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CW bismuth fibre laser

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***Abstract*. A new fibre laser based on a bismuth-doped aluminosilicate glass fibre is proposed and fabricated. CW lasing is obtained in the spectral region between 1150 and 1300 nm. The fibres are fabricated by the method of modified chemical vapour deposition.**

Keywords: *telecommunication, active fibres, fibre laser.*

The necessity of expanding the spectral range of fibreoptic communication links requires the mastering of the second telecommunication transparency window from 1.20 to 1.35 μm, which is characterised by rather low optical losses and a low chromatic dispersion of silica glass [1]. At the same time, no efficient silica fibre lasers and amplifiers for this spectral range that would be compatible with standard telecommunication fibres were fabricated so far.

Currently the observation of a broadband luminescence in the near-IR region from 1.1 to 1.7 μm was reported in a number of bismuth-doped glasses (silicate, germanate, phosphate, borate) obtained by melting in a crucible [2–6]. However, the nature of luminescence centres is still not quite clear.

Recently we reported the fabrication of bismuth-doped fibres by the method of modified chemical vapour deposition (MCVD) and the results of their spectroscopic study [7]. The spectral position of the luminescence band in the range from 1050 – 1200 nm, its width equal to 150 – 200 nm, and the long lifetime of luminescence (about 1 ms) make such fibres promising for the development of tunable femtosecond lasers and broadband amplifiers for the second telecommunication window. In this paper, we demonstrate lasing obtained for the first time in fibres of this type.

Preforms for single-mode fibres were fabricated by the MCVD method by using a silica glass-support tube. The core of preforms was formed by the chemical vapour deposition of aluminium and silicon oxides. Doping with bismuth oxide was performed by impregnating a porous layer of the core glass with the solution of bismuth salts. The molar concentration of bismuth oxide in the core glass did not exceed 0.1 %.

Fibres exhibit characteristic absorption bands at 500, 700, 800, and 1000 nm. The luminescence band excited in the 1000-nm region has a maximum at 1150 nm and a width (FWHM) of 150 nm. The luminescence lifetime is ~ 1 ms. Figure 1 shows the absorption and luminescence cross sections calculated from spectroscopic parameters. The maximum luminescence cross section at a wavelength of 1150 nm is 6×10^{-21} cm^2, which is quite comparable with the luminescence cross section of Er^{3+} at 1.5 μm in erbium-doped fibres.

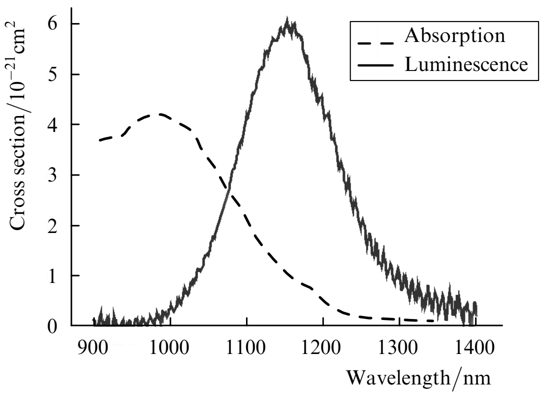

Figure 1. Absorption and luminescence cross section spectra of a bismuth-doped aluminosilicate fibre.

The scheme of bismuth fibre laser is shown in Fig. 2. CW lasing was obtained at wavelengths 1146, 1215, 1250, and 1300 nm upon pumping at $\lambda_p = 1064$ nm. The cut-off wavelength of the active fibre was ~ 1 μm, the absorption coefficient at the pump wavelength in a fibre used was 55 dB. Pairs of Bragg gratings with the reflectivities of 3 and 20 dB for the above wavelengths were written in germano-

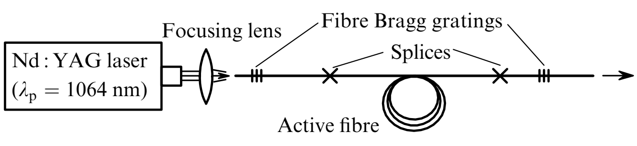

Figure 2. Laser scheme with a resonator formed by fibre Bragg gratings.

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silicate fibres with the cut-off wavelength at 1.1 μm. The two-mode character of propagation of radiation in these fibres resulted in partial optical losses in splices with the active fibre.

