LASING OF HIGH–REPETITION–RATE PULSE TRAINS IN A TITANIUM–DOPED SAPPHIRE LASER

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The feasibility of realizing high–repetition–rate pulse trains of subnanosecond duration in a tunable titanium–doped sapphire laser, which is pumped by a pulse of nanosecond duration, has been demonstrated experimentally. Hypothetical physical mechanisms are discussed.

In the solution of a number of practical problems, sources of tunable laser radiation in the from of high–repetition–rate pulse trains (HRRPT) of subnanosecond duration are required. Such regimes of lasing are realized, as a rule, with active or passive mode–locking in the resonator as well as in lasers with synchronous pumping.[1] Techniques based on the HRRPT excitation by means of short–duration (less than the axial period of the resonator) perturbations of the initial lasing conditions are not widely used.[2]

A realization of the HRRPT regime in the $Ti^{3+}:Al_2O_3$ lasers, which have the best lasing and operating characteristics among the tunable solid–state lasers, is of a considerable practical interest. Such regime was first realized with a synchronous pumping of the titanium–doped sapphire crystal by the radiation consisted of the second harmonic of the picosecond pulse train of a Nd^{3+}:YAG laser.[3] In this paper we present the experimental results, which demonstrate a feasibility of realizing the same regime with pumping of an $Ti^{3+}:Al_2O_3$ laser by the pulses of radiation with a smooth shape of nanosecond duration when there are no intraresonator modulating elements in the tunable laser.

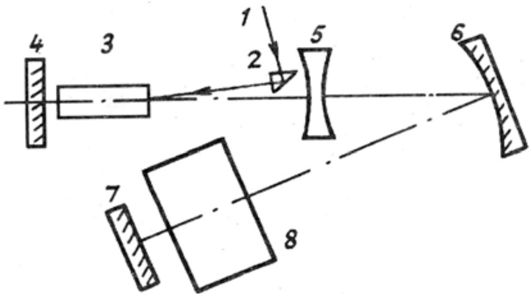

FIG. 1. Optical diagram of the laser. 1) pump radiation, 2) rotating prism, 3) active element, 4) output mirror, 5) negative lens, 6) spherical mirror, 7) nontransmitting mirror, and 8) selector.

An optical diagram of the laser is shown in Fig. 1. The $Ti^{3+}:Al_2O_3$ crystal is pumped quasi–longitudinally by the second–harmonic radiation of an Nd^{3+}:YAG laser operating in the periodic–pulse regime with pulse duration of the order of 10 ns. The active element *3* of the tunable laser with dopant concentration ~ 0.1 wt % has a length of 10–15 mm and is positioned near the mirror *4*. Its ends are aligned parallel to the plane of the mirror. A block consisting of three TF–5 glass prisms is employed as the spectral selector *8*. An intracavityr two–component collimator consisting of the lens *5* and mirror *6* makes it possible to vary the baseline within wide limits (0.3–5 m) by movement of the mirror *7*.

Experiments have shown that the build–up of lasing of a tunable laser has a well–pronounced two–threshold character. When the pump energy exceeds the first threshold (about 4 mJ for reflectance of the output mirror equal to 0.95), the lasing of pulses with a smooth shape and duration of 40–80 ns is realized in the spectral range 760–810 nm and with a delay relative to the maximum of the pump pulse in the case of a nonselective resonator. With increase of the pump energy, the pulse duration and delay decrease, while the width of the lasing spectrum remains virtually unchanged.

When the pump energy reaches the second threshold (about 8 mJ), at the start of lasing of the tunable laser a pulse with duration $\tau \le 1$ ns is observed followed the HRRPT with a period equal to the axial period of the cavity T (Fig. 2*a*). If $\tau < T$ the degree of HRRPT modulation reaches 100%, decreasing with increase of τ for fixed values of T (at the expense of an increase in the distance between the crystal and the mirror *4*), or with decrease of T for fixed value of τ (moving the mirror *7*). The spectral characteristics of the radiation in the case of a nonselective resonator remain the same.

Shaping of the initial (seed) pulse was performed in the short arm of the resonator, which is formed by the mirror *4* and the end of the active element opposite to it. As a result of misalignment of the crystal ends with respect to the mirror *4*, the seed pulse was not observed, and the lasing kinetics of the tunable laser became similar to the regime characteristic of the first threshold (nanosecond pulse with smooth shape).

