OBSERVATION OF SELF-SYNCHRONIZATION OF TRANSVERSE MODES IN A SOLID-STATE LASER

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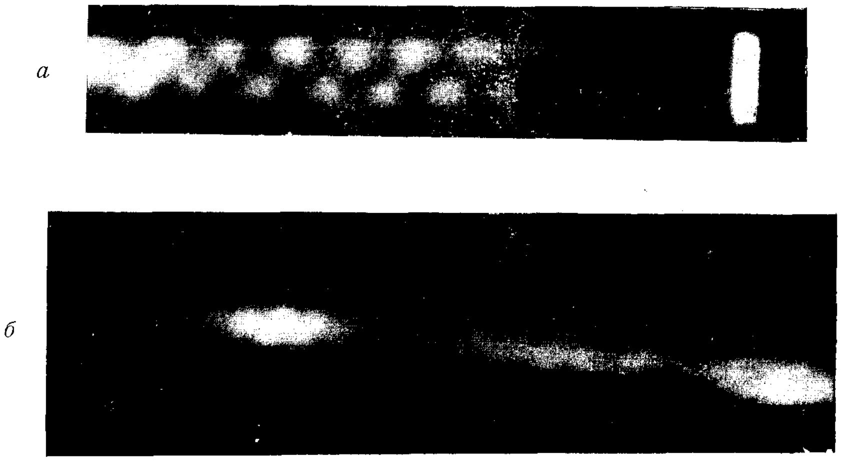
Until recently, only synchronization of axial modes in laser has been observed and investigated (e.g., [1, 2]). The possibility of synchronization of transverse modes was considered in a recent paper [3], where the author expressed doubts concerning the feasibility of spontaneous synchronization. An attempt to observe the effect of induced synchronization of transverse modes was made in [4]. We have observed the effect of self-synchronization of transverse modes in an investigation of the kinetics of the spatial evolution of free generation in solid-state lasers having elements of large cross section.

The active element was glass with 2% Nd_2O_3, in the form of a parallelepiped with cross section 120 x 15 mm (along the axes X and Y respectively) and length 150 mm (Z axis). Four pump flash lamps were placed above and below the active element along the X axis. The inversion produced in the direction of the X axis was uniformly distributed over the cross section in the active element. The pump energy was varied in the range from 3.5 to 6 kJ, and the pulse duration was ∿ 700 μsec. The resonator was planar, and mirror transmission coefficients were $\tau = 0.5\%$ and 24%. The resonator length ranged from 25 to 200 cm. The aperture dimensions were varied by introducing into the resonator a diaphragm whose X-dimension ranged from 5 to 95 mm and whose Y dimension was 2.5 mm. An SFR-2M moving-image camera was used to effect a simultaneous time sweep of the pictures of the near and far fields of the laser (the sweep was in the Y direction).

The generation had a spike character, and peridic oscillations of the generating band over the mirror, perpendicular to the spike direction, were observed in individual spikes. The figure shows certain characteristic features of the time sweeps of laser near field.

Figure a shows the form of the end face during the entire lasing pulse at the start of the sweep. The observed scanning of the generating zone is characteristic of the synchronization of several transverse modes. The oscillation frequency of the generation zone was usually 10 - 20% lower than the beat frequency $\Delta\nu_{12}$ of the neighboring lower transverse modes



Fragments of time sweep of near field of laser: a - aperture 8 x 25 mm, resonator length 200 cm, b - aperture 15 x 2.5 mm, resonator length 40 cm.

of the empty resonator. This is apparently connected with the mode frequency pulling [5]. According to [6], $\Delta\nu_{12} = 1.2/d^2$ MHz, where d (in cm) is the dimension of the radiation region. If oscillations of the generating zone are observed, then d is determined by the dimension of that section of the mirror, within which the oscillations take place. The dimension of the scanning generation spot was usually (0.3 - 0.5)d.

