COMPARISON OF THE PARAMETERS OF RUBY AND NEODYMIUM
Q-SWITCHED LASERS

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It is shown that the rate of resonator Q-switching which determines the nature of a laser's output depends not only on the speed of prism rotation, but also on the optical properties of the active medium.

We have already studied the operation of neodymium Q-switched lasers [1]. The switching was effected by means of a rotating total internal reflection prism. Satisfactory agreement between the parameters computed from analytical formulas and those obtained experimentally indicated that in the case of a neodymium laser such an arrangement afforded practically instantaneous Q-switching.

The present paper contains the results of a study of a ruby Q-switched laser using the same Q-switching technique as in the first study. The measurements showed the giant pulses generated by the ruby laser to differ markedly in their parameters from the neodymium laser pulses. With the prism rotating at 25,500 rpm and a pumping energy of 2020 J, the neodymium laser generated a single pulse. With the same speed of prism rotation and a lower pumping energy (1520 J), the ruby laser generated two or three pulses of decreasing power. It was therefore of interest to make an experimental comparison of the ruby and neodymium laser parameters under similar operating conditions.

To this end we employed neodymium glass and ruby rods of the same dimensions. The illuminator, rotating prism, electrical components, and measuring portion of the apparatus were the same in both cases. The prism rotated at 24,000 rpm. The optimal mirror on the exit side of the neodymium laser had a 60% reflectance; in the case of the ruby laser the reflectance was 42%.

Fig. 1. Oscillograms of giant pulses from a neodymium (a) and ruby (b) lasers with the prism rotating at 24,000 rpm. Pumping energy: 1520 J (neodymium) and 2020 J (ruby); threshold pumping energies: 1000 and 1400 J, respectively; scanning rate: 50 and 100 nsec/division.

It is apparent from studies on Q-switched lasers [2-5] that the difference in generation pulses which we noted can be explained by taking account of the rates of change of the resonator Q from the threshold value \( Q_{\text{thr}} \) to the maximum value \( Q_{\text{max}} \). It was, of course, assumed that the active medium of the laser was supplied by the pumping source with power sufficient to produce the threshold inverse population \( n_{\text{thr}} \). With a pumping system capable of providing a broad range of energies, the quantity \( n_{\text{thr}} \) can be made to vary over a broad interval determined by the limits of variation of resonator Q-switching.

A qualitative illustration of the formation of various types of emission pulses (their number, energy, and time parameters) is presented below. Since rotation of the prism results in variation of the resonator \( Q \) from \( Q_{\text{min}} \) to \( Q_{\text{max}} \), the magnitude of the threshold inverse population varies continuously from \( n_{\text{thr}} \) to \( n_{\text{thr}} \). In describing the operation of Q-switched lasers one usually considers the Q-switch-on time \( t_{Q} \) and the pulse rise time \( t_{p} \). In the case of a rotating prism modulator, the Q-switch-on time is defined as the time of rotation of the prism from the angle \( \phi_{\text{thr}} \) which corresponds to the threshold value \( Q_{\text{thr}} \) for a given pumping power to the angle \( \phi = 0 \) corresponding to the maximum value \( Q_{\text{max}} \). Here \( \phi \) is the angle of nonparallelism of the resonator reflectors. The pulse rise time \( t_{p} \) is measured from the instant of attainment by the prism of the angle \( \phi_{\text{thr}} \) to the instant corresponding to the peak of the single pulse (or the peak of the first
pulse). The number of pulses and their power depend on the ratio of the quantities $t_Q$ and $t_p$. If $t_Q \approx t_p$, we can assume that Q-switching is instantaneous, and that generation takes the form of a single high-power pulse.

Evidently, for $t_Q > t_p$ and $Q_{\text{thr}} < Q_{\text{max}}$, the threshold value of the inverse population cannot attain the minimum value following generation of the first pulse, so that further increases in the resonator quality result in the appearance of the subsequent generation pulses. Since $\varphi_{\text{thr}}$ increases with increasing pumping power, for a given speed of prism rotation the number of pulses increases with the energy applied to the illuminator tubes. Hence, with high pumping energies, a high-power single pulse can be produced only with substantial prism rotation speeds. The rotating reflector is the most efficient type of modulator for use with a plane-parallel resonator, which is more sensitive with respect to reflector alignment than are other (spherical, cofocal, etc.) resonators.

Fig. 2. Oscillograms of giant pulses generated by a neodymium laser with different speeds of prism rotation. a) 25 500 rpm; b) 5500 rpm. The pumping energy in both cases was 1520 J. Scanning rate: 100 nsec/division.

The measured parameters of pulses generated by ruby and neodymium lasers given below are in good agreement with the pattern of Q-switched laser operation described above.

Figure 1 shows oscillograms of pulses generated by neodymium and ruby lasers. Comparing the oscillograms, we see that despite the equal speeds of prism rotation and the same pumping energy excess over the threshold level for the two specimens, the pulse parameters differed markedly. The first reason for this difference which comes to mind is, of