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Diode-pumped *Q*-switched Nd^{3+} : YAG laser operating in a wide temperature range without thermal stabilisation of pump diodes*

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Abstract. **A model sample of a compact low-power-consumption Nd^{3+} : YAG laser emitting 20-mJ pulses with a pulse repetition rate up to 20 Hz (in cyclic duty) at a wavelength of 1064 nm is developed and studied. The laser is designed for operating at external temperatures from –40 to +50 °C. This was achieved by using quasi-end diode pumping without thermal stabilisation of pump diodes.**

Keywords: *Nd^{3+} : YAG laser, diode pumping.*

One of the advantages of pumping solid-state lasers by diode lasers instead of pulsed gas-discharge lamps is lower power consumption and, as a result, lower weight and dimensions of the electronic control and power supply units. In addition, due to considerably lower heat release in the pump source and in the laser rod, in most cases it is not necessary to use liquid cooling of laser components.

However, the wavelengths of available high-power laser diodes strongly depend on the heterojunction temperature, which varies, in particular, due to heterojunction self-heating. For example, a change in the heterojunction temperature by 100 °C shifts the emission line by about 25 nm. At the same time, the typical width of the intense absorption line of Nd^{3+} ions in YAG crystals in the region of traditional pumping near 808 nm is ~1 nm. Therefore, as a rule, it is necessary to stabilise the temperature of pump laser diodes, which significantly increases the weight, size, and power consumption of laser systems.

Below, we present the results of development and investigation of a compact Nd^{3+} : YAG laser with a low power consumption and a pulse energy exceeding 20 mJ at a pulse repetition rate of 20 Hz (in cyclic duty). The laser operates in a wide temperature range without thermal stabilisation of pump laser diodes. The principal possibility of operating without thermal stabilisation is demonstrated by Fig. 1, which shows the absorption spectrum of a Nd^{3+} : YAG crystal in the region of the intense line with the wavelength $\lambda = 808$ nm, which is usually used for diode pumping.

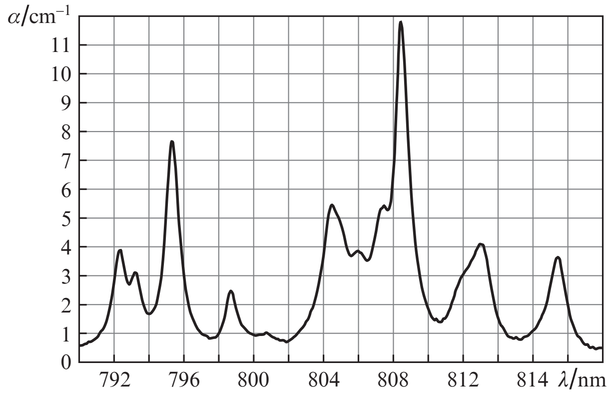

Figure 1. Absorption spectrum of Nd^{3+} ions in the YAG crystal.

From Fig. 1, one can see that the absorption coefficient of Nd^{3+} : YAG exceeds 0.5 cm^{-1} in the entire wavelength range from 790 to 820 nm, which corresponds to the wavelength range of the pump laser diodes at temperatures varying by 100 °C. Thus, the efficiency of absorption of longitudinal pumping by Nd^{3+} ions in a Nd^{3+} : YAG rod ~5 cm long in this wavelength range must be no lower than 90 %.

The pump beam is incident on the active element face at angles varying in a wide range. The polished lateral surface of the active element may provide waveguide propagation of the pump beam along the rod. However, in the *Q*-switched regime, the reflection from the polished lateral surface prevents the accumulation of sufficient inverse population due to the occurrence of parasitic oscillations inside the laser rod. To avoid the parasitic oscillation, one usually uses rods with matted lateral surfaces. On the other hand, in the case of end pumping, the most part of pump beams does not propagate along the active element but falls onto its rough lateral surface, scatters on it, and thus leaves the rod. The parasitic oscillations can also be suppressed by using Nd^{3+} : YAG laser rods with a cladding that absorbs radiation at $\lambda = 1064$ nm and transmits the pump radiation [1].

To increase the pump efficiency for a laser rod with the matted lateral surface, we used a scheme of so-called quasi-longitudinal pumping (a variant of this scheme is given, for example, in [2]). The optical scheme of the laser head is presented in Fig. 2.

