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Multimode cladding-pumped erbium-doped fibre laser

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***Abstract*. A multimode cladding-pumped erbium-doped fibre laser is described. The maximum output power and the slope efficiency of the laser at 1.6 μm are 4.2 W and 30 %, respectively.**

Keywords: *erbium-doped laser, double-clad fibres, lasing efficiency*.

High output powers of fibre lasers are achieved, as a rule, by using double-clad active fibres. In this case, the external cladding is pumped by high-power semiconductor lasers and lasing is produced in the single-mode fibre doped with active ions [1, 2]. The main disadvantage of this pump method is that the absorption of pump radiation is very weak due to a small overlap of the latter with the active region of the fibre. In fact, the pump absorption cross section in double-clad fibres decreases proportionally to the ratio of areas of the cladding and the active core, which is usually of the order of $10^2 - 10^3$. As a result, it is difficult to achieve a high degree of the population inversion in double-clad fibres.

In the case of a three-level system, the conversion efficiency of the pump radiation to laser radiation strongly depends on the reabsorption of radiation by noninverted active ions. For widely used ytterbium-doped fibre lasers [3], this problem is alleviated due to a high absorption cross section for pump radiation, exceeding by 2 – 4 orders of magnitude the absorption cross section in the laser emission region [4]. Erbium-doped fibre lasers emitting in the spectral range between 1.53 and 1.6 μm are also three-level lasers. However, unlike ytterbium-doped fibres, the pump absorption cross section of the erbium-doped fibre core at 980 nm is about 3×10^{-21} cm^2. In this case, the absorption cross section at a wavelength of 1.53 μm achieves 6×10^{-21} cm^2 and decreases down to 2×10^{-21} cm^2 at 1.6 μm. Therefore, it is more difficult to obtain the inverse population in double-clad erbium-doped fibres than in ytterbium-doped fibres, and radiation is reabsorbed stronger in the former.

To obtain high-power lasing in this spectral region, optical fibres co-doped with ytterbium and erbium ions are used, as a rule [5]. The pump radiation is efficiently absorbed in such fibres by ytterbium ions and is transferred to erbium ions, thereby increasing the inverse population. However, the disadvantage of this method is that the manufacturing technology of co-doped optical fibres, which provides the efficient excitation energy transfer from ytterbium to erbium ions, is quite complicated.

In this paper, we consider the possibility of producing efficient lasing in cladding-pumped erbium-doped fibres without additional doping with ytterbium ions. To increase the absorption of pump radiation, we proposed to use a multimode erbium-doped fibre with the increased core diameter.

Lasing was studied in a fibre with the active core of diameter 20 μm. The concentration of erbium ions in the fibre core was about 10^{19} cm^{-3}. The silica cladding of the fibre had the 100×100-μm square cross section. A polymer with a lower refractive index was used as an outer jacket, which provided the number aperture of the fibre equal to 0.38.

The laser scheme was very simple. Pumping was performed through a multimode fibre with a Bragg grating written in it, which was used as the input mirror. This scheme for single-mode and multimode ytterbium-doped lasers was described in [6, 7]. In our case, the fibre Bragg grating had the reflection maximum at 1600 nm. This lasing wavelength was chosen to minimise reabsorption due to the incomplete inversion of the active medium. The multimode fibre was welded with the active fibre, whose output end was the output reflector. The active fibre length was about 25 m. Pumping was performed by a 18-W, 975-nm Lakhta diode laser (Milon-Laser, St. Petersburg).

Figure 1 shows the dependence of the output power of the laser at 1600 nm on the pump power. The maximum output power was 4.1 W and the slope lasing efficiency was 30%, corresponding to the quantum efficiency of about 50%. According to the results obtained in [8], the maximum quantum efficiency at the concentration of erbium ions used in our fibre was about 80 %. The decrease in the lasing efficiency is our case is explained by the incomplete use of the pump radiation. Thus, approximately 2 W of the 18-W input power was not absorbed. In addition, the lasing efficiency was reduced due to excess optical losses in the fibre cladding, amounting to ~ 1 dB over the active fibre length.

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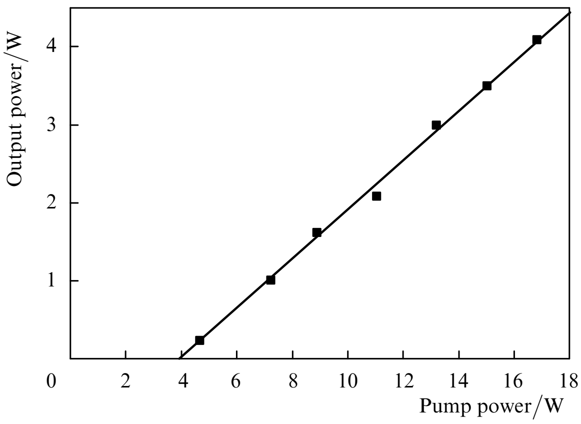

Figure 1. Dependence of the output laser power at 1600 nm on the pump power.

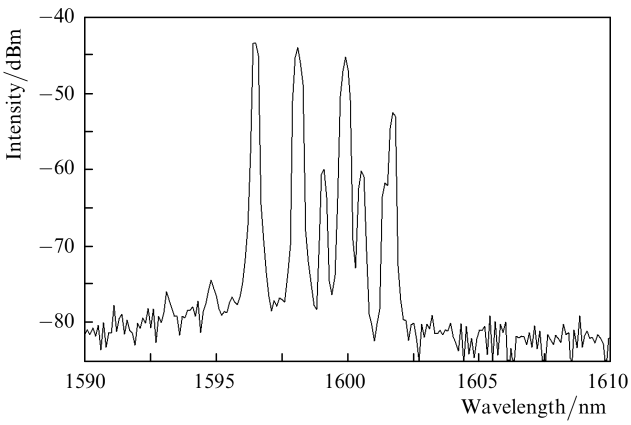

Figure 2. The emission spectrum of the fibre laser.

The emission spectrum of the fibre laser is presented in Fig. 2. It consists of a number of bands located in the region from 1597 to 1602 nm. The complex structure of the output spectrum appears because different groups of modes have somewhat different wavelengths of reflection from the multimode fibre Bragg grating.

Thus, we have shown that cladding-pumped erbium-doped fibres can emit quite high output powers at 1600 μm. The fibre core should be large enough in this case. Such lasers can be used, for example, in laser medicine.

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