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Broadband Ho^{3+}-doped fibre radiation source emitting at 2 μm

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***Abstract*. A 2-μm broadband radiation source based on a fibre doped with holmium ions, which is pumped by a 1.12-μm ytterbium fibre laser, is developed. The maximum output power of 8 mW is achieved for the emission spectrum width of 45 nm.**

Keywords: *holmium fibre, broadband emission.*

Radiation sources emitting bands of width of several tens of nanometers find applications in optical sensors, in low-coherence reflectometry, spectroscopy, etc. These sources are usually semiconductor emitters and devices based on active fibres. Compared to semiconductor sources, fibre devices have a number of advantages such as higher power, the absence of the spectral modulation of the output spectrum, and lower degree of the residual polarisation. At the same time, the emission spectrum of fibre lasers is limited by the luminescence spectrum of active ions. Because of this, fibre emitters are mainly used in the 1.55-μm spectral region [1] (fibres doped with Er^{3+} ions) and in the 1.06-μm region [2] (fibres doped with Yb^{3+} ions). This limitation does not apply to supercontinuum sources based on microstructured fibres covering the spectral range of hundreds of nanometers. However, such devices operate, as a rule, in the pulsed regime, which restricts the field of their applications. In addition, they are complex and expensive because they require high peak pump powers.

Because the required spectral ranges of broadband emission sources are determined by their possible applications, the development of such sources with different spectral properties is urgent. This paper presents the results of experiments on the development of a 2-μm superluminescence source based on a Ho^{3+} doped fibre pumped by an ytterbium fibre laser.

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Optical silica fibres with the core doped with Ho^{3+} ions have a broad luminescence band at ~ 2 μm, corresponding to the $^5I_7 - {}^5I_8$ transition, and absorption bands in the visible and near-IR region (Fig. 1). The luminescence spectrum of the fibre was recorded upon excitation of the fibre by a 676-nm krypton laser. The full width at half-maximum (FWHM) of the luminescence band was ~ 150 nm. The concentration of Ho^{3+} in the fibre was $\sim 1.2 \times 10^{19}$ cm^{-3}. The fibre core was doped with GeO_2 and Al_2O_3 (the latter dopant with the molar concentration of about 1% was used to reduce the possible clastering of active ions, similarly to erbium optical fibres [3]). The refractive index difference between the fibre core and cladding was 0.08 and the cut-off wavelength of the first higher mode was ~ 1.5 μm.

Among the absorption bands that can be used to excite the active medium, of special interest is the band corresponding to the $^5I_8 - {}^5I_6$ transition at ~ 1.15 μm. The spectral position of this band is close to the emission band of clad-pumped ytterbium fibre lasers [4]. In papers [5, 6], an ytterbium fibre laser was used to pump a Ho^{3+} fibre laser and the efficient lasing in the region from 2 to 2.1 μm was demonstrated. Thus, it is quite natural to use this approach for the development of a broadband source whose scheme is shown in Fig. 2.

As a pump laser, we used an ytterbium fibre laser clad-pumped by a 0.95-μm, 5-W semiconductor laser. The lasing wavelength of the ytterbium laser was determined by fibre Bragg gratings (FBGs) forming the resonator and was equal

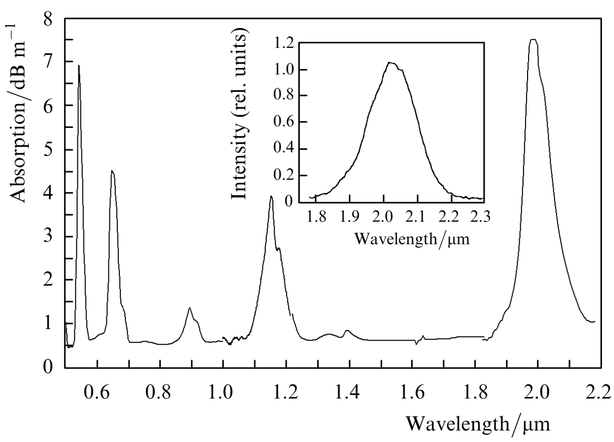

Figure 1. Absorption spectrum of a Ho^{3+}-doped fibre. The inset shows its luminescence spectrum.

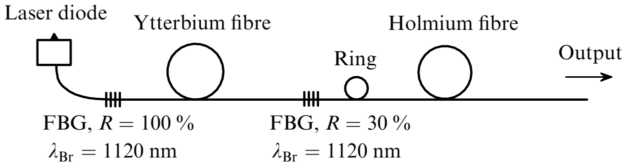

Figure 2. Scheme of a 2-μm broadband radiation source.

to 1120 nm. This wavelength does not coincide with the maximum of the corresponding absorption band, however, the increase in λ results in a drastic decrease in the lasing efficiency of the ytterbium laser [7]. The broadband source employs a simple configuration with end-pumped ytterbium laser and holmium fibre. To prevent the lasing regime of the source, the fibre piece with the output Bragg grating at 1120 nm was bent at a small radius. This resulted in the appearance of bending losses at 2 μm [8] and eliminated the appearance of the feedback due to reflection from the semiconductor laser end-face and the fibre end-face.

The broadband emission at 2 μm was observed in the entire power range of the ytterbium fibre laser – from 1 to 2 W. The source power linearly increased from 1 mW upon pumping by 1 W to 8 mW upon pumping by 2 W. Figure 3 presents the normalised emission spectra for two output powers. The emission spectrum FWHM was 52 nm and 45 nm for output powers 1 and 8 mW, respectively.

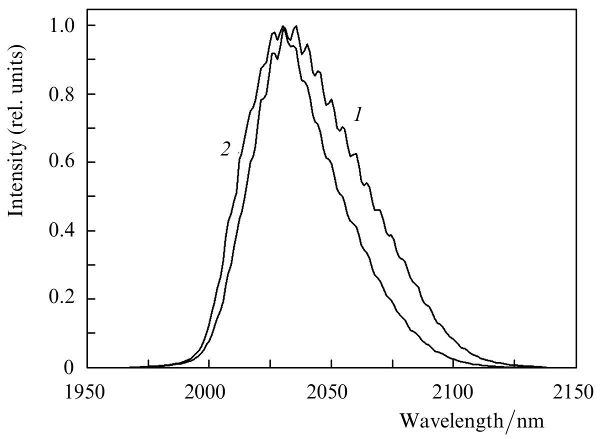

Figure 3. Emission spectra of the source for output powers 1 (*1*) and 8 mW (*2*).

Thus, we have shown that optical fibres doped with holmium ions can be used to fabricate a 2-μm compact broadband emitter pumped by an ytterbium laser. Although the pump-radiation conversion efficiency is not high (less than 1 %), due to the relatively low cost of semiconductor pump sources and active optical fibres, such sources can be of practical interest.

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