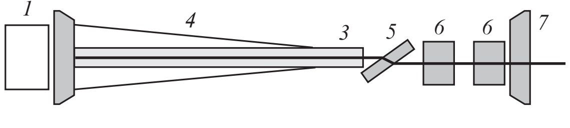

Figure 2. Optical scheme of the laser head (see explanation in the text).

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The emission of a pump laser diode array (*1*) is coupled into a laser rod (*3*) of the solid-state laser through a cavity mirror (*2*). The reflection coefficient of this mirror at the laser wavelength is near 100% and is low in the wavelength range $\lambda = 790-820$ nm (the mirror transmittance is no lower than 95% in the entire range of angles of pump beam incidence). The Nd^{3+} : YAG laser rod has a length of 5 cm and a diameter of 3 mm, while the diode array has an emitting area with dimensions of 4×10 mm and an output power up to 2 kW at a wavelength of 800 nm at room temperature. A portion of the laser diode array radiation is incident directly onto the end of the laser rod, and the most part of radiation passed through the lateral surface of the laser element is returned into it by a hollow silvered cone concentrator (*4*). It should be noted that this concentrator allows one not only to obtain efficient quasi-longitudinal pumping, but also to considerably decreases the laser head length in comparison with typical concentrators [3] for purely longitudinal pumping. A quarter-wave electrooptic Q-switch (*6*) is placed between an output coupler (*7*) and a thin-film interference polariser (*5*). The components of the optical scheme are located in a closed titanium housing. The weight of the head is 200 g, and the dimensions are 33×39×126 mm. The external appearance of the laser head is shown in Fig. 3.

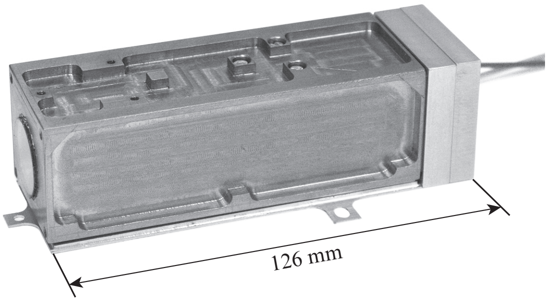

Figure 3. Appearance of the laser head.

The electronic scheme of the laser consists of a pulsed high-current laser diode driver (LDD) supplying the laser diode array and a HV Q-switch driver.

The LDD principle of operation is based on a partial discharge of a capacitive energy storage in the form of a battery of aluminum electrolytic capacitors with a low equivalent serial resistance (low ESR) via a two-channel high-frequency switch-mode current regulator.

In the more widespread LDDs with a partial discharge of the capacitive storage via a controlled cw current regulator, the battery of capacitors occupies almost the entire LDD volume. The LDD with a high-frequency switch-mode current regulator makes it possible to considerably increase the storage voltage (which increases the energy density of capacitors) and simultaneously to decrease the total storage energy. As a result, we managed to reduce the total volume of capacitors at least by 2–2.5 times compared to pulsed LDDs with cw discharge current regulators. The LDD output current is variable from 200 (and lower) to 350 A, and the load voltage can be changed within the range of 15–20 V. The current pulse duration can be controlled within 70–220 μs, while the current pulse rise time changes from 5 to 10 μs (increases with increasing current). The output pulse energy reaches 1 J, and the maximum average load power is 20 W.

The principle of operation of the Q-switch driver is based on switching of high voltage in the Q-switch circuit by a transistor gate. The Q-switch driver provides dc and pulsed voltage from 0.5 to 1.6 kV with a pulse rise time of about 10 ns. The Q-switch driver dimensions are 109×33×15 mm.

The LDD and the Q-switch driver were supplied from a non-stabilised dc voltage source. The operating voltage ranged from 10 to 17 V. The total volume occupied by the LDD and the Q-switch driver is about 200 cm^3, and their working temperature range extends from –40 °C to +60 °C.

