

PACS numbers: 42.55.Px; 42.60.Da; 42.81.Wg
DOI: 10.1070/QE2001v031n06ABEH001994

Bragg fibre grating semiconductor lasers with the narrow emission spectrum in the 1530–1560-nm region

V P Duraev, E T Nedelin, T P Nedobyvailo, M A Sumarokov, K I Klimov

***Abstract*. The design of a cw single-frequency semiconductor laser with a Bragg fibre grating in a composite resonator emitting at a wavelength of 1553.6 nm and intended for fibre-optic communication systems with wavelength-division multiplexing is descried and its main parameters are presented. It is shown that the suppression of longitudinal eigenmodes of the laser diode caused by the antireflection coating deposited on the internal face of the crystal leads to lasing on a single longitudinal mode of the composite resonator. The lasing line half-width is no more than 0.1 nm and the lasing wavelength, which corresponds to the Bragg wavelength of a fibre grating, remains stable in the dynamic mode.**

Keywords: *semiconductor laser, external cavity, Bragg fibre grating.*

Fibre-optic communication lines (FOCLs) have established themselves firmly in modern systems of data transmission. Wavelength-division multiplexing (WDM or DWDM) is currently used for increasing the amount of information being transmitted through fibre-optic communication lines. One of the most important problems in FOCLs with WDM is the creation of laser sources with a narrow stable spectrum (no wider than 0.1 nm), which must be preserved in the dynamic mode upon modulation by the information signal with frequencies up to 10 GHz [1, 2, 4]. This condition is determined by the fact that the difference in the wavelengths of adjacent spectral channels should be fractions of a nanometer (0.2 – 0.8 nm), the deviation of the wavelengths of the radiation source not exceeding 0.01 nm. These requirements are satisfied most completely for diode lasers optically coupled to Bragg fibre grating (BFG) recorded in single-mode optical fibres (SOFs).

In this work, we describe BFG diode lasers emitting in the 1530 – 1560-nm wavelength range and intended for operation in FOCLs with WDM and erbium fibre-optic amplifiers.

Lasing in the required wavelength range with a preset spectral interval is provided by Bragg refractive index gratings recorded in the SOF core [3]. When the grating is included into the external resonator with a laser diode (LD) (in analogy with Ref. [4]), the lasing wavelength lies at the maximum of the profile of spectrally selective reflection of the grating. For stabilising the wavelength and ensuring one-frequency narrow-band lasing, we proposed and realised the following physical and technological solutions.

(1) A small width (less than 0.3 nm) of the BFG reflection spectral profile.

(2) A large BFG reflection coefficient at the maximum (80 %) ensuring the required Q-factor of the external cavity.

(3) An LD with the cavity length of 200 μm and the reflection coefficient of the end no more than 0.5 %.

(4) A short external cavity and a sparse longitudinal-mode spectrum of the composite resonator obtained by bringing BFG close to the antireflection-coated end of the LD.

(5) Antireflection coating of the microlens for increasing the strength of coupling between LD and BFG and suppression of longitudinal modes of undesired composite resonators.

(6) The coincidence of the maximum of the spectral gain profile of an antireflection-coated laser with the maximum of the grating selectivity profile (λ_B).

Schematic of a BFG laser emitting in the wavelength range 1530 – 1560 nm is shown in Fig. 1.

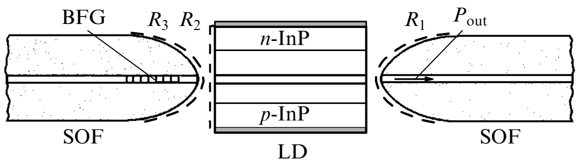

Figure 1. Schematic of a BFG single-frequency laser: $R_1 = R_2 = R_3 \simeq 0.5$ % are the reflection coefficients of antireflection coatings.

We used lasers based on InGaAsP – InP heterostructures with quantum-well layers prepared by the method of MOS hydride epitaxy on a p-InP substrate in analogy with Ref. [5]. Mesa stripe laser diodes with a mesa strip width of 3 μm and a 200-μm long cavity were prepared from the initial quantum-well heterostructures. The rear face of the cavity was coated with multilayered antireflection coating with the reflection coefficient $R_2 \approx 0.5$ %.

The LD was mounted on a copper heat sink placed in a thermoelectric microcooler controlled by a thermal stabilisation circuit. The radiation emitted from the rear face of the LD was coupled to a single-mode fibre containing a

V P Duraev, E T Nedelin, T P Nedobyvailo, M A Sumarokov, K I Klimov Federal Unitary State Enterprise, M F Stel'makh Research Institute 'Polyus', ul. Vvedenskogo 3, 117342 Moscow, Russia

Received 12 February 2001
Kvantovaya Elektronika **31** (6) 529 – 530 (2001)
Translated by Ram Wadhwa

BFG with the reflectivity 80 %. For wavelengths from the range 1530 – 1560 nm separated by an interval of 0.8 nm, the BFG period was chosen on the basis of the relation $\Lambda = \lambda_B/(2n_{eff})$ (where n_{eff} is the effective refractive index of the optical fibre at a given wavelength) and was ~ 0.5 μm. The length of the grating along the fibre axis was 3 mm, which ensured a width of the grating selective reflection profile of ~ 0.3 nm. A microlens with a radius of curvature less than 10 μm was formed at the end of the fibre in front of the grating. The surface of this lens was covered with an antireflection coating with the reflectivity $R_3 \approx 0.5$ %. The radiation emitted from the front mirror of the cleaved face of the LD was coupled to the fibre having a microlens at the end and covered with an antireflection coating with $R_1 \approx 0.5$ %. The core diameter of the single-mode fibre was 9 μm and the diameter of the cladding was 125 μm. The radius of curvature of the microlens was 10 μm.

