

Structural and optical studies of Er³⁺-doped alkali/alkaline oxide containing zinc boro-aluminosilicate glasses for 1.5 μm optical amplifier applications

ABSTRACT

In the present work, we report on the optical spectral properties of Er³⁺-doped zinc boro-aluminosilicate glasses with an addition of 10 mol % alkali/alkaline modifier regarding the fabrication of new optical materials for optical amplifiers. A total of 10 glasses were prepared using melt-quenching technique with the compositions (40-x)B₂O₃ – 10- SiO₂ – 10Al₂O₃ – 30ZnO – 10Li₂O – xEr₂O₃ and (40-x)B₂O₃ – 10SiO₂ – 10Al₂O₃ – 30ZnO – 10MgO – xEr₂O₃ (x = 0.1, 0.25, 0.5, 1.0, and 2.0 mol %). We confirm the amorphous-like structure for all the prepared glasses using X-ray diffraction (XRD). To study the functional groups of the glass composition after the melt-quenching process, Raman spectroscopy was used, and various structural units such as triangular and tetrahedral-borates (BO₃ and BO₄) have been identified. All the samples were characterized using optical absorption for UV, visible and NIR regions. Judd-Ofelt (JO) intensity parameters (Ω_λ , $\lambda = 2, 4$ and 6) were calculated from the optical absorption spectra of two glasses LiEr 2.0 and MgEr 2.0 (doped with 2 mol % of Er³⁺). JO parameters for LiEr 2.0 and MgEr 2.0 glasses follow the trend as $\Omega_6 > \Omega_2 > \Omega_4$. Using Judd-Ofelt intensity parameters, we obtained radiative probability $A(S-1)$, branching ratios (β), radiative decay lifetimes τ_{rad} (μs) of emissions from excited Er³⁺ ions in LiEr 2.0 and MgEr 2.0 to all lower levels. Quantum efficiency (η) of $4 I_{13/2}$ and $4 S_{3/2}$ levels for LiEr 2.0 and MgEr 2.0 with and without $4D_{7/2}$ level was calculated using the radiative decay lifetimes τ_{rad} (μs) and measured lifetimes τ_{exp} (μs). We measured the visible photoluminescence under 377 nm excitation for both LiEr and MgEr glass series within the region 390–580 nm. Three bands were observed in the visible region at 407 nm, 530 nm, and 554 nm, as a result of $2H_{9/2} \rightarrow 4 I_{15/2}$, $2H_{11/2} \rightarrow 4 I_{15/2}$ and $4 S_{3/2} \rightarrow 4 I_{15/2}$ transitions, respectively. Decay lifetimes for emissions at 407 nm, 530 nm, and 554 nm were measured and they show single exponential behavior for all the LiEr and MgEr glass series. From the photoluminescence and radiative decay lifetimes (τ_{rad}), we calculated the full-width at half-maximum (FWHM), emission cross-section (σ) and bandwidth gain (FWHM σ) parameters. Near-infrared photoluminescence under 980 nm excitation was measured for all the LiEr and MgEr glass series in the region 1420–1620 nm. NIR emissions show a broadband centered at ~1530 nm due to the transition of Er³⁺: $4 I_{13/2} \rightarrow 4 I_{15/2}$. Decay lifetimes for NIR emission at ~1530 nm were measured and they show a quite exponential nature for all the LiEr and MgEr glass series. From the NIR emission spectra and decay lifetimes, we calculated the full-width at half-maximum (FWHM), the emission cross-section (σ) and the bandwidth gain (FWHM σ) for the NIR emission and it shows FWHM of 50–70 nm for prepared glasses, emission cross-section of (~ 3.5) 10^{-20} cm², while bandwidth gain was (~ 25) 10^{-26} cm³.

Keyword: Zinc boro-aluminosilicate glasses; Green emission; 1.53 μm Optical amplifier; Emission cross-section; FWHM; Bandwidth gain