The performed tests of the laser showed that, at a pump energy of 260 mJ (laser diode array power 2 kW, pump pulse duration 130 μs), the single pulse energy reached 35 mJ. Further increase in the pump energy and, hence, in the laser pulse energy, could cause laser breakdown of resonator components, first of all, of the electrooptic Q-switch, which has the lowest radiation resistance among the cavity elements. The single pulse duration was 5–7 ns, and the divergence was 3 mrad. It should be noted that these tests were carried out under room conditions with pumping both by single pulses and by pulses with a repetition rate of 2 Hz. The pump radiation wavelength was recorded by a high-speed spectrometer, and, at a pulse repetition rate of 2 Hz in the considered regimes, was found to change from 800 to 802.5 nm due to the laser diode array self-heating. Thus, as follows from Fig. 1, our pump scheme showed satisfactory results even at one of the critical points of the considered spectral range, namely, at the point of the minimum absorption coefficient. At higher pulse repetition rates, the laser operated in cyclic duty. For example, at a pulse repetition rate of 20 Hz, the energy of single pulses of this laser did not fall below 20 mJ in a cycle with a duration up to 60 s. A typical time dependence of the output laser energy at a 20-Hz pulse repetition rate is shown in Fig. 4.

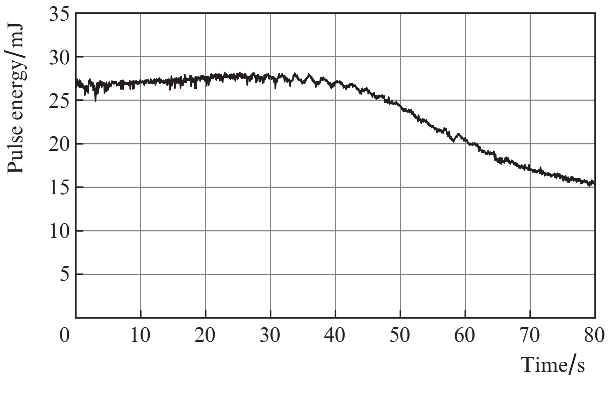

Figure 4. Typical time dependence of the laser output energy at a pulse repetition rate of 20 Hz.

The operation of the laser head placed into a chamber with controlled temperature is demonstrated in Fig. 5. The pump radiation wavelength was measured by a high-speed spectrometer. For clearness, Fig. 5 also presents the absorption spectrum of Nd^{3+} ions in the YAG crystal. One can see that the working temperature at which the laser energy decreases to 10 mJ is approximately –30 °C. Obviously, the output energy decreases because the pump wavelength at this temperature is shorter than the short-wavelength edge of the Nd^{3+} absorption in the YAG crystal, since the laser diode array wavelength at room temperature is 800 nm. We may expect that, at

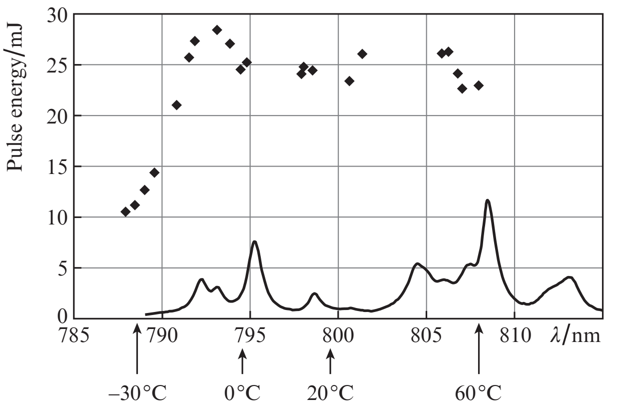

Figure 5. Laser output energy vs. the pump wavelength (points) and Nd^{3+} : YAG absorption spectrum (curve).

the initial laser diode array wavelength of ~805 nm, the laser will also be able to operate at a temperature of –40 °C.

Thus, the use of quasi-end diode pumping makes it possible to develop compact Nd^{3+} : YAG lasers with a weight of about 0.5 kg operating with a pulse energy higher than 20 mJ and a pulse repetition rate of 20 Hz (in cyclic duty) in a wide temperature range without thermal stabilisation of pump laser diodes.

References

1. Huß R., Wilhelm R., Kolleck C., Neumann J. *Opt. Express*, **18** (12), 13094 (2010).
2. Yuan G., Chong T.C., Xu B. *Appl. Opt.*, **37** (18), 3971 (1998).
3. Shilling B.W., Chinn S.R., Hays A.D., Goldberg L., Trussell C.W. *Appl. Opt.*, **45** (25), 6607 (2006).