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Effect of optical feedback on the output parameters of quantum-well superluminescent diodes

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***Abstract*. The effect of a weak optical feedback on the power and spectral parameters of light-emitting modules based on near-IR quantum-well superluminescent diodes (SLDs) is studied. It is shown that even very weak parasitic feedback ($k_{fb} < -30$ dB) distorts the emission spectrum of high-power SLDs and noticeably reduces their output power.**

Keywords: *superluminescent diode, quantum-well heterostructure, optical feedback*.

1. Introduction

A superluminescent diode (SLD) is a semiconductor laser amplifier having typically a high single-pass optical gain but operating without any external perturbations in the regime of amplification of its own spontaneous emission. An external spectrally matched signal can radically change the output parameters of the SLD and, under certain conditions, even can cause its degradation. This also concerns the intrinsic superluminescence, which can return to the active channel of the SLD due to parasitic reflections in the elements of optical schemes.

In most practical applications the SLD modules with fibre pigtails are used. In this case, the above-mentioned problem is solved by placing an optical isolator at the module output. Numerous highly efficient miniature fibreoptic isolators have been developed for the telecommunication spectral range between 1300 and 1600 nm. Unfortunately, optical isolators in the near-IR region are rather bulky, very expensive, have a higher relative level of losses and a narrower spectral isolation band. For this reason, the designers of the corresponding optoelectronic equipment prefer to avoid the use of near-IR isolators whenever possible. Therefore, reliable data on the parasitic feedback level admissible for SLD modules are of current interest.

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Applications of a new contactless and nondestructive method of medical diagnostics, optical coherent tomography (OCT), are rapidly expanding in the last years [1]. This method is especially widely used in ophthalmology. The corresponding OCT systems employ mostly near-IR radiation sources emitting in the region between 800 and 950 nm. The most popular among them are SLDs. In particular, SLD-371 light-emitting modules based on a single-layer quantum-well (GaAl)As heterostructure [2, 3], which have been developed in the mid-1990s and are being improved till now, have found applications in various high-resolution OCT systems. Depending on the design of these SLDs, their cw power at the output of a single-mode fibre (SMF) can be from 1.0 to 25.0 mW, while the half-width of the emission spectrum of an SLD at a certain injection current can achieve $\sim$50 nm, which is provided by equating the spectral maxima corresponding to quantum transitions from the ground and first excited subbands. A change in the operation regime caused by a change in the injection current results in the deformation and narrowing of the spectrum, thereby increasing the coherence length. The same can occur when an optical feedback appears due to parasitic reflections of the SLD emission from external optical elements. The aim of this paper was to study and describe quantitatively this effect for different SLD modules.

2. Scheme of measurements and experimental results

At present four types of light-emitting SLD-371 modules are manufactured, MP, HP1, HP2, and HP3, with the minimal power at the SMF output equal to 1.0, 5.0, 10.0, and 20.0 mW, respectively. Modules of the first two types are usually assembled in DIL housings, while higher-power modules – in Butterly housings. A standard module contains an SLD mounted on a thermoelectric microcooler, a thermistor built in the SLD heat conductor, and a photodiode monitor located opposite the rear face of the SLD. The photodiode allows the use of SLD modules in systems with the automatically controlled optical power. The location of the photodiode inside the modulus excludes the appearance of a parasitic optical feedback. The front facet of the SLD is precisely adjusted and rigidly fixed with respect to the input facet of SMF. At the output facet of the latter, an FC/APC connector is usually mounted, which also excludes the appearance of an optical feedback. If the pigtail of the SLD module is connected with the help of a connector or spliced to the external fibreoptic system, in which parasitic reflections are present, then in the absence

