Wide dynamic range picosecond distributed feedback dye laser

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One of the most important merits of the dynamic distributed feedback (DFB) dye lasers is their ability to generate single ultrashort (US) pulses by relaxation oscillations mechanism under nano-, subnanosecond excitation [1]. In fact, such an approach represents the simplest way to obtain single US pulses of a few tens of ps duration with continuously tunable wavelength. With this method, single US pulses are generated when the pump energy E_P is not very far from its threshold value E_{Thr}. Otherwise, the multi spike emission takes place. The maximum permissible degree of the threshold exceeding at which single US pulse is still generated is called the dynamic range $\gamma_{1\text{-}2}$ of the picosecond DFB dye laser. The latter is given by $\gamma_{1\text{-}2} = 100\,\%(E_{2Thr} - E_{Thr})/E_{Thr}$, where E_{2Thr} is the second pulse threshold. The value of this parameter is of great practical importance: the larger the $\gamma_{1\text{-}2}$, the less stringent are the requirements to the energy stability of the pump source and the more stable and powerful are generated single US pulses. Therefore, the development of simple and reliable methods for extending the dynamic range of the picosecond DFB dye lasers is an urgent task.

To date, a set of methods for the single US pulse generation by the DFB dye lasers pumped well above the threshold have been proposed and realized [2–7]. Unfortunately, most of them suffer from the complicity and insufficient efficiency. In this work, a new simple and efficient technique for extending the dynamic range of the picosecond DFB dye lasers is proposed and implemented. The essence of the method is illustrated by Fig.1, which shows the traditional (*a*) and proposed (*b*) geometry of the DFB dye laser active medium excitation. In the first case, a spatial grating of length L_{DFB} and height *h* is formed along the entire length L of the excited dye volume (EDV) ($L_{DFB} = L$), and its planes are perpendicular to the longitudinal axis of the specified volume. Since the DFB lasing radiation is formed along the direction, normal to the grating planes, and the amplified spontaneous emission (ASE) is developed along the longitudinal axis of the EDV, their beams are spatially coincident. In the second case, the EDV of length *L* and height *h* is rotated by an angle α relative to the plane of incidence of the two pumping beams 1, 2. As a result, the grating planes form the angle (90° – α) with the longitudinal axis of the EDV. Additionally, on the part of the EDV of length $l = L - L_{DFB}$ there is no grating

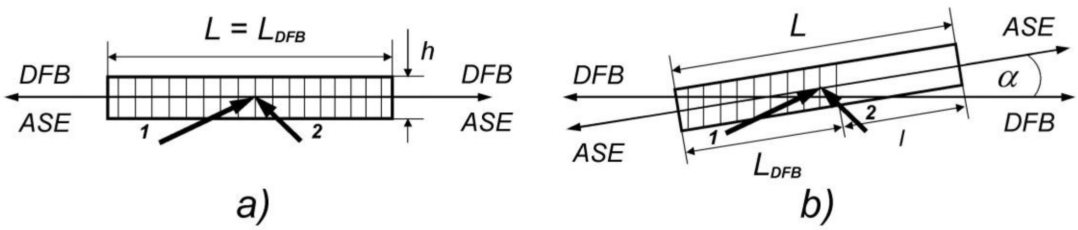

Fig.1. The traditional (*a*) and proposed (*b*) geometry of the DFB dye laser active medium excitation

(the latter is easily achievable by partially blocking one of the pumping beams). As a result, this zone becomes the source of ASE rather than DFB lasing. With such a geometry, the DFB lasing and ASE beams turn out to be spatially separated by the above angle α. This creates favorable conditions for the light quenching of the active medium gain in the EDV with grating by the ASE beam coming from the EDV without grating. We established that at a given pump power density the rise times and peak intensities of the DFB lasing and ASE pulses are functions of their zone lengths and tend, respectively, to decrease and increase with increasing the L_{DFB} and l values. It means that by gradually changing the ratio L_{DFB}/l (at $L = const$) it becomes possible to smoothly adjust the DFB lasing and ASE relative rise times and intensities. In this way, the conditions can be realized under which the ASE pulse at the right time passing through the EDV with grating as through an amplifier becomes able to reduce the active medium gain to a subthreshold level just after the first US pulse is generated. In this way, the generation of all subsequent undesired pulses in the US pulse train can be completely suppressed.

