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Holmium fibre laser emitting at 2.21 μm

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Abstract. **A holmium fibre laser emitting at 2.21 μm has been demonstrated. This wavelength is the longest for silica-based fibre lasers. The output power of the laser is 130 mW.**

Keywords: *holmium, fibre laser, two micron spectral region.*

A major trend in the development of fibre lasers is extension of their emission range, in particular to the two micron spectral region, which contains absorption lines of some gases (e.g. CO_2) and water vapour [1]. Among silica glass-based fibre lasers, those having a holmium-doped gain medium offer the longest emission wavelength. Kurkov et al. have demonstrated lasing in the range 2.02–2.15 μm [2] and obtained a slope efficiency of 0.45 with respect to absorbed pump power at 1.15 μm [3]. It is worth noting that the longest output wavelength (2.193 μm) among silica fibre lasers has been achieved by Dianov et al. [4], who used a silica-cladding, germanate-core Raman fibre laser. Kamynin et al. [5] have demonstrated supercontinuum generation up to 2.4 μm in standard optical fibres. The purpose of this work was to reach as long an emission wavelength as possible in a holmium fibre laser.

The lasing wavelength was chosen to lie in the 2.2 μm range, where the holmium luminescence intensity does not exceed 1% of its highest level (at a wavelength of 1.95 μm). In addition, the optical loss associated with the phonon absorption edge in this region is about 0.4 dB m^{-1}. Using silica fibre with an increased holmium concentration (3×10^{20} cm^{-3}), we were able to reduce the length of the active fibre and, accordingly, the effect of the optical loss. Two Bragg gratings served as laser mirrors. The holmium laser was pumped by an ytterbium fibre laser operating at 1.125 μm.

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In the first series of experiments, we used an input Bragg reflector with a reflectivity of 0.95–0.97 and a low-reflectivity (~0.2) output reflector. This resulted in spontaneous high-intensity lasing in the range 2–2.1 μm, but there was no lasing at the resonance wavelength of the Bragg gratings. In a second series of experiments, a high-density grating with a reflectivity of 0.95–0.97 was used as an output reflector, which ensured stable lasing at a wavelength of 2.21 μm. The corresponding emission spectrum measured with a 0.6-nm resolution is shown in Fig. 1.

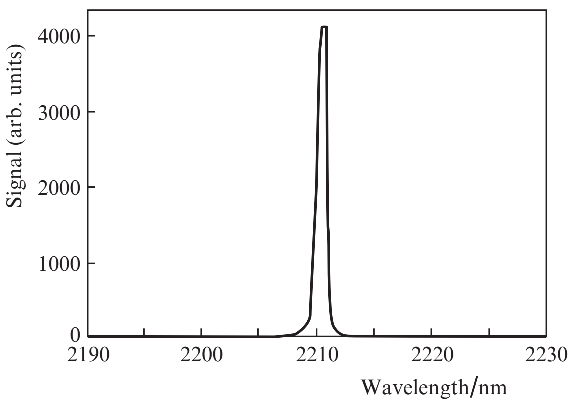

Figure 1. Emission spectrum of the holmium fibre laser.

The output power of the laser depended significantly on the length of the active fibre, as illustrated by the data in Fig. 2. It is seen that, with the active fibre under consideration, the laser efficiency has a maximum at a cavity length of 0.8–1 m. At smaller active fibre lengths, the output power drops sharply because of the competition from spontaneous luminescence. The maximum output power of the holmium fibre laser was 130 mW. The corresponding plot of the output power against pump power is presented in Fig. 3. During continuous test operation of the laser for 20 min, fluctuations in its output power were less than 5%. It is worth noting that, in spite of the high active ion concentration, the laser had a spikeless output [6], which can be accounted for by the fact that the holmium ion does not absorb at the wavelength in question.

The laser slope efficiency was about 4%. One cause of the low efficiency was that Bragg gratings identical in reflectivity were used as mirrors. This reduced the laser output power by a factor of 2 because equal powers were decoupled through the two cavity mirrors. An obvious way to enhance the laser efficiency is to reduce the reflectivity of the output Bragg grat-

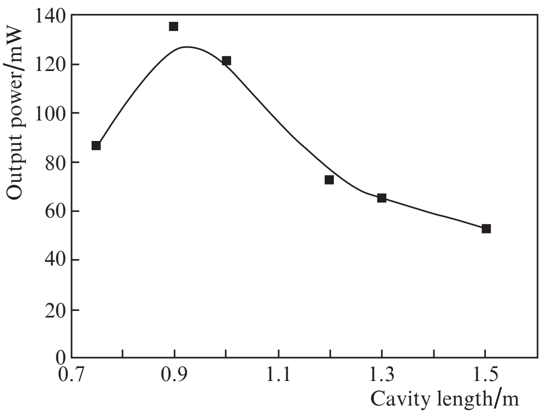

Figure 2. Output power as a function of the length of the active fibre in the laser cavity.

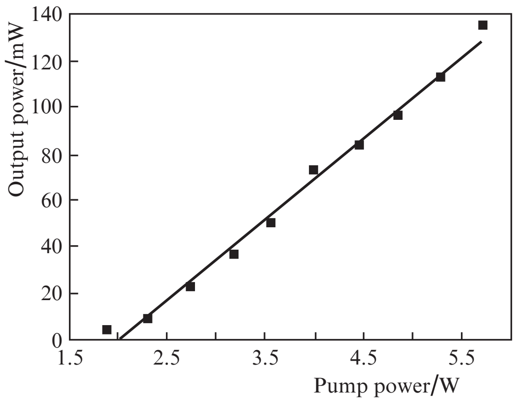

Figure 3. Laser output power as a function of pump power.

ing. The output grating reflectivity is however difficult to optimise for a number of reasons. Firstly, the gain coefficient at the wavelength under consideration is difficult to evaluate because the luminescence intensity is low and there are no relevant data in the literature. Estimation from the lasing threshold is also impeded by the lack of accurate reflectivity data for the Bragg gratings, which is explained by the necessity of using specialised instruments for reliable measurements in the two micron range. In view of this, we plan to empirically optimise the cavity configuration.

Thus, a holmium fibre laser with the longest wavelength among silica-based fibre lasers has been demonstrated.

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