It should be noted that at diaphragm dimensions exceeding 10 mm the dimension d of the radiating region in each spike did not exceed on the average 5 - 10 mm, this being obviously connected with aberrations in the resonator (see, for example [7]). It is seen from Fig. a that the scanning of the generating zone over the mirror is not uniform, being slower at the edges than at the center. The total angular divergence of the radiation amounts in this case to $(3 - 3.5)\lambda/d$ at half the maximum intensity level, indicating synchronization of 3 - 4 transverse modes. Sometimes more complicated displacements of the generation zone over the mirror were observed. The laser beam scanning in the far field is similar to that in the near field. The uniform displacement of the generation zone over the mirror (Fig. b) is most probably due to the beats between two neighboring transverse modes, since the angular divergence of the radiation amounts to $(2.2 - 2.4)\lambda/d$ in this case (at half the maximum intensity level).

If generation occurs only on one transverse mode, then there is no scanning of the generation zone over the mirror. The position of the active element relative to the resonator mirrors does not influence the scanning, whereas a slight misalignment of the resonator mirrors ($\sim$2 - 3') or an inclination of the active element relative to the resonator axis by an angle $\alpha \gtrsim 10''$ makes the scanning disappear. Experiments have shown that no scanning is observed in the case of non-uniform distribution of the inversion over the cross section.

Self-synchronization of transverse modes can occur in our case as a result of modulation of the inverse population by the beat frequency of the neighboring transverse modes [8]. To produce synchronization, the mode frequencies should be equidistant. This is not the case for the transverse modes of an "empty" planar resonator. However, if account is taken of the prescence of combination tones induced in the active medium, and of the fact that the widths of the resonance curves of our generator ($\sim 10^7$ Hz) exceed the frequency differences between the neighboring transverse modes, it is perfectly obvious that 3 - 4 modes can be equidistantly excited. For axial modes in a gas laser, the overlap of the resonance curves, attained by increasing the resonator length, led to self-synchronization of the modes [9]. We note that in a spherical resonator we observed no mode synchronization, owing to the fact that not more than one transverse mode was excited (with appreciable intensity) in each spike.

Thus, conditions for the synchronization of several transverse modes can be created in individual spikes of generation from solid-state lasers with uniform distribution of the inversion over cross sections. The result is the scanning of the generation zone over the mirror and in the far field.

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PARAMETRIC EXCITATION OF SPIN WAVES IN ANTIFERROMAGNETIC $CsMnF_3$

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We describe in this article the results of observation of excitation of electron spin waves in an antiferromagnet when the static and microwave magnetic fields are parallel.

The investigations were made on $CsMnF_3$. The low-frequency branch of the AFMR spectrum in $CsMnF_3$ is described by the formula [1, 2]

$$(\nu/\gamma)^2 = H^2 + 2H_E H_{AT} . \quad (1)$$

The second term in this formula is due to the hyperfine interaction. According to the data of Lee, Portis, and Witt [1] H_E = 350 kOE and H_{AT} = 9.15/T Oe.

We investigated the dependence of the absorption of the microwave power in the sample on the magnitude of the external magnetic field. The investigations were made at 9.43 GHz with a pulsed source (τ = 1 μsec) and at 36 GHz with a continuous source. The sample was placed in a high-Q resonator such that the static magnetic field (H) and the microwave magnetic field (h) were in the basal plane of the crystal.

It was observed that when h and H are parallel, starting with a certain value of the microwave power, absorption in the sample sets in at field values below a definite limit H_1. Within the limits of measurement accuracy, the field value H_1 does not depend on the power. Figures 1a and 1b show several curves characterizing the observed absorption at different power levels. The lower curve of Fig. 1a was obtained at high power, but unlike the other curves, with h perpendicular to H. The observed sharp absorption peak at a magnetic field value corresponding to ordinary AFMR can be explained, in accordance with (1), as being due to insufficient parallelism of the fields.

The absorption at 9.4 GHz is very small, practically the same for all fields lower than H_1, and increases continuously with increasing power. At 36 GHz the absorption is much more pronounced. It is seen from Fig. 1b that at a slight excess of power above threshold, the absorption is not observed at all fields lower than H_1. The range of the fields expands with increasing power. At the field value H_1, the absorption vanishes jumpwise. For a fixed value of the magnetic field, the absorption increases sharply with increasing power, passes through a maximum, and then starts to decrease, as seen from Fig. 2. Estimates of the value of the threshold microwave fields h_c yield $h_c \sim 2$ Oe and $h_c \sim 0.5$ Oe for experiments at 9.4 and 36 GHz, respectively.

We propose that the observed absorption is due to parametric excitation of spin waves