PACS numbers: 42.55.Rz; 42.55.Xi; 42.60.Fc
DOI: 10.1070/QE2008v038n10ABEH013836

Jitter and the minimal pulse repetition rate of a diode-pumped passively *Q*-switched solid-state laser

M.I. Belovolov, A.F. Shatalov

***Abstract*.** **The jitter of radiation pulses from diode-pumped passively *Q*-switched $Nd^{3+}:Y_3Al_5O_{12}$ (Nd : YAG) and $Nd^{3+}:Ca_3Ga_2Ge_3O_{12}$ (Nd : CGGG) crystal lasers is studied. It is found that the jitter j depends on the laser pulse repetition rate f as $j = A/f^{\gamma}$. It is shown that the minimal pulse repetition rate f_L of the laser is determined by the jitter parameters A and γ and is equal to $A^{1/(\gamma-1)}$. For the Nd : YAG and Nd : CGGG lasers, f_L was 14 Hz and 5 Hz, respectively.**

Keywords: *solid-state lasers, diode pumping, passive Q-switching, pulse jitter.*

1. Introduction

The application of diode-pumped pulsed solid-state lasers (SSLs) in various fields of science and technology is promising due to their reliability as well as the simplicity of the device and maintenance. At present, compact diode-pumped pulsed passively *Q*-switched SSLs are being actively developed [1 – 3]. In these SSLs both the well-known $Nd^{3+}:Y_3Al_5O_{12}$ (Nd : YAG) [1, 3] crystal and a calcium – gallium – germanium garnet $Nd^{3+}:Ca_3Ga_2Ge_3O_{12}$ (Nd : CGGG) [2], which is relatively new for these applications, are used as laser elements.

Along with other operation parameters of pulsed SSLs, the stability and the minimal laser pulse repetition rate f are of interest. These parameters are determined by the jitter of SSL pulses.

In this paper, we studied the jitter of radiation pulses from diode-pumped passively *Q*-switched Nd : YAG and Nd : CGGG lasers and determined the lowest pulse repetition rate f_L of these lasers.

2. Experimental

The scheme of the experimental setup for studying the jitter of SSL pulses is presented in Fig. 1. Laser diode (*1*) with fibre output (*2*) (numerical aperture NA = 0.22, the core diameter $d_c = 100$ μm) was used for pumping. The pump wavelength λ_p was 805 nm and the laser linewidth $\Delta\lambda$ was ~ 2 nm. Microlens (*3*) focused radiation from the output end-face of fibre (*2*) into a 90-μm spot on laser element (LE) (*4*) fixed on a copper heatsink with a thermal paste. The front LE face (blackened in Fig. 1) served as the input mirror, while spherical mirror (*6*) (radius 5 cm, transmission coefficient 0.01) was the output mirror of the laser resonator. 1-mm-thick Cr^{4+} : YAG saturable absorber (*5*) which had an AR coating at 1.06 μm and the transmission coefficient 0.9 at low radiation intensities incident on it was placed in the laser resonator. The concentration of Nd^{3+} ions in the Nd : YAG laser crystal was 0.8×10^{20} cm^{-3} and its thickness was 4.1 mm and 70 % of pump radiation was absorbed per transit in this LE. The Nd^{3+} concentration in the Nd : CGGG crystal was 2.0×10^{20} cm^{-3}, the LE thickness was 1.5 and 70 % of pump radiation was absorbed per transit.

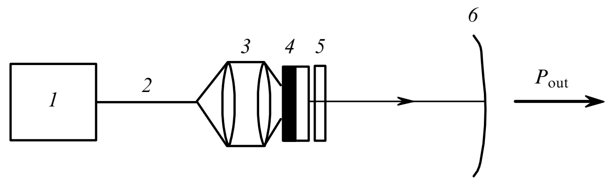

Figure 1. Scheme of the experimental setup for studying the jitter of radiation pulses from a diode-pumped passively *Q*-switched SSL: (*1*) laser diode; (*2*) optical fibre; (*3*) microlens; (*4*) laser element; (*5*) saturable absorber; (*6*) output spherical mirror.

3. Results and discussion

The typical shape of the SSL pulse is shown in Fig. 2a. The Nd : YAG laser emitted 15-ns, 2.1-μJ pulses. The pulse repetition rate f of the Nd : YAG laser varied from 4 to 35 kHz, when the absorbed pump power was changed from 0.35 to 1 W. The Nd : CGGG laser emitted 11-ns, 3.5-μJ pulses. The pulse repetition rate f varied from 3 to 13 kHz when the absorbed pump power was changed from 0.45 to 1 W. The wavelength of these lasers was 1.06 μm.

The jitter of the SSL pulses was manifested as random variations in the SSL repetition rate or pulse repetition period, i.e. time intervals between the peaks of adjacent laser pulses. The random scatter in the SSL pulse repetition periods was visualised on the oscilloscope screen (Fig. 2b). The oscilloscope operated in the storage regime, when each subsequent pulse was recorded on the screen with respect to

M.I. Belovolov, A.F. Shatalov Fiber Optics Research Center, Russian Academy of Sciences, ul. Vavilova 38, 119333 Moscow, Russia; e-mail: bmi@fo.gpi.ru, shatalov@fo.gpi.ru

Received 27 February 2008
Kvantovaya Elektronika **38** (10) 933 – 934 (2008)
Translated by I.A. Ulitkin