The above considerations were verified by us experimentally. For this purpose a DFB dye laser of original design excited with a *STA01SH-500* diode-pumped solid-state (DPSS) *Nd:LSB* micro laser ($\tau_{0.5} \approx$ 0.5 ns; λ_P = 532 nm; $E_P \leq$ 80 μJ; $f \leq$ 500 Hz) (*Standa Ltd., Lithuania*) was employed. Rhodamine 6G ethanol solution with a concentration of C_d ≈ 0.25 mM was used as an active medium. The energy characteristics were investigated with calibrated *FD-24K* photodiodes coupled to an *ADC20M/20-2* analog-to-digital converter. The transient behavior of the pump and DFB laser output pulse intensities was studied using an *Agat-SF3* streak camera (temporal resolution up to ~ 2 ps). Spectral measurements were performed with a fiber-coupled *S3804* automated diffraction grating spectrograph (spectral resolution up to ~ 0.08 nm). A DFB laser was set to operate at f = 10 Hz, $L \approx 1$ cm and λ_L = 568 nm, falling into the dye amplification band maximum.

Our studies have shown that at L = const by an appropriate adjustment of the α and L_{DFB} values it is really possible to quench all subsequent pulses in the US pulse train except the first one. As an example, Fig. 2 shows pulses from the unquenched (*a*) and quenched (*b*) DFB dye lasers under the highest possible in the experiment pumping level $\gamma = E_P / E_{Thr} \approx 6.8$ ($E_{Thr} \approx 1.9$ μJ). The other parameters were as follows: $\alpha \sim 2.1°$, $L_{DFB} \approx 5$ mm; $h \approx 0.16$ mm.

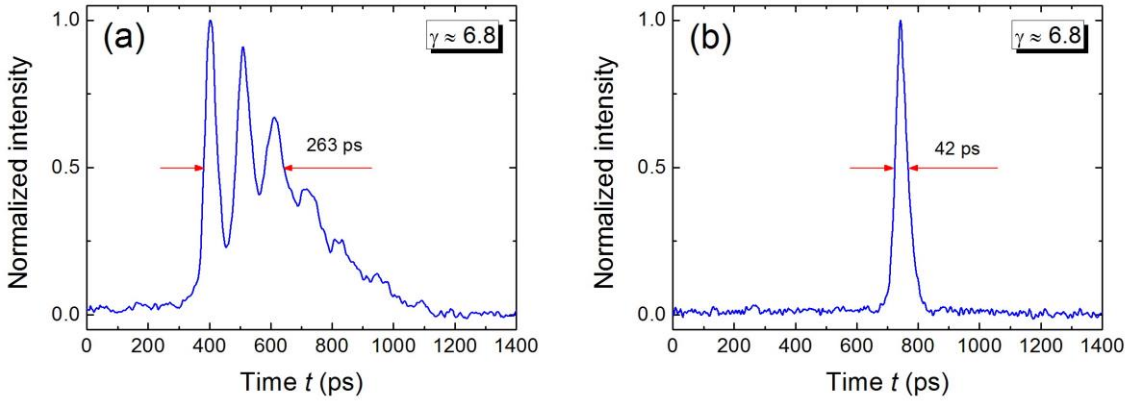

Fig. 2. Unquenched (*a*) and quenched (*b*) DFB dye laser pulses

It can be seen from Fig. 2 that in the absence of quenching a DFB laser generates a structural pulse with a duration of $\tau_{0.5} \approx 0.263$ ns under integral width of $\tau \sim 0.9$ ns. At the same time, with quenching a single US pulse of $\tau_{0.5} \approx 42$ ps length is produced by a DFB laser thus exhibiting $\gamma_{1\text{-}2} \approx 580$ %. The energy of thus obtained single US pulses was $E_L \approx 0.204$ μJ, which is ~ 5 times higher than that provided by an unquenched DFB laser generating ~ 20–30 % longer single US pulses at a considerably lower value of $\gamma_{1\text{-}2} \approx 50$ %.

Thus, the realized method for the single US pulse generation allowed us by ~ 12 times to extend the dynamic range of the subnanosecond laser pumped picosecond DFB dye laser while simultaneously reducing the US pulse width and significantly increasing its energy. To the best of our knowledge, the dynamic range achieved in this work is the widest among ever reported for picosecond DFB dye lasers of this type.

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