The output light – current characteristics recorded from the front mirror of the LD before and after its coupling with the BFG are shown in Fig. 2. The threshold current of the initial LD without coating was 20 mA and the working current was 50 mA for the output power 5 mW. After the application of coating with reflectivities R_1, R_2, R_3 and coupling with BFG and SOF, the threshold current of the LD was 30 mA and the output power of 1 mW from the SOF was attained for a pumping current of 50 mA. The efficiency of coupling of the LD radiation into the SOF was 30 % – 50 %.

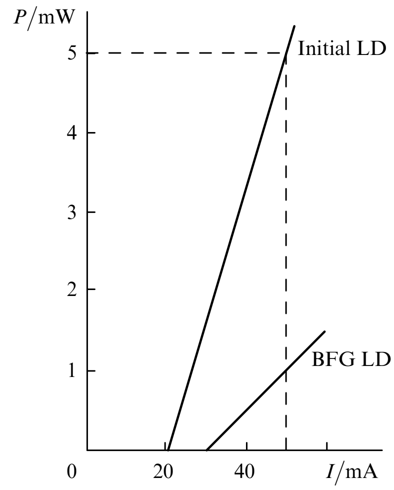

Figure 2. Watt–ampere characteristics recorded from the front (right) mirror of the initial LD before and after its coupling with a BFG.

Fig. 3 shows the spectral parameters of the LD before and after its coupling with the BFG. The wavelength of the initial LD at the maximum λ_{max} of the emission spectrum was 1576 nm. The emission line half-width was $\Delta\lambda = 4.5$ nm and the intermode spacing was $\delta\lambda = 1.5$ nm. The wavelength of the antireflection-coated LD for $I = 100$ mA was 1550 nm and the emission spectrum half-width was $\Delta\lambda =$ 41 nm; the maximum of the envelope of the emission spectrum was shifted relative to λ_{max} of the initial LD by 26 nm to the blue.

The output emission spectrum of the SOF after establishing an efficient optical coupling between the LD and BFG contains a single longitudinal mode of the composite resonator (Fig. 3c). One can see that the luminescence spectrum of the antireflection-coated LD and the spectrum of the laser with the BFG do not contain the longitudinal modes of the intrinsic cavity of the LD as well as of other parasitic resonators which could be formed by the ends of fibres during coupling. This indicates a high quality of the antireflection coating of the ends of the fibres and the LD face coupled to the fibre grating.

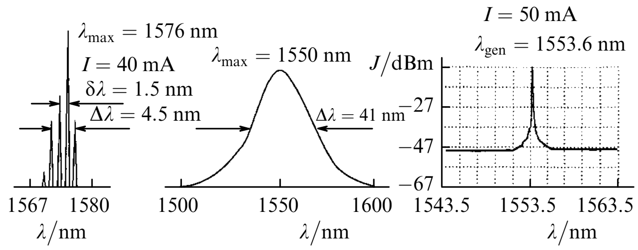

Figure 3. Spectral characteristics of the initial LD (a), after application of antireflection coating (b), and after coupling with BFG (c).

The lasing wavelength of the BFG LD was λ_{gen} =1553.6 nm, which coincides with the Bragg wavelength λ_B of the fibre grating used. The half-width of the lasing line did not exceed 0.1 nm upon modulation of the laser by pumping current pulses with a frequency up to ~ 5 GHz, indicating the stability of lasing in the dynamic mode. The Bragg wavelength detuning relative to the maximum of the gain line of the antireflection-coated LD was 3.6 nm to the red.

Thus, the implementation of the structural and technological features listed above allows us to obtain stable single-frequency lasing on a longitudinal mode of a BFG composite resonator with the linewidth smaller than 0.1 nm and to create transmitting optical modules operating in the dynamic mode with stable parameters in the wavelength range 1530 – 1560 nm for fibre-optic data communication systems with wavelength-division multiplexing.

References

1. Duraev V P *Lazer. Tekhn. Optoelektron.* (3 – 4) 40 (1992)
2. Dianov E M *Kvantovaya Elektron.* **30** 659 (2000) [*Quantum Electron.* **30** 659 (2000)]
3. Dianov E M, et al. *Kvantovaya Elektron.* **23** 1059 (1996) [*Quantum Electron.* **26** 1029 (1996)]
4. Duraev V P, et al. *Kvantovaya Elektron.* **25** 301 (1998) [*Quantum Electron.* **28** 290 (1998)]
5. Golikova E G, Duraev V P, et al. *Kvantovaya Elektron.* **22** 105 (1995) [*Quantum Electron.* **25** 96 (1995)]