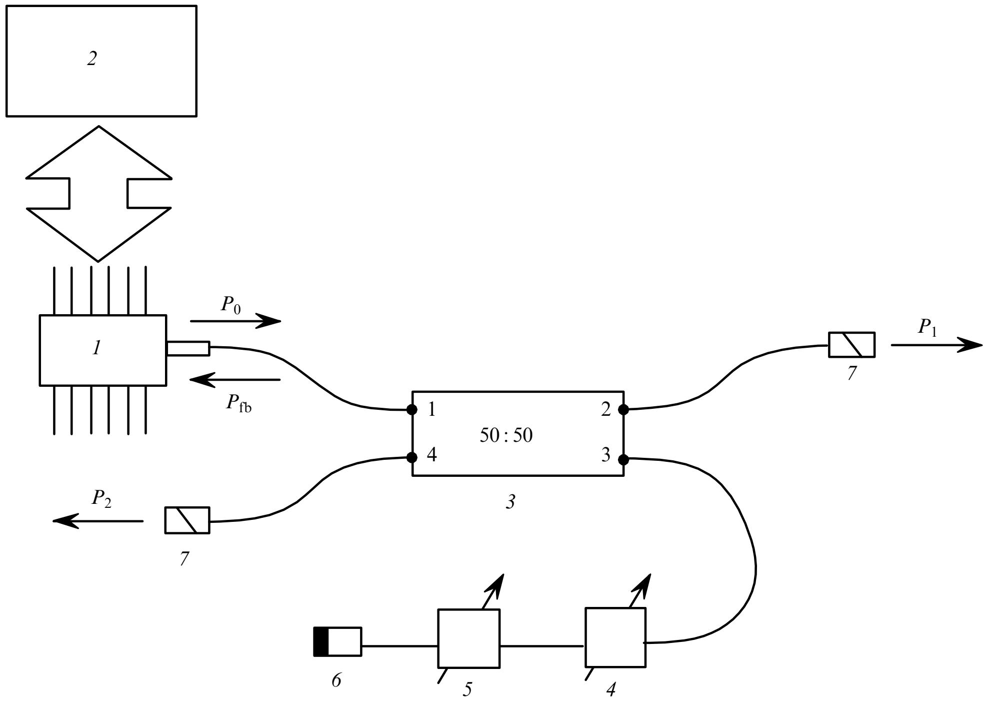

Figure 1. Measuring scheme: (*1*) SLD-371 light-emitting module; (*2*) PILOT-4 electronic driver; (*3*) single-mode X-coupler; (*4*) polarisation controller; (*5*) tunable optical attenuator; (*6*) fibreoptic mirror; (*7*) FC/APC fibreoptic connector.

of an optical isolator a reflected signal can easily enter the active channel of the SLD.

The measuring scheme is shown in Fig. 1. SLD module (*1*), mounted in a special holder, was connected to PILOT-4 specialised electronic driver (*2*), which provided the injection current for the SLD, its thermal stabilisation, and displayed the current I_{phd} of the built-in photodiode. All the measurements were performed at a temperature of 25 °C in the regime of automatic control of the cw injection current. The automatic power control system was not used. The output SMF of the modules was spliced to port 1 of symmetric broadband SMF X-coupler (*3*). The optical transfer characteristics T_{ij} $(i, j = 1 - 4)$ between all the ports of the coupler were preliminary measured. The output SMF of port 3 was spliced to polarisation controller (*4*), which allowed the tuning to the maximum of the reflected optical signal, because SLDs under study were sensitive to polarisation. The scheme also contained tunable optical attenuator (*5*) and fibreoptic mirror (*6*) prepared by the deposition of gold on the normal cleavage of the SMF. The SMF splices and measuring equipment are not shown in Fig. 1.

