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SELF-SYNCHRONIZATION OF TRANSVERSE MODES OF A CO$_2$ LASER

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We report here the results of experiments on the synchronization of the transverse modes of a CO$_2$ laser with the aid of a nonlinear BCl$_3$ absorber. The self-synchronization was accompanied by spatial rocking of the laser emission at the frequency of the intermode beats.

Wood and Schwarz [1] synchronized several longitudinal modes of a CO$_2$ laser with a nonlinear SF$_6$ absorber. In our experiments we used BCl$_3$, which is a more suitable saturating filter for CO$_2$ lasers from the spectral point of view [2, 3].

The experiments were performed with a laser with a semi-confocal resonator 17.6 m long. The output mirror was a plane-parallel germanium plate. The cell with the BCl$_3$ was located near the output mirror. A rectangular graphite diaghragm placed near the spherical mirror separated the TEM$_{moq}$ modes. The frequency intervals were 8.5 and 4.25 MHz between the longitudinal and transverse modes, respectively.

The laser emission was recorded with a Ge:Zn receiver, using an S-1-11 oscilloscope and an S-4-8 spectrum analyzer.

Stable synchronization of the transverse modes was observed for a cell 1 mm thick at BCl$_3$ pressures from 2 to 12 torr. The synchronization of the transverse modes was accompanied by transverse rocking of the laser beam [4]. In this case, when the receiver was moved relative to the aperture of the rocking beam, a sequence of pulses, following each other with the frequency of the intermode beats, was observed at the points of maximum deflection. At the center, the pulse repetition frequency was doubled. Figure 1 shows oscillograms of the pulse sequences of the laser emission at the edge of the laser output aperture (a) and at the center (b).

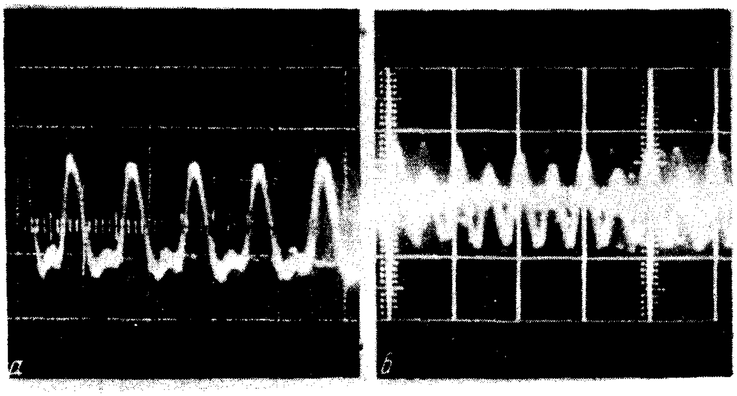
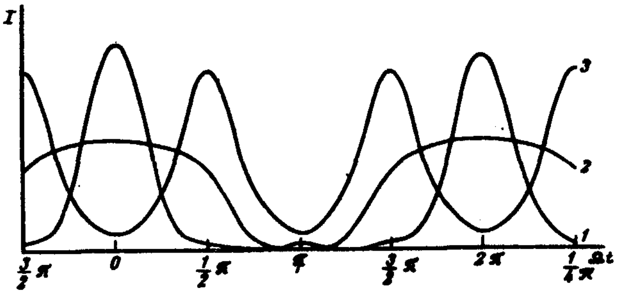


Fig. 1. Oscillograms of rocking laser beam at the point of maximum deflection (a) and at the center (b). Time scale: 1 division = 250 nsec.

Fig. 2. Intensity of summary field of three synchronized transverse modes on the time for different values of the dimensionless coordinate z: 1 - z = 0.9, 2 - z = 0.4, 3 - z = 0. Width of aperture of receiving element 2Δz = 0.6.



Short-duration and unstable self-synchronization of transverse modes was observed in the absence of BCl_3 at a suitable setting of the resonator mirrors. When a round diaphragm was introduced into the resonator to separate the fundamental mode, synchronization of the longitudinal mode was observed in the presence of BCl_3.

Readjustment of the mirrors in the presence of a rectangular diaphragm led sometimes to simultaneous occurrence of synchronization of the transverse and longitudinal modes. A similar effect was observed by Smith [5] in the synchronization of the modes of a helium-neon laser by a nonlinear neon absorber.

We note that the occurrence of synchronization was accompanied by the appearance of strong difference-frequency signals, which were revealed by the spectrum analyzer.

The synchronization of the modes in CO_2 laser has certain unique features connected with the small width of the amplification line (50 - 60 MHz). In the analysis of the sychronization it is necessary to take into account the interaction between a small number of modes.

