Short wavelength up-converted emission studies in Er^{3+} and Yb^{3+} doped ZBLAN glasses

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Short-wavelength light sources and specifically lasers, operating within near-UV, violet and blue-green spectral range, are presently one of the key elements of various optoelectronic devices. Wherever high focusing ability, radiation intensity, and wavelength selectivity are indispensable – like data storage, high-resolution imaging, photolitography, quantum optics, etc. – short-wavelength lasers seem to be irreplaceable. High efficiency and low cost have been primary motivators for searching new ways of obtaining short-wavelength, coherent radiation. Research effort in this area generally shows two main streams, one of which focuses on wide band gap semiconductor lasers, while the other on frequency multiplication effects in solid state lasers. Despite these, a still interesting alternative in obtaining short-wavelength emission and lasing are various up-conversion excitation schemes, which result in emission at wavelengths shorter than those used for pumping.

Trivalent erbium is known in photonics mainly for its outstanding performance in the near infrared spectral range (1,55 μm), crucial for fiber optic communication systems. Visible spectral range coverage of trivalent erbium is most commonly associated with $^4S_{3/2}+^2H_{11/2}\rightarrow^4I_{15/2}$ optical transition in green, at around 550 nm. This emission may be excited with low-cost laser diodes: 1480 nm, 980 nm, 808 nm and 657 nm, in either energy transfer or excited state absorption schemes. Co-doping erbium with ytterbium sensitizer strengthens the absorption band at around 960-980 nm and in low phonon materials enables efficient excitation of green laser action via a two-step $Yb^{3+}\rightarrow Er^{3+}$ energy transfer process. It should be noted, however, that erbium ions provide also access to shorter wavelengths due to transitions from energy levels located above $^4S_{3/2}$.

In this work we present the results of our recent studies on up-conversion phenomena in erbium and ytterbium doubly doped ZBLAN glasses. The very unique excitation sources - pressure-tuned semiconductor laser diodes enabled investigation of up-conversion phenomena in these materials over a broad spectral range, not easily accessible for typical coherent light sources. The unique set of bulk ZBLAN samples differing in Er^{3+} and Yb^{3+} concentrations was carefully investigated by means of highly-resolved laser spectroscopy, with specific attention focused on the efficiency of up-conversion processes resulting in short-wavelength emission in UV, violet and green part of the spectrum. The concentration-dependent up-converted excitation and emission characteristics were measured for all disposed samples. These measurements were complemented by analysis of the visible luminescence decay profiles obtained under direct and IR excitation and power dependencies as well. The obtained results enabled in-depth analysis of the nature of up-conversion processes observed in both types of active media and discussion of the influence of matrix properties on up-conversion efficiency.

Keywords: up-conversion, erbium, ytterbium, ZBLAN, short wavelength luminescence

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