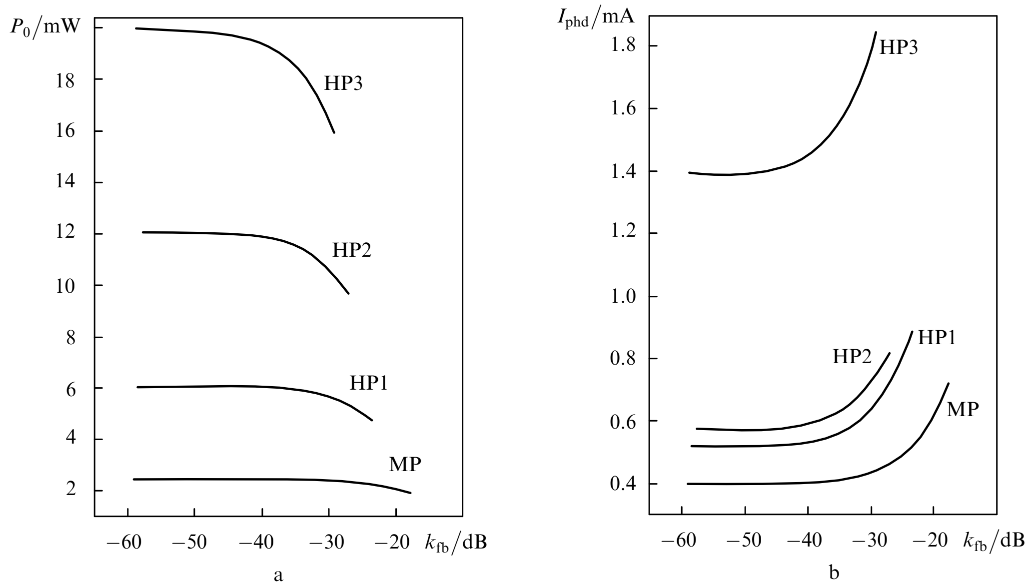

Figure 2. Typical dependences of the output power P_0 (a) and the built-in photodiode current I_{phd} (b) on the feedback coefficient for SLD-371 modules of different types.

By measuring signals P_1 and P_2 for different adjustments of attenuator (*5*), we found the real output power P_0 and the feedback coefficient k_{fb} from simple relations

$$P_0 = \frac{P_1}{T_{12}}, \quad k_{fb} = \frac{P_{fb}}{P_0} = \frac{T_{12}T_{31}}{T_{34}}\frac{P_2}{P_1}. \qquad (1)$$

Note that relations (1) do not contain the mirror reflectance and attenuator transmittance, which noticeably simplifies measurements.

Figure 2 presents the dependences of P_0 and I_{phd} on the feedback coefficient k_{fb}. One can see that, beginning from a certain value of k_{fb} (the higher is the SLD power, the smaller is k_{fb}), the output power rapidly decreases and the monitor photocurrent rapidly increases. This suggests that the output power from the rear facet increases, i.e. the single-pass SLD transforms to the double-pass SLD. The output power decreased by 20 % for $k_{fb} \sim -17$, -23, -27, and -30 dB for modules of types MP, HP1, HP2, and HP3, respectively. Obviously, this effect will be even stronger when the SLD operates in the regime of automatic power control. When the feedback appears, the power control system will maintain I_{phd} at the initial level, by reducing the SLD injection current and further decreasing the output power.

Figure 3 shows distortions of the output emission spectrum with increasing the feedback coefficient.

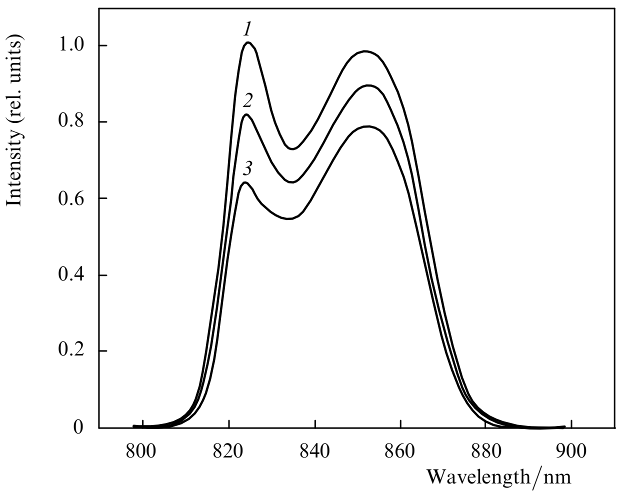

Figure 3. Emission spectra of the SLD-371-HP1 module for different feedback coefficients $k_{fb} = -40$ (*1*), -28 (*2*), and -23 dB (*3*).

The study of the output parameters of superluminescent diodes performed in our paper allows us to propose quantitative recommendations concerning the admissible level of parasitic feedback for numerous users of SLD-371 devices.

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