Stabilization of a ruby laser using an He-Ne laser as a frequency reference

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(Submitted September 19, 1974; resubmitted June 25, 1975)
Pis'ma Zh. Eksp. Teor. Fiz. **22**, No. 2, 103–106 (July 20, 1975)

A method is proposed for active stabilization of the ruby-laser frequency. The gist of the method is that the Q of the laser resonator is chosen to be low enough to make the lasing frequency and its stability governed by a high-Q Fabry–Perot interferometer placed inside the resonator at a small angle to its axis. The distance between the interferometer mirror is rigidly stabilized with the aid of an electron-optical negative-feedback system that consists of a stabilized He-Ne laser, a photoreceiver, and a differential amplifier. The absolute instability of the frequency amounts to 3×10^{-3} cm^{-1}.

PACS numbers: 42.60.G

In this paper we propose, for the first time, a method for active stabilization of the frequency of a pulsed solid-state laser, whereby the relative instability of the lasers can be made comparable with the instability of gas lasers. The gist of the method consists of selecting the Q of the laser resonator low enough to make the lasing frequency and its stability governed by a high Q-selector interferometer placed inside the resonator at a small angle to its axis. The distances between the mirrors of the selector interferometer (base) is rigidly stabilized with the aid of an electron-optical system consisting of a stabilized He-Ne laser ($\lambda = 0.63\ \mu$) 11, a scanning selector interferometer 4, and interference light filter ($\lambda = 0.63\ \mu$) 7, a photoreceiver 8, and a differential amplifier 9 (Fig. 1). The He-Ne laser radiation is fed to the photoreceiver 8 through interferometer 4, as shown in Fig. 1. The photoreceiver signal applied to input 1 of the differential amplifier depends on the interferometer base and is chosen equal to half its maximum value. Input 2 of the amplifier receives a reference signal of equal magnitude. The system is balanced. A slight change in the interferometer base leads to a change of the photoreceiver signal, producing at the output of the differential amplifier an amplified difference signal that is fed to a piezoceramic and returns the mirror to the initial position.

The frequency stability was investigated with the ruby laser operating in the free-running regime, with a pump exceeding the threshold levels by 1.3 times. The spectrum was recorded with the aid of the Fabry-Perot interferometer 6. One of its mirrors was secured to a piezoceramic cylinder to compensate for the temperature drift of the base. To this end, the He-Ne laser

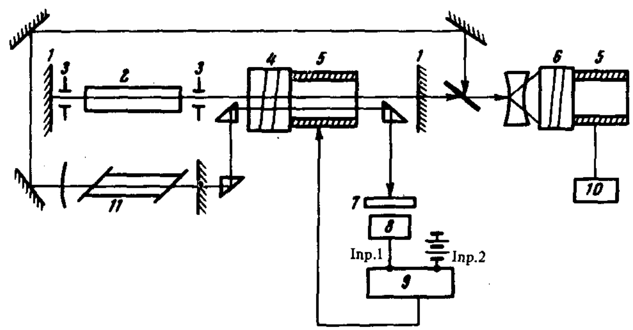

FIG. 1. Experimental setup: 1—resonator mirrors, 2—ruby crystal, 12×120 mm; 3—diaphragm, 2 mm dia; 4—selector interferometer with mirror reflectivity $R = 0.9$ and base 3 mm; 5—piezoceramic cylinders, 6—measuring Fabry-Perot interferometer with $R = 0.95$ and base 3 cm; 7—interference light filter ($\lambda = 0.63\ \mu$); 8—type FD-7K photocell; 9—differential amplifier; 10—dc voltage source; 11—stabilized He-Ne laser.

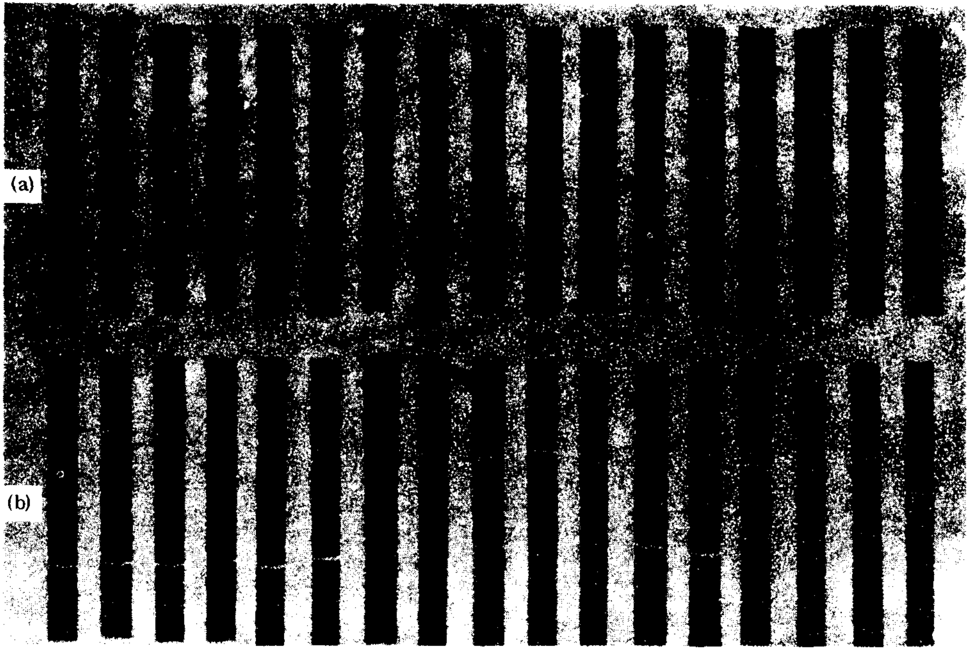

FIG. 2. Spectrum of ruby laser generation with the stabilization system turned on (a) and off (b).

radiation was incident on the interferometer 6 and the interferometer was attuned, with the aid of a dc source connected to the piezoceramic, to the form of the interference pattern (so that the zeroth order was always observed at the center). The gas-laser beam was covered when the ruby-laser spectrum was photographed.

The measurements have shown that after 1.5 hours of operation of the ruby laser (45 flashes 2 minutes apart) the rms deviation of the lasing frequency from the mean value, with the stabilization system turned on, amounted to 0.003 cm^{-1}, as against 0.12 cm^{-1} with the system turned off under the same conditions. The lasing frequency can be varied smoothly within the limits of the dispersion region of the interferometer 4 (within 1.7 cm^{-1} in our experiment) by varying the angle of incidence of the gas-laser beam on the working surface of this interferometer. Measurement of the energy and of the lasing threshold has shown that these parameters also become stabilized when the frequency is stabilized.

To generate giant pulses with the same frequency stability, we used the method of superregenerative amplification,[1] in which the external-signal source was the laser described above.

[1]A. N. Bondarenko, G. V. Krivoshchekov, and V. A. Smirnov, ZhETF Pis. Red. **9**, 100 (1969) [JETP Lett. **9**, 57 (1969). Zh. Eksp. Teor. Fiz. **56**, 1815 (1969) [Sov. Phys.-JETP **29**, 975 (1969)].