Single-frequency tunable traveling-wave ruby laser with active Q-switching

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A stable single-frequency regime is obtained in a traveling-wave ruby laser with active Q-switching, using a single selecting plate inside the resonator. Frequency tuning in a range 0.6 cm^{-1} is accomplished by varying the inclination angle of the selector.

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There are two aspects to the problem of developing single-frequency pulsed solid-state high-power nanosecond lasers with strict time synchronization of the emitted pulse and with a tunable wavelength. First, to solve the problem it is necessary to effect a mode selection whereby active Q-switching (and only such a switching ensures temporal synchronization on the order of several nanoseconds) results in a single-frequency regime. Second, the selection scheme should include an element with which the working wavelength of the laser can be varied in a controlled manner.

It was proposed at one time to solve the problem by using a relatively simple selection scheme and slow down the rate of turning on the shutter,[1] or else to use strong selection in conjunction with ordinary Q-switches (the so-called "dispersion resonators").[2] In the former case, together with lowering the laser efficiency, we make the time synchronization worse, and in the latter case the resonator becomes extremely complicated, and with it also the system used for varying the wavelength.

A recently proposed[3] method of obtaining a single-frequency regime in solid state lasers with active Q-switching is based on the use of a "priming" free-generation radiation excited in a traveling-wave ring resonator. The first experimental results obtained by using this method have revealed the exceedingly strong role of the weak selectors present in this resonator. This permits this method to be used not only to obtain a stabilized single-frequency regime in solid-state lasers with active Q-switching, but also to produce very simple schemes for tuning the working frequency of such lasers.

We report in this paper the development of a stabilized single-frequency ruby laser with a traveling-wave ring resonator and with active Q-switching; its frequency could be varied in controllable fashion in a band of approximately 0.6 cm^{-1}.

A three-mirror ring resonator was used with rotating total internal reflection prisms serving as the mirrors. Inside the resonator we placed a ruby rod of 10 mm diameter and 120 mm length, a Faraday switch, an electro-optical shutter (KDP crystal), and a diaphragm to separate the TEM_{00q} modes. The transmission of the entrance mirror was 30%. The optical length of the resonator was 180 cm. The Faraday switch, the ruby, and the KDP crystal had end faces cut at the Brewster angle to the resonator axis. The selector was a plane-parallel glass plate 3 mm thick, and its inclination to the resonator axis could be varied accurate to $\pm 10''$. The emerging radiation was investigated with a photodiode connected to an S1-16 oscilloscope, and with a Fabry-Perot interferometer having a distance between plates from 3 to 30 mm.

Figures 1a and 1b show a typical oscillogram and interference pattern of the giant pulse obtained with the shutter completely closed, after several free-generation spikes. The width of the spectrum, as seen from the interference pattern, is determined by the apparatus function and does not exceed $\Delta\nu_a \approx 0.01$ cm^{-1}. The width of the spectrum is actually even smaller, since the intermode distance is in our case $\delta\nu_m = 1/L \approx 0.0056$ cm^{-1}, and if two or three modes are excited we should observe on the time picture of the giant pulse beats having a period $T = L/c \approx 1.7$ nsec. However, the giant pulse registered with an FÉK-09 photocell and an I2-7 oscilloscope, always had a smooth waveform and an approximate duration 25 nsec. This allows us to state that a single frequency regime is realized in our case. The

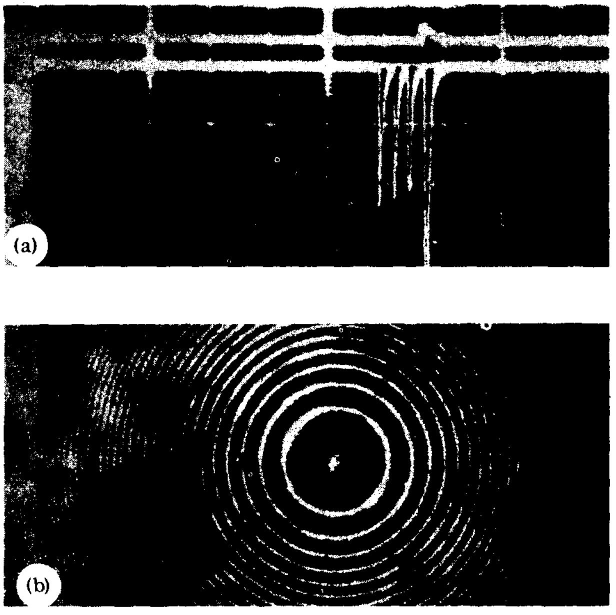

FIG. 1. Oscillogram (a) and interference pattern (b) of the laser emission with the Q switch completely turned on after the third free generation spike. Sweep scale 100 μsec/div. The gain of the upper beam is smaller by a factor 10^3 than that of the lower one. The interferometer base is 2.5 cm.

FIG. 2. Interference pattern of laser radiation with the Q-switch fully turned on, after several free-generation spikes, at selecting-plate inclination angles 0°00′ (a), 0°15′ (b), 0°22′ (c), and 0°30′ (d). The interferometer dispersion is 1.67 cm^{-1}.

frequency drift from pulse to pulse at a fixed position of the resonator elements likewise did not exceed the width of the apparatus function. It is therefore possible to obtain in our experiment, in addition to frequency tuning, also reproducible generation of single-frequency radiation with an accuracy not worse than $10^{-2} cm^{-1}$. It should be noted that when the shutter was turned on without first exciting the preliminary free generation the spectrum was practically without structure and had an overall width of approximately 1 cm^{-1}.

Figure 2 shows interference pattern of the radiation of giant pulse with a time dependence similar to Fig. 1a, at various fixed inclinations of the selecting plate. It is seen from these patterns that the radiation frequency varies in a range 0.6 cm^{-1}, and in each case the spectrum remains single-frequency.

It should be noted that by using our procedure, a suitable choice of selector construction allows a broadening of the ruby-laser tuning range to a value determined by the ruby gain-line width, i.e., to $\Delta\nu \sim 10$ cm^{-1}. Since our method works also in the case of media with inhomogeneous broadening of the gain line, the tuning range of a neodymium-glass laser can be broadened to $\Delta\nu \sim 250$ cm^{-1}.

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