Method development to secure the stability of the parameters of pulsed and continuous radiation in laser systems with semiconductor pumping

S R Abdurakhmanova¹, ², G D Bukharov¹, Z S Gheisser², V V Davydov¹, ³ and V Yu Rud³

¹ Peter the Great Saint-Petersburg Polytechnic University, Saint Petersburg, Russia, 195251
² LLC FEDAL, Saint Petersburg, Russia, 197342
³ All-Russian Research Institute of Phytopathology, Moscow Region 143050, Russia

sofya.abdurakhmanova@mail.ru

Abstract. The necessity of increasing the stability of the parameters of pulsed and cw laser radiation when operating at peak powers is substantiated. Particular attention is paid to the parameters of pulsed laser radiation in systems with semiconductor pumping. The main requirement in this case is the repeatability of the parameters of the output pulses with high accuracy. This condition is ensured by the stability of the diode supply drivers, especially at peak powers, which are required for scientific research. It was found that even a short-term excess (about 1 ms) of the upper range of the permissible current leads to damage to the laser diode, which instantly degrades the parameters of laser radiation. The developed technique can significantly reduce the likelihood of these phenomena and increase the reliability of the laser.

1. Introduction

At present, lasers are used in all areas of nanophotonics and in many areas of optics [1–10]. The most widely used are diode-pumped semiconductor lasers operating in both cw and pulsed modes [10-18]. When carrying out many scientific research and practical work, especially in industry, high power of laser radiation with a high degree of stability of its parameters is required [7-10, 13-15, 19-24]. The most critical is the operation in a pulsed mode [25-29]. Special requirements for the stability of pulsed laser radiation arise when it is used in radars for various purposes or in lidar installations when working with moving objects [30–37].

Any failure in the operation of laser systems at high powers is highly undesirable. Taking into account the fact that constantly to solve new problems it is necessary to increase the peak power of laser radiation [38-41], the need to develop devices that will control, adjust and maintain expensive laser equipment is extremely urgent. The paper presents a developed technique for monitoring the parameters of power supplies for diode drivers that perform semiconductor pumping of a laser and its practical implementation.

2. Experimental setup and research method

In laser systems currently in operation, there are allowable offsets in the wavelength λ for laser diodes, which differ in operating ranges. For example, in IR for λ = 808 nm and higher, the shift to longer wavelengths with increasing temperature is 0.2-0.3 nm per degree. The presence of such tolerances
allows the stabilization system to restore the temperature regime and control the process of changing \( \lambda \). With large sharp temperature effects or an increase in current (operation at peak powers), which leads to heating, mode effects appear in laser radiation. The pulse duration changes, the edges are distorted, etc. It becomes impractical to use such radiation.

The current stabilization circuits of the pump diode operating mode when operating at peak powers with short pulses (on the order of microseconds or less) and high duty cycle do not provide the necessary stability of the edges, etc. The classic circuit for comparing currents is malfunctioning. Therefore, in the method developed by us to stabilize the parameters of laser radiation, it is proposed to use a modernized current comparison circuit. Calculations and experiments have shown that the use of the bridge method with a voltage difference of 10 V between the arms of the circuit allows you to work out a sharp increase in voltage and start the stabilization process at the initial distortion section, in contrast to other circuits that work out the result of the completed process or at the stage of its completion.

To implement our proposed technique in the current comparison circuit, we developed a voltage converter supplied to the input of the laser diode power supply to a constant voltage of 10 V. The circuit of the new converter is shown in figure 1.

![Figure 1. The voltage converter.](image)

The main control element in the LM5007 converter is the feedback comparator. The output voltage of the regulator is measured at the feedback pin (FB) and compared to an internal 2.5 V reference. If the FB signal is below the reference voltage, the comparator switch is turned on for a fixed time pulse determined by the input voltage and resistor R17. The minimum recommended opening time is 300 ns, at the maximum input voltage. Accordingly, the resistor is selected so that at 55 V at the input, the opening time is at least 300 ns. If the voltage at the FB pin remains below the reference value, the comparator will turn on again. This switching will continue until the voltage at the FB pin reaches the reference voltage level.

Also, the LM5007 has a built-in comparator designed to protect the output of the circuit from overvoltage due to a surge in the input voltage or a change in the load at the output. The overvoltage comparator monitors the FB pin against an internal 2.875 V reference. If the voltage on the FB rises above 2.875 V, the comparator shuts down the regulator immediately.

Thus, a voltage equal to the driver supply voltage is supplied to the input of the converter, and a stable voltage of 10 V is obtained at the output of the circuit, which is fed to the voltage adjustment pin of the LM5116 controller. In figure 2 shows a new circuit for comparing currents developed by us.

In the current comparison circuit, the target current supplied to the UPR input is compared with the actual load current supplied to the left arm of the circuit at the Iout input. The principle of operation of the circuit is as follows. If the sum of the voltages in the left and right arms of the circuit is 10 V, then
the system is stabilized, a signal of 1.215 V is applied to the FB input of the LM5116 microcircuit, equal to the reference voltage of the error amplifier in the microcircuit, in this case, the driver works in a steady state.

![Figure 2. The current comparison circuit.](image)

If the sum of the voltages is more than 10 V, then a signal is supplied to the input of the LM5116 FB microcircuit that is greater than the reference voltage of the error amplifier. In this case, the error amplifier will reduce the duty cycle, and, accordingly, reduce the input voltage, thereby the current supplying the load will also be less.

If the FB signal is less than the reference, then the amplifier will increase the output voltage, thereby increasing the output current, respectively, the signal supplied to the $I_{\text{out}}$ input of the comparison circuit will increase, while in the left arm of the circuit, the voltage will increase until the sum of the voltages becomes 10 V, and the FB signal equals the reference signal of the error amplifier in the microcircuit.

3. Result of experimental investigations

In figure 3 the results of the work of a new power driver circuit developed by us with the current comparison method implemented in it are shown.

![Figure 3. Power driver output signal: (a) - unstable mode is present; (b) - compensation of signal distortions.](image)

The results obtained show that the use of the new circuit makes the distortion values insignificant in relation to the signal amplitude at the output of the power driver.

As an optical result, figure 4 shows the directional diagram of laser radiation, where curve 1 was taken after stabilization of the power supply, curve 2 - before stabilization of the noise of the power supply at the initial stage.
Analysis presented in figure 4 of the measurement results shows that even with small noise in the power driver, distortions occur in the laser radiation pattern, which do not allow the use of this radiation for solving many practical and scientific problems.

4. Conclusion
The obtained experimental results of the operation of the stabilization scheme with the developed technique showed that most of the distortions in the fronts of laser pulses associated with the initial section of overheating of the laser diode becomes insignificant, even at its high steepness. There is also no mode distortion in laser radiation compared to the use for stabilization of other techniques.

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