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Lasing in diode-pumped fluoride nanostructure F_2^- : LiF colour centre ceramics

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***Abstract*. The spectral and lasing properties of a new nanostructure F_2^- : LiF colour centre ceramics are studied and compared with those for single crystal samples. The slope lasing efficiency up to 26 % is achieved in the diode-pumped F_2^- : LiF laser ceramics.**

Keywords: *nanostructure laser ceramics, colour centres, lasing.*

The development of efficient picosecond and femtosecond lasers, as well as lasers tunable in a broad wavelength range requires searching for and studying materials with a broad amplification band. One of the most promising laser materials for this purpose is LIF crystals with aggregate F_2^- colour centres. The broad amplification band, achieving 300 nm (1 – 1.3 μm), the high luminescence cross section ($\sim 10^{-17}$ cm^2), the broad absorption band convenient for pumping by ~ 1-μm lasers, and the high heat conduction of these crystals make them almost ideal for using in tunable and mode-locked lasers [1, 2]. The development of laser diodes emitting in the region between 960 and 980 nm makes it possible to develop also compact efficient F_2^- : LiF lasers directly pumped by laser diodes.

Recent studies [3] have shown that, despite the short excited-state lifetime of F_2^- colour centres (~ 50 ns), diode-pumped F_2^- : LiF crystals can generate pulses of duration exceeding the excited-state lifetime by many orders of magnitude (up to cw lasing) at temperatures close to room temperature. However, a disadvantage of these crystals is their low hardness and strength, which can prevent their applications in high-average-power lasers.

One of the efficient methods for overcoming this drawback is the synthesis of a laser ceramics based on F_2^- : LiF crystals. It is known from papers devoted to the synthesis of oxide optical ceramics based on yttrium – aluminium garnet and yttrium oxide that the spectral and luminescence properties of these materials compare well with those of corresponding single crystals [4, 5], while the homogeneity and mechanical strength of ceramics are better.

In [6], the results of studies on the synthesis of optical ceramics based on LiF crystals are presented. The ceramics was prepared from lithium fluoride single crystals grown by the Kyropoulos technique in air. Polycrystalline samples were obtained by using hot moulding when cubic samples were deposited under pressure at a temperature of about 600 °C. The polycrystalline nature of samples prepared after deposition was determined by X-ray analysis, which showed that upon deformations exceeding 80 %, the diffraction patterns of the powder and deformed sample were qualitatively the same. Laser F_2^- colour centres were produced by irradiating ceramic samples by 21-MeV electrons in a Mikrotron-CT accelerator at room temperature.

The luminescence spectra and decay times of F_2^- colour centres in ceramic samples measured upon excitation by a tunable nanosecond F_2^+ : LiF laser at ~ 920 nm coincided with those measured for a 7-mm-thick single crystal sample under the same conditions. Lasing in F_2^- : LiF crystals and ceramics was studied upon pumping by 967-nm, 1-ms, 12-W pulses from an IPG laser diode with a fibre pigtail (the core diameter was 100 μm) at a pulse repetition rate of 5 Hz. The laser diode radiation was focused into a sample by a lens with a focal length of 5 mm. The F_2^- : LiF laser resonator was formed by a plane dichroic mirror with 95 % transmission at the pump wavelength and 100 % reflection at the laser wavelength (about 1.117 μm) and the output spherical mirror with the reflectance 95 % and the radius of curvature 100 mm, which was located at a distance of 40 mm from the plane mirror. The average output and pump powers were measured with an EPM-100 power meter, and the laser and pump wavelengths – with an LRL005 wavelength meter.

The dependences of the average output lasing power of ceramic and single crystal samples on the pump power are presented in Fig. 1. One can see that the lasing threshold of ceramic samples is lower. A 4-mm-thick ceramic sample with the absorption coefficient $k = 1.8$ cm^{-1} had the highest slope lasing efficiency $\eta_{\text{sl}} = 26\,\%$ and the maximum efficiency with respect to the absorbed pump power ($\eta = 12\,\%$), whereas the slope efficiency for a 7-mm-thick single crystal with the absorption coefficient 1.7 cm^{-1} was only 18 % and the total efficiency was 8.2 %. Figure 2 shows the lasing, absorption, and luminescence spectra of a ceramic sample. The maximum of the lasing spectrum was at 1.117 μm and the width of the spectrum was about 5 nm.

Thus, we have obtained for the first time lasing in a LiF ceramics with F_2^- colour centres, compared the lasing

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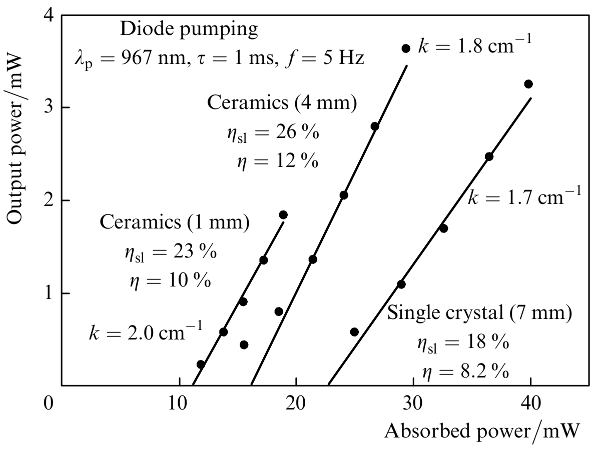

Figure 1. Dependences of the average output lasing power on the average absorbed diode pump power for ceramic and single-crystal F_2^- : LiF samples measured under the same conditions.

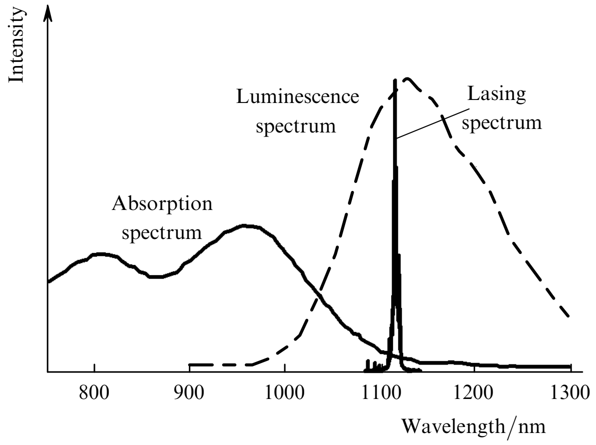

Figure 2. Absorption, luminescence and lasing spectra of a F_2^- : LiF ceramics laser.

properties of single-crystal and ceramic F_2^- : LiF samples, and have demonstrated that F_2^- : LiF ceramics is a promising laser material.

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