{Im}\, F(s) = F(s) f_1^*(s)\,\theta(s - 4\mu^2) = F^*(s) f_1(s)\,\theta(s - 4\mu^2). \qquad (5)$$

Here $f_1(s)$ is the partial amplitude of $\pi\pi$ scattering with ℓ, I = 1. The last equation in (5) follows from the fact that the imaginary part of the form factor is real if s is real. To determine the phase $\delta(s)$, we consider the partial amplitude $H_1(s) = (16\pi\sqrt{s}/k) f_1(s)$ in the Veneziano model [5, 6]

$$H_1(s) = \frac{1}{2}\int_{-1}^{1} dz P_1(z) T^{I=1}(s,t) = \frac{1}{2}\int_{-1}^{1} dz P_1(z)[A(s,t) - A(s,u)]$$
$$= \int_{-1}^{1} dz\, P_1(z) A(s,t), \qquad t = \frac{s - 4\mu^2}{2}(z - 1), \qquad (6)$$