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FLUORIDE NANOCRYSTALS $NaYF_4:Yb^{3+},Er^{3+}$ FOR POLYMER WAVEGUIDE AMPLIFIERS OF TELECOMMUNICATION C-RANGE

K.V. Khaidukov, P.A. Demina, I.O. Goryachuk, V.I. Sokolov

National Research Centre "Kurchatov Institute", Moscow, Russia

Annotation: Fluoride nanocrystals b-$NaYF_4:Yb^{3+},Er^{3+}$ in the size range of 40-50 nm, possessing intense photoluminescence in the telecommunication C - wavelength range l = 1550 ± 30 nm when pumped by IR radiation with l = 980 nm, have been synthesized. The method of introduction of nanocrystals into polymer matrix in high concentration was developed. Using the obtained composite material, waveguide amplifiers of optical radiation for the C - range of the spectrum were fabricated. The obtained amplification at the wavelength l = 1532 nm was 19 dB at the waveguide length of 15 mm.

Keywords: fluoride nanocrystals, rare-earth elements, photoluminescence, waveguide optical amplifiers.

Introduction

Fluoride nanocrystals ($NaYF_4$, $NaLuF_4$, etc.) doped with ytterbium and erbium ions are promising for the creation of compact waveguide amplifiers operating in the telecommunication C-band of the spectrum near 1550 nm. For this purpose, nanocrystals are introduced into a polymer matrix in high concentration and the resulting composite material is used to form single-mode optical waveguides [1-6]. Waveguide amplifiers can be used, for example, in high-speed optical data buses for microprocessor-based computing devices on printed circuit boards [7]. By the method of thermal decomposition of trifluoroacetates of rare-earth elements and sodium in a mixture of oleic acid and 1-octadecene, we synthesized nanocrystals b-$NaYF_4:Yb^{3+},Er^{3+}$ in the size range of 40-50 nm with an inert silicon oxide shell. The nanoparticles were incorporated into SU-8 photoresist at a concentration

of »40%, which was used to form the waveguides. When pumping with 980 nm IR radiation, the amplification at the wavelength l = 1532 nm in a 15 mm long waveguide was 19 dB.

Experimental part

Commercial reagents: yttrium, ytterbium, erbium oxides, sodium carbonate, oleic acid 90%, 1-octadecene 90% (Sigma-Aldrich) and trifluoroacetic acid 99% (PanReac) were used for the synthesis of fluoride nanocrystals b-$NaYF_4$:Yb^{3+},Er^{3+}. The nanocrystals were synthesized according to the methodology we described in [7]. The Er^{3+} concentration in the b-$NaYF_4$ matrix was »2%. Figure 1a shows a photograph of the synthesized nanoparticles obtained using TEM electron microscope and Figure 1b shows their photoluminescence (PL) spectrum in down-conversion excited by 980 nm IR radiation. The intense PL band with a center near 1532 nm and 74 nm wide is due to $^4I_{13/2}$ ® $^4I_{15/2}$ transitions in Er^{3+} ions. Structural diagnostics of the obtained nanocrystals, carried out on a Rigaku Miniflex600 X-ray diffractometer (Cu, l = 1.54184 Å), showed that they have hexagonal b - phase crystal lattice.

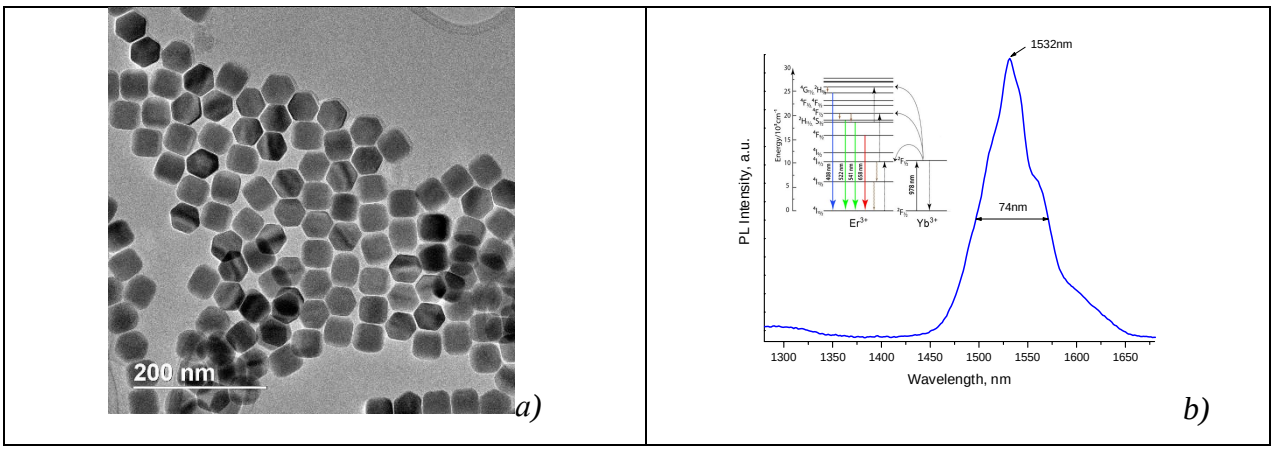

Figure 1. *(a) TEM photograph of synthesized fluoride nanocrystals b-$NaYF_4$:Yb^{3+},Er^{3+}. (b) PL spectrum of the nanocrystals when pumping by 980 nm IR radiation. The simplified energy level system of ytterbium and erbium is shown in the inset.*

The synthesized nanoparticles b-$NaYF_4$:Yb^{3+},Er^{3+} were introduced into the photoresistive material SU-8 at a concentration of 40%. The obtained composite material was used to form single-mode optical waveguides on a silicon substrate with a thermally grown oxide layer by UV photolithography (wavelength 365 nm). The width and thickness of the waveguide were 6 × 6 μm. Figure 2 shows the measured dependence of the gain coefficient of the optical signal at a wavelength of 1532 nm in a 15 mm long waveguide on the pumping radiation power with l = 980 nm. As follows from Figure 2, the achieved gain coefficient is 19 dB.

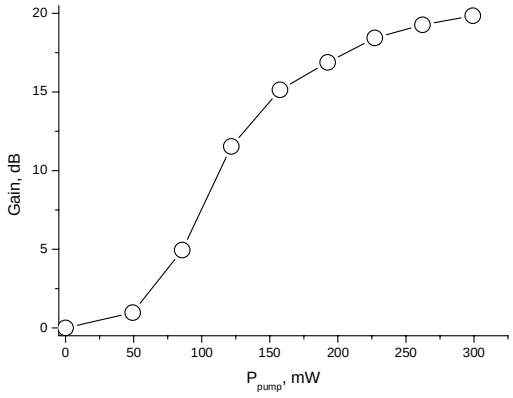

Figure 2. *The dependence of the gain* coefficient *(Gain) of the optical signal at a wavelength of 1532 nm in a waveguide amplifier with a 15 mm length from the pumping radiation power P_{pump} at a wavelength of 980 nm.*

Conclusion

The possibility of creating compact waveguide amplifiers for a telecommunication C-range of wavelengths near 1550 nm based on fluoride nanocrystals of b-$NaYF_4$:Yb^{3+},Er^{3+} with a shell of silicon oxide introduced into the photoresist SU -8 has been demonstrated. The obtained gain at a wavelength of 1532 nm in a 15 mm long waveguide was 19 dB. The synthesized $NaYF_4$:Yb^{3+},Er^{3+} nanocrystals are also promising for the creation of waveguide lasers with distributed feedback.

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