

modes. As was shown in [1], the width of the self-synchronization band increases with increasing L when $L > L_{cr}^{(1)}$ (for a ruby laser $L_{cr}^{(1)}$ is of the order of 50 m).

4. We investigated the dependence of the width of the laser generation spectrum on the time. A narrowing of the generation spectrum during one spike was observed. This narrowing is relatively small at small values of L ($L \sim 50$ m), but increases with increasing L and becomes appreciable at $L \sim 300$ m. The interference pattern shown in Fig. 3 is a time-scanned modulated spike of radiation at $L = 352$ m. We see that, during the generation time the width of the spectrum is narrowed from 5000 to 400 MHz, which is the resolution limit of the employed interferometer at a distance of 1 cm between plates.

These results agree qualitatively with the conclusions drawn in [1].

We measured also the beam divergence of a laser with delay line. It turned out to be equal to the diffraction limit. This allows us to conclude that only longitudinal modes were excited in the investigated laser.

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PARAMETRIC "COOLING" OF A SLOW CYCLOTRON WAVE OF AN ELECTRON BEAM IN CROSSED FIELDS

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Much evidence has been accumulated recently indicating that the instabilities in the operation of powerful beam amplifiers of the magnetron type are due to the interaction between the slow cyclotron noise wave and the fast electromagnetic wave produced between the cold cathode and the case of the instrument [1 - 3].

We discuss in this paper the possibility of developing a parametric suppressor for the slow cyclotron noise wave of an electron beam in crossed fields¹⁾.

The electron beam passes in succession through two high-frequency sections (see the figure) in which a "conjugate" type of interaction is used (a left-polarized electromagnetic wave is excited in the interaction region) [6, 7]. Assume that the noise left-polarized synchronous wave is suppressed at the end of region I at a certain frequency ω_+ . The beam "rid" of this wave enters region II, where it is acted upon by an electromagnetic wave with pump frequency ω_p , having a propagation constant β_H . Let us stop to analyze the processes in region II, since the results for section I are known. We use the model and the notation of [5]. Then the equations describing the high-frequency processes in region II can be written in the form

¹⁾The method of parametric "cooling" of a space-charge slow wave in type-0 beam devices was discussed earlier [4], but turned out to be ineffective because of the weak dispersion of the space-charge waves.

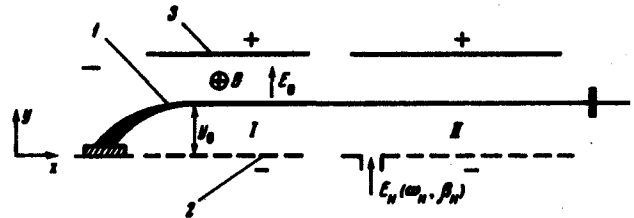
$$\left. \begin{aligned} \frac{dv_x}{dt} - \omega_c v_y &= \eta E_x \\ \frac{dv_y}{dt} + \omega_c v_x &= \eta E_y \end{aligned} \right\}, \quad (1)$$

$$E_x = \frac{i}{2} \left[\epsilon_x(y_0) + \frac{\partial \epsilon_x}{\partial y} \bigg|_{y=y_0} \tilde{y} \right] \{ \exp[i(\omega_H t - \beta_H x)] - \exp[-i(\omega_H t - \beta_H x)] \},$$

$$E_y = \mp \frac{1}{2} \left[\epsilon_y(y_0) + \frac{\partial \epsilon_y}{\partial y} \bigg|_{y=y_0} \tilde{y} \right] \{ \exp[i(\omega_H t - \beta_H x)] + \exp[-i(\omega_H t - \beta_H x)] \}, \quad (2)$$

where v_x and v_y are the longitudinal and transverse components of the high-frequency velocity of the electrons, \tilde{y} is the alternating component of the transverse high-frequency displacement of the electrons, and $\omega_c = \eta B$ is the cyclotron frequency. Equations (1) - (2) are valid if there are excited in section II both a wave with left-hand polarization in the propagation plane (upper sign) and a right-polarized wave (lower sign; see the figure).

Following [8], we introduce the normal waves of the electron beam in the following manner: $a_1(x, t) = v_y + i v_x$ is the fast cyclotron wave of the beam; $a_2(x, t) = v_y - i v_x$ is the slow cyclotron wave; $a_3(x, t) = a_1 - i \omega_c (y + i x)$ is the right-polarized synchronous wave; $a_4(x, t) = a_2 + i \omega_c (\tilde{y} - i \tilde{x})$ is the left-polarized synchronous wave (\tilde{x} is the high-frequency longitudinal displacement of the electrons).



Scheme of parametric suppression of noise in a slow cyclotron wave: 1 - electron beam, 2 - slow-wave system, 3 - cold cathode.

Assuming that $d/dt = i\omega + v_0(\partial/\partial x)$, it can be easily shown that $a_k(x, t)$ satisfies the equation

$$\frac{\partial a_k(x, t)}{\partial x} = -i\beta_k a_k(x, t) + \frac{\eta}{v_0} E_{\pm}(x, t), \quad (3)$$

where $\beta_{1,2} = \beta_e \mp \beta_c$, $\beta_{3,4} = \beta_e$, $\beta_c = \omega_c/v_0$, $v_0 = E_0/B$, $\beta_e = \omega/v_0$, $E_+ = E_y + iE_x$, and $E_- = E_y - iE_x$. The upper sign should be taken in Eq. (3) when $k = 1$ and 3, and the lower one when $k = 2$ and 4.

Let us assume that a strong parametric coupling is produced of the wave a_2 of frequency ω_2 and propagation constant $\beta_2(\omega_2)$ with the wave a_4 of frequency ω_4 with propagation constant $\beta_4(\omega_4)$, calling for satisfaction of the conditions

$$\omega_H = \omega_2 + \omega_4, \quad \beta_H = \beta_2(\omega_2) + \beta_4(\omega_4) \quad (4)$$

Assuming further that the pump field has left-hand circular polarization²⁾, using (1) - (4), and introducing the notation $a_{2,4} = A_{2,4}(x)\exp[i(\omega_{2,4}t - \beta_{2,4}x)]$, we arrive at the system of equations

$$\frac{dA_4^*}{dx} = -i \frac{\Omega^2}{\omega_c v_0} A_2; \quad \frac{dA_2}{dx} = -i \frac{\Omega^2}{\omega_c v_0} A_4^* \quad (5)$$

with boundary conditions

$$A_4^*(0) = 0; \quad A_2(0) = A_{20}. \quad (6)$$

In relations (5) and (6) we have

$$\Omega^2 = \frac{\eta}{2} \left| \frac{\partial \epsilon_y}{\partial y} \right|_{y=v_0}$$

and A_{20} is the amplitude of the slow cyclotron noise wave at the entrance into the region II.

The solutions of (5) under the conditions (6) are

$$A_2 = A_{20} \cos \frac{\Omega^2}{\omega_c v_0} x; \quad A_4^* = -i A_{20} \sin \frac{\Omega^2}{\omega_c v_0} x. \quad (7)$$

It is seen from (7) that if the length of the region II is $l = \pi \omega_c v_0 / 2\Omega^2$, full energy exchange between waves a_2 and a_4 takes place. The noise power of the slow cyclotron wave of frequency ω_2 goes over completely into the noise power of the left-polarized synchronous wave of frequency ω_4 .

An electron beam "cooled" in this fashion can be used in an M-type traveling-wave beam device for the amplification of signals having a frequency close to ω_2 .

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²⁾This is necessary for a strong parametric coupling between the waves a_2 and a_4 , which also have left-hand circular polarization.