In the case of a selective resonator (the spectral width of the lasing line is about 2 nm), the spectral range of the seed pulse is 760–810 nm, and the lasing spectrum in the total resonator can be regulated over a wider range 720–880 nm. The maximum degree of the HRRPT modulation is reached in the spectral range corresponding to that of the seed pulse. In this case, with increase of the degree of detuning of the spectral characteristics of the HRTT from the seed pulse, the time delay between their maxima also increases up to several tens or even hundreds of nanoseconds, which exceeds the period of the axial cavity by an order of magnitude or more (Fig. 2*b*).

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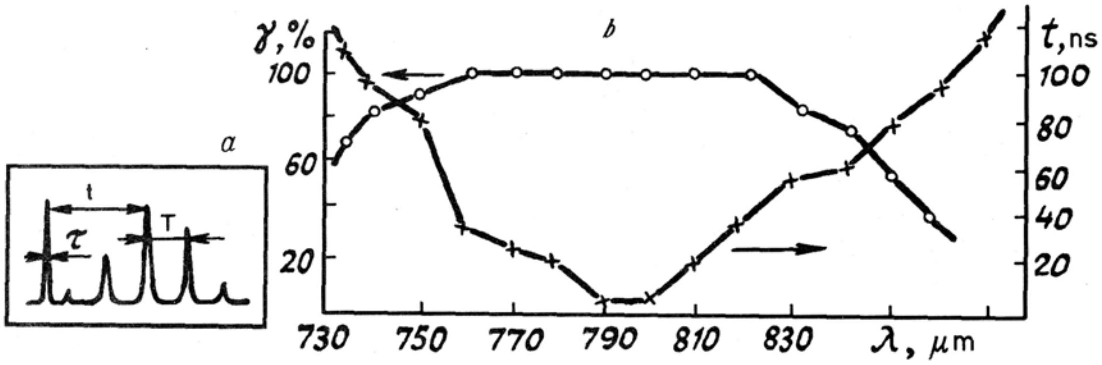

FIG. 2. Typical lasing time sweep in the HRRPT regime (a) and the degree of modulation γ and delay time t of the HRRPT relative to the maximum of the seed pulse (b).

The above–presented experimental data allow one to assume that the physical mechanisms associated with the injection of the seed pulse into the total cavity lie at the basis of HRRPT regime and affect the ratio between the gain and the losses taking into account their dynamic characteristics. Thus, if $\tau < T$, the fact of HRRPT lasing testifies to an appreciable influence of the initial conditions on the build–up of lasing of the tunable laser, which is similar to the process of rapid switching of the Q–factor of the cavity.[2,4] In this case both resonators make up a system of coupled resonators. At the same time, it is not excluded that the seed pulse shaped in the short arm of the resonator simultaneously affects the luminescent parameters of the $Ti^{3+}:Al_2O_3$ crystal as was characteristic in Refs. 3 and 4. And, finally, the influence of the mechanism of Q–switching of the cavity on the lasing kinetics is also possible.[5]

In order to test a feasibility of the phase matching in the $Ti^{3+}:Al_2O_3$ crystal, an additional experiment was performed with an Nd^{3+}:YAG laser, whose output mirror was based on a plane–parallel backing fabricated from titanium–doped sapphire, and there were no intracavity modulating elements. In exciting the Nd^{3+}:YAG laser by a pump flash–lamp, a typical chaotic pulse of free lasing at a wavelength of 1.078 μm with pulse duration of several tens of microseconds was observed. In the case of simultaneous excitation of the mirror fabricated from $Ti^{3+}:Al_2O_3$ crystals by single–pulse radiation consisting of the second harmonic of an Nd^{3+}:YAG laser, wide–band lasing of the titanium ions with pulse duration less than 1 ns was recorded. The lasing kinetics of an Nd^{3+}:YAG laser changes significantly: the duration of the output pulse was about 20–50 ns, and the pulse shape was modulated with a frequency corresponding to the axial period of the cavity and the degree of modulation reached 30–40%.

In conclusion, it should be noted that the HRRPT regime in a $Ti^{3+}:Al_2O_3$ laser has also been realized with the help of an LTI–701 quasi–continuous laser as the pump source, which provides a pulse repetition rate equal to several tens of kilohertz with a pulse duration about 200 ns, which makes it possible to significantly increase the HRRPT repetition rate.

The results discussed here can be used in the design of simple arrangements of $Ti^{3+}:Al_2O_3$ lasers lasing HRRPT's, in the absence of intracavity nonlinear elements.

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