The lasing parameters were measured at wavelengths 1146 nm (Fig. 3) and 1215 nm. The maximum output power obtained upon pumping by ~ 5 W was 460 mW at 1146 nm and 400 mW at 1215 nm. The lasing threshold at 1146 nm was 420 mW, and the slope efficiency recalculated to the input power was 10.2 %. The lasing threshold at 1215 nm was 890 mW and the slope efficiency was 14.3 %.

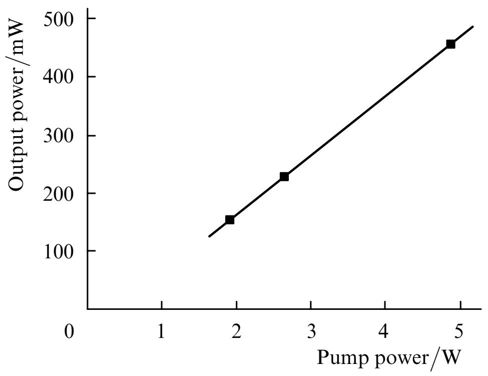

Figure 3. Dependence of the output power of the fibre laser at 1146 nm on the pump power at 1064 nm coupled to the fibre.

Although the scheme of the laser was not optimised, the obtained parameters are already of practical interest. After optimisation of the optical losses in the laser, the maximum lasing efficiency for this active fibre can achieve ~ 30 %.

Along with a linear scheme, we also obtained generation in a ring laser (Fig. 4). A coupler used to form a ring resonator was fabricated of a standard germanosilicate fibre with the cut-off wavelength at 1.1 μm. The coupling coefficient of the resonator weakly depended on the wavelength in the region 1.1 – 1.2 μm and was less than 20 %. The emission spectra of this laser pumped at 1064 nm are shown in Fig. 5. Because of a weak selectivity of the resonator, lasing slightly above the threshold developed at once on many longitudinal modes, the spectral position of peaks being unstable. As the pump power was increased, the number of peaks reduced, and only one peak remained at 1172 nm when the lasing threshold was considerably exceeded.

One can see from Fig. 5 that lasing is observed in a broad band of width ~ 100 nm, which can be used for laser tuning. The width of the band can be increased by reducing the level of parasitic losses in the resonator and optimising the laser scheme. Thus, there is reason to hope that lasing in

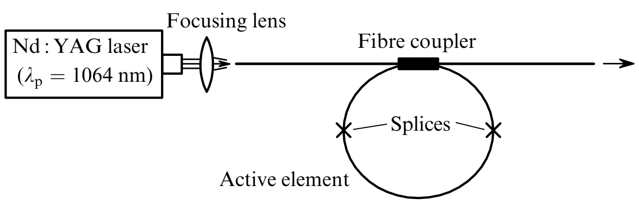

Figure 4. Scheme of a ring laser with a fibre coupler forming a resonator.

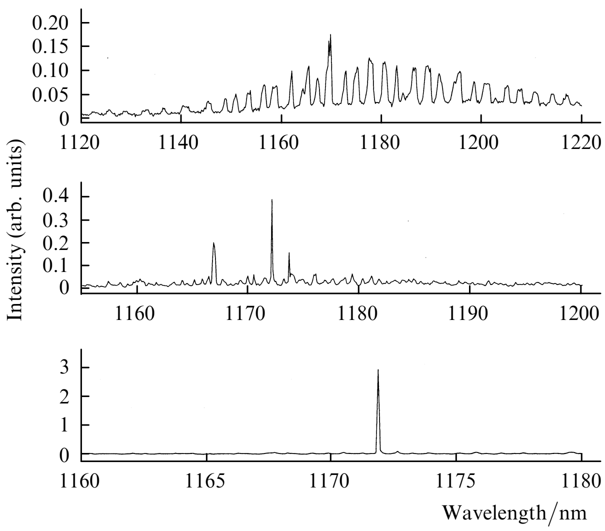

Figure 5. Evolution of the emission spectrum of the ring laser with increasing the pump power (from top to bottom). The spectral resolution is 0.5 nm.

fibres of this composition can be obtained in the spectral range from 1 to 1.35 μm.

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