ON ONE POSSIBILITY OF INCREASING THE Q-FACTOR OF THE RESONATOR OF A NEODYMIUM OPTICAL QUANTUM GENERATOR

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Abstract

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ON ONE POSSIBILITY OF INCREASING THE Q-FACTOR OF THE RESONATOR OF A NEODYMIUM OPTICAL QUANTUM GENERATOR

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The Q-factor of the resonator of a solid-state optical quantum generator is determined by inactive absorption and scattering in the active medium, as well as by diffraction losses, which depend on the form of the resonator. In the case where the main losses are diffraction losses, the Q-factor depends substantially on defects in the manufacture of the resonator and on its thermal deformation caused by optical pumping of the active medium. The latter factor, owing to the spatial nonuniformity of the pumping, usually leads to an increase of losses in the resonator. In the present work it is shown that, under appropriate conditions, thermal deformation of the resonator can be used for a considerable increase of the resonator Q-factor.

By studying the dependence of the threshold pumping and of the generation power on the transmittance of the resonator mirror (^{1}), the losses (over a double length) σ_p and σ_g were measured in a plane resonator of an optical quantum generator on neodymium glass (the subscripts p and g correspond to losses measured from the threshold and from the generation power, respectively). Deviations from resonator flatness did not exceed $0.05\,\mu$, and the wedge was no more than $5''$. Light scattering in the glass samples did not exceed 0.004 cm^{-1}, and inactive absorption at wavelength $1.06\,\mu$ was $1.5 \cdot 10^{-3}$ cm^{-1}. The pumping regime ensured substantial excesses over threshold ($\geq 6 \div 20$) in the absence of noticeable thermal deformation.

The measurements showed that the resonator Q-factor under the experimental conditions is determined mainly by diffraction losses in the plane resonator. In particular, for a rod of diameter 0.5 cm and length 8 cm, with resonator length 28 cm, $\sigma_\mathrm{p} \simeq 0.41$, $\sigma_\mathrm{g} \simeq 0.09$. It can be shown that, taking into account the spatial competition of modes in the resonator, the expression for the generation intensity for a large number of excited modes and a considerable excess over threshold may be written in the form

$$W_{\mathrm{g}} \sim \frac{\ln 1/R}{\ln 1/R + \sigma_{\mathrm{av}}},$$

where R is the reflection coefficient of the mirror, and σ_{av} is the average diffraction loss for the oscillating modes. The angular divergence of the radiation in the case considered was $4'$ (at the level 0.1 of the maximum intensity), which corresponds to the excitation of $12 \div 18$ angular modes. Using the results of work (^{2}), one can find that in this case $\sigma_{\mathrm{av}} = 0.06 \div 0.1$, i.e., it agrees well with the measured value of σ_{g}^*. We note that the large value of σ_{p} is due, as special experiments have shown, to the nonuniformity of pumping over the cross section of the rod, which leads (at threshold) to the excitation of generation in a small (~ 0.15 cm) central zone of the rod, the losses then being large. At large excess over threshold

* The data obtained apparently indicate the absence of strong coupling between modes, under which the losses in the resonator decrease (^{3}).

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Fig. 1. Interferogram of the rod under periodic pumping.

saturation of the inverse population leads to leveling of the inversion over the cross section, and the quality factor of the resonator increases (see, for example, ^{4}).

To reduce diffraction losses in the resonator, thermal deformation of a neodymium-glass rod under optical pumping by periodically repeated pulses was used. The pumping system, consisting of a straight pulsed lamp and an illuminator, provided practically uniform illumination of the lateral water-cooled surface of the rod. At an electrical energy supplied to the pump lamp of $W_{\mathrm{e}} = 60$ J, the flatness of the resonator was not disturbed. If, however, at the same energy the pump pulses were periodically repeated with a frequency of the order of several hertz, a steady-state temperature gradient was established in the rod, leading to an axially symmetric spherical deformation of the rod (see Fig. 1, insert to p. 539). The focal length of the resulting positive lens in the resonator was ~ 1 m, which corresponded to the formation of a spherical resonator with a mirror curvature radius of 2 m (^{5}). In this case the quality factor of the resonator increased substantially, as was revealed from the change in the energy parameters of the optical quantum generator.

	$W_{\mathrm{e,thr}}$, J	W_{g}, J	W_{e}, J
Single pulses	25	0.2	60
Periodic pulses	9	1.2	60

When a rotating prism was used as one of the mirrors, the optical quantum generator operated in a monoimpulse mode; the generation energy decreased by only a factor of 2 compared with the free-running generation mode under identical pumping parameters ($W_\mathrm{e} = 200$ J) and sphericity of the resonator.

The formation of a spherical resonator is accompanied by an increase in the angular divergence of the radiation to $20'$. Since the diffraction losses of the resulting spherical resonator are very small, it is possible to reduce the radiation angle without a noticeable change in the output of the optical quantum generator by partial compensation of the thermal deformation. Thus, introduction into the resonator of an additional negative lens ($f = 2.9$ m) led to a decrease of the angle by ~ 2 times, while the generation energy decreased by 35%.

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