Let us take three transverse modes. Assuming a rigid phase coupling, the summary field can be represented in the form

$$E = A(1 + 2z\cos\Omega t + \frac{4z^2 - 1}{\sqrt{2}}\cos 2\Omega t)\,e^{-z^2},$$

where Ω is the frequency of the intermode beats, and z is the dimensionless coordinate. In this form, the coefficients of the Hermite polynomials were normalized to equal integral intensity of the modes.

Figure 2 shows a plot of the intensity of the summary field E, calculated for different values of z at a finite aperture of the receiving element. We see that three synchronized modes suffice to obtain a clearly pronounced periodic rocking of the laser emission, and that this model agrees quite well with the foregoing experimental results. We call attention to the decrease of the depth of modulation at z = 0.4, which was also observed experimentally.

The experiments and their analysis show that a rapid spatial scanning of the CO_2-laser beam and a sequence of short pulses of CO_2-laser emission can be obtained, using a diaphragmed rocking beam, by synchronizing a small number of transverse modes of this laser with a nonlinear BCl_3 absorber.

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FEATURES OF FORMATION OF INTENSE ELECTRON BEAMS IN A BOUNDED PLASMA

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Previous efforts [1 - 3] to obtain large-current electron beams from the surface of a plasma yielded currents not exceeding $(1 - 2) \times 10^3$ A. New methods and possibilities of greatly increasing the currents are afforded by forming the beams in a plasma filling beforehand a bounded gap through which a current of $10^4 - 10^5$ A is made to flow.

The schematic diagram of the experiments is shown in Fig. 1. The plasma flows from spark source 1 into an accelerating gap 2 (1 - 2 cm). The accelerating field is applied to the plasma-filled gap ($n \sim 10^{12} - 10^{13}$ cm^{-3}) with a delay $\tau \sim 1 - 2$ μsec, and is maintained by a capacitor $C_2 = 0.4$ μF. A distinguishing feature of the formation of electron beam by first filling the accelerating gap with plasma is that during the initial stage of current development the gap is short-circuited by the plasma and the voltage drop across it is low. When the current in the gap reaches a certain critical value, the ohmic resistance of the gap increases, and this leads to an interruption of the electron current (Fig. 2a) and to a sharp increase of the potential difference on the gap, to a value exceeding the initial voltage of the power supply. During the stage of interruption of the total current, an electron beam is formed in the plasma, and an appreciable fraction of this current (1/2 - 1/3, Fig. 2b) passes through the grid to the anode and is measured with a Faraday cylinder. The critical current increases with increasing plasma concentration in the gap, and reached 2×10^4 A in our experiments. The beam current reached in this case 10^4 A, at a pulse duration 3×10^{-7} sec. A characteristic feature of the regimes investigated by us, as shown by probe measurement, is the concentration of the potential difference near the cathode. Such a po-

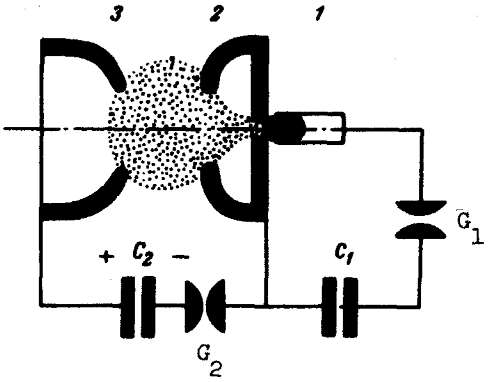

Fig. 1. Schematic diagram of experiment. 1 - spark source, 2 - accelerating gap, 3 - accelerating electrode; G_1, G_2 - discharge gaps.

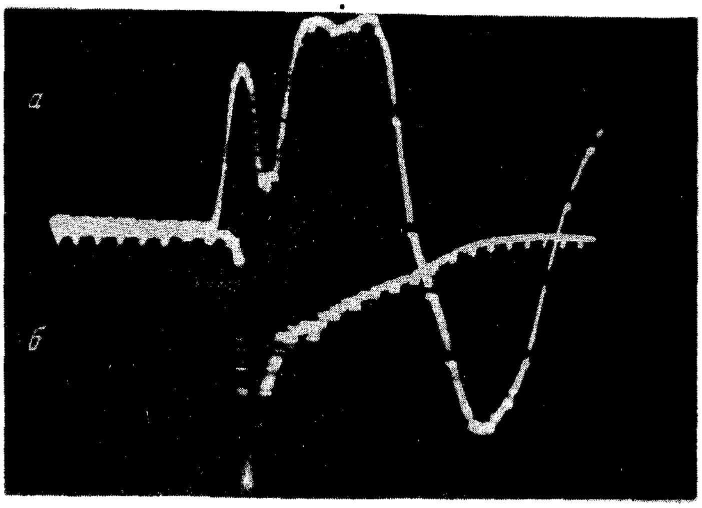

Fig. 2. Current oscillograms: 1 - total current, 2 - current to Faraday cylinder.