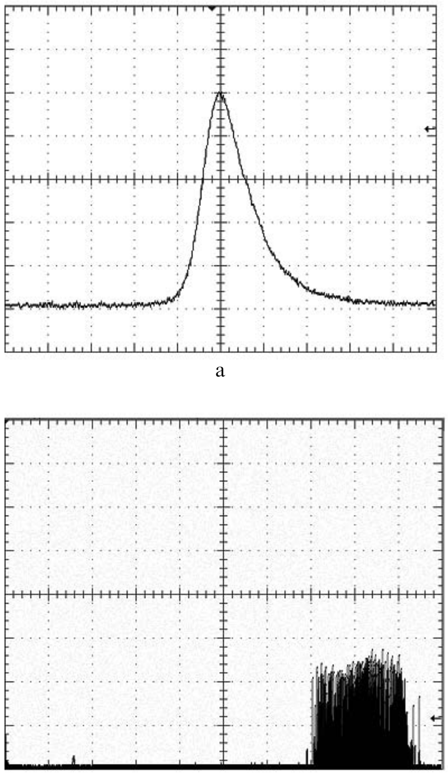

Figure 2. Typical shape of a SSL pulse, the scan rate is 10 ns div^{-1} (a) and the random scatter in the pulse repetition periods, the scan rate is 10 μs div^{-1} (b).

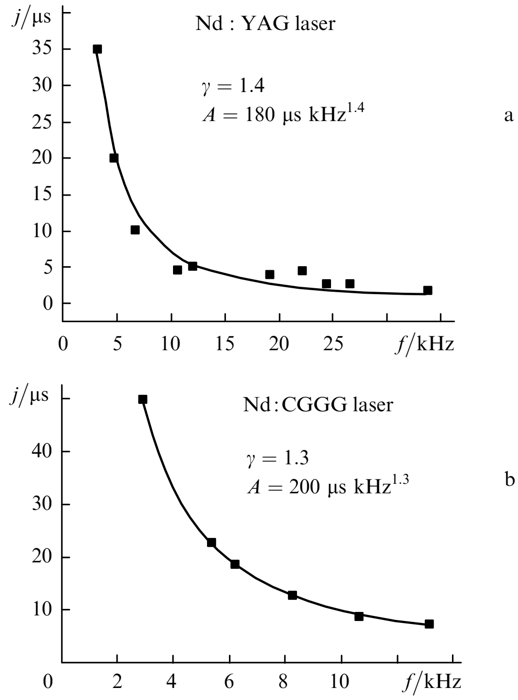

Figure 3. Experimental dependences of the jitter j of SSL pulses on the pulse repetition rate f for the Nd : YAG and Nd : CGGG lasers (points). The solid curve shows the function $j = A/f^{\gamma}$.

the previous one serving as the scan onset. The jitter j of SSL pulses was set equal to 1/4 of the pulse scatter on the oscilloscope screen and was determined as a standard deviation of the pulse repetition period from its average (expected) value T. The pulse repetition rate f was also assumed equal to its average value for $f = 1/T$.

Figure 3 presents the dependences of the jitter j of SSL pulses on the pulse repetition rate f of both lasers. The analysis of the obtained results shows that the value of the jitter j is well approximated by the function $j = A/f^{\gamma}$, where the jitter parameters γ and A are 1.4 and 180 μs kHz$^{1.4}$ for the Nd : YAG laser and 1.3 and 200 μs kHz$^{1.4}$ for the Nd : CGGG laser, respectively.

The jitter is the most considerable at the lowest pulse repetition rate f of the generation range of Nd : YAG and Nd : CGGG lasers, when the absorbed power P insignificantly exceeds the SSL threshold. When f increases, j decreases and becomes less than 10 % at the maximal pulse repetition rate of laser pulses.

If the jitter j becomes equal to the pulse repetition period $T = 1/f$ of the SSL, the concept of the pulse repetition rate f and period T makes no sense. Therefore, we determined the minimal pulse repetition rate of the SSL from the condition $j = 1/f_L = A/f_L^{\gamma}$. In this case, the pulse repetition rate f_L is expressed in terms of the jitter parameters A and γ as $f_L = A^{1/(\gamma-1)}$. Then, the value of the minimal pulse repetition rate f_L will be 14 Hz and 5 Hz for the Nd : YAG and Nd : CGGG lasers, respectively.

4. Conclusions

The jitter j of pulses from diode-pumped passively Q-switched Nd : YAG and Nd : CGGG SSLs has been studied. The wavelength of both lasers was 1.06 μm, the pulse duration and energy were 15 ns and 2.1 μJ, respectively, for the Nd : YAG laser and 11 ns and 3.5 μJ, respectively, for the Nd : CGGG laser, and when the absorbed pump power was changed, the pulse repetition rate f was in the range from 4 to 35 kHz and from 3 to 13 kHz, respectively.

It has been found that the jitter j is depends on the pulse repetition rate f as $j = A/f^{\gamma}$. It has been shown that the minimal laser pulse repetition rate f_L is determined by the jitter parameters γ and A and is equal $A^{1/(\gamma-1)}$. The parameters γ, A and the pulse repetition rate f_L for the Nd : YAG and Nd : CGGG lasers are 1.4, 180 μs kHz$^{1.4}$, 14 Hz and 1.3, 200 μs kHz$^{1.3}$, 5 Hz, respectively.

References

1. Agnesi A., Dell'Acqua S., Morello C., Piccino G., Reali C.G., Zhaoyang Sun. *IEEE J. Sel. Top. Quantum Electron.*, **3**, 45 (1997).
2. Montes M., Heras C., Jaque D. *Opt. Materials*, **28**, 408 (2006).
3. Zayhowski J.J., Dill C. *Opt. Lett.*, **19**, 1427 (1994).