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Photoluminescence, nonlinear optical and gamma radiation shielding properties of high concentration of Eu_2O_3 doped heavy metal borate glasses

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Abstract

In this study, highly Eu^{3+}—doped (up to 5 mol%) $10ZnO—40Bi_2O_3—50B_2O_3$ glasses were prepared by melt quench process. The excitation and emission results of the prepared glasses were recorded in the visible region. The Judd—Ofelt intensity and CIE chromaticity parameters of the glasses were calculated and discussed. The nonlinear optical properties of glasses were studied at a pumping wavelength of 532 nm under a nanosecond regime utilizing the sensitive Z—scan technique. We investigated the linear attenuation coefficient (LAC) for the prepared glasses for energies ranging from 0.296 to 1.458 MeV. According to the Z_{eff} results, $10ZnO—40Bi_2O_3—45B_2O_3—5Eu_2O_3$ exhibited good attenuation properties among the fabricated samples.

Introduction

Since the past, researchers have been exploring the types of optical materials for visible to near—infrared (NIR) light emission, conversion, and monitoring purposes for photonics and optoelectronic devices. Solid—state materials such as crystals and glasses offer desirable properties such as transparency and act as a host material for optically active ions such as RE ions, quantum dots, and d—block ions [1], [2], [3]. Compared to crystals, glassy materials are advantageous because of their high RE ion solubility, molding ability, and

chemical inertness [4]. Therefore, RE ions activated optical materials are used in optical fiber lasers, amplifiers, and gain media for solid—state NIR laser applications [5], [6]. In particular, Eu^{3+} doped glass will offer emission of light in the visible region and can be easily devised into solid—state LEDs under near ultra—violet (UV) / Blue light—emitting diodes [7], [8]. The melt—quenching of appropriate compositions of oxides results in desirable optical glass for technical applications [9]. In the host glass composition, oxides of borate, silicate, and phosphates are readily used as glass—forming agents, and heavy metals are used to modify the glass network [10]. Using a glass former, B_2O_3 and glass modifiers such as ZnO and Bi_2O_3 glass can be prepared at low melting temperature [11], [12]. Interestingly, the inscription of large RE concentrations in the borate network is quite easy because of its boron anomaly character compared to other oxide networks [13]. Along with ZnO, the addition of Bi_2O_3 into the vitreous network makes glass a moisture resistor, which further reduces the phonon vibrations of the host glass by bridging the glass network by the BiO_6 functional group [14]. High—density bismuthate glasses are useful for optical limiting applications owing to the presence of highly polarizable functional groups in the network. The doping of Eu^{3+} ions into the borate bismuth glass causes glass to exhibit exceptional optical properties such as absorption of near UV, blue radiation, and luminescence in a wide orange—reddish region [15], [16]. The emission band position, emission intensity, and lasing potential of Eu^{3+} ions are always linked to the phonon vibrations of the host glasses and the doping percentage [17], [18], [19].

The investigation of nonlinear optical properties of (NLO) RE—doped glasses has gained great importance in recent years for the development of glassy materials for optical limiting, optical switching, and signal processing applications [20]. Optical limiters or optical limiting (OL) materials normally exhibit the third order—NLO properties because this is the OL materials provoked the benefits such as low limiting threshold and high damage threshold values [21]. Hence, it is important to study the third—order NLO properties to demonstrate an effective host for the fabrication of good optical limiters. Among the different materials of interest to date for OL—limiting applications, borate materials are of significance because of high laser damage and low limiting threshold values [22]. To improve the NLO features of the parent glasses, the doping of metal nanoparticles [23], bi—metallic nanoparticles [24], embedding the crystal [25] and ceramizing [26] are the routes developed by researchers worldwide. However, the activation of RE ions in the host glasses is the alternative route developed in 1997 by Terashima et al. [27]. However, the investigation of third—order NLO properties on RE—doped glasses has increased in recent years. Of all the RE ions in the periodic table, the trivalent europium ions possess less absorption cross sections in the visible region; therefore, the NLO features are the same in resonant and even in non—resonant excitation which is essential for the real application of RE glasses in OL device construction [28]. With all the motivations, we prepared zinc bismuth borate glasses with high concentrations of Eu_2O_3 (up to 5mol%) and their NLO along with OL features were investigated in the visible region using nanosecond laser pulses.

Currently, the radiation attenuation coefficient of Eu^{3+}—doped glass has been evaluated for radiation shielding applications [29]. These heavy metal glasses with RE offer superior radiation hardness against ionizing radiation compared to existing shielding materials such as concrete [30], [31]. Growing interest in the use of gamma and beta rays in the medical and agricultural fields requires versatile shielding materials such as highly dense transparent and easily moldable radiation shielding structures. Therefore, in this study, a glass batch of $10ZnO—40Bi_2O_3—50B_2O_3$ was used to host the Eu^{3+} ions to study their photoluminescence and radiation shielding properties.

Section snippets

Experimental details

The designed glass matrices with Eu^{3+} doping were $10ZnO—40Bi_2O_3—(50–x)B_2O_3—xEu_2O_3$(x=0, 1, 2, 3, 4, and 5 mol%). The 99.9% pure oxides such as ZnO, Bi_2O_3, B_2O_3, and Eu_2O_3 were weighed according to the batch calculations. Then, glass batch (7.5 g) was weighed using an agate mortar and pestle for 1 h. Later, homogenized oxides were transferred into a crucible and then kept in a preheated muffle furnace for melting. The glass batch was quenched at 1000 °C on a preheated stainless—steel plate, before …

Physical properties

The physical properties of Eu^{3+}—doped $10ZnO–40Bi_2O_3—50B_2O_3$ glass matrices, such as molar volume, molar refractivity, and electronic polarizability, were calculated using the equations mentioned in reference [34] and values are mentioned in Table 1. In the present case, Eu_2O_3 was substituted for B_2O_3. Hence, the molar mass of Eu_2O_3 is larger than that of B_2O_3; therefore, Eu_2O_3 incorporation increases the density along with refractive indices of S1, S2, S3, S4, S5, and S6 samples, respectively. The …

Conclusions

Heavily Eu^{3+}—doped glasses were prepared by the melt quenching method. The prepared glasses consisted of an amorphous network composed of BiO_6 groups of bismuth, BO_3, and BO_4 units of borate structural groups. The addition of Eu^{3+} resulted in a greater number of non—bridging oxygen atoms in the glass. The branching ratio, stimulated emission cross—section, and measured radiative lifetime for the $^5D_0 \rightarrow {}^7F_2$ transition at 613 nm are optimum for continuous lasing performance. The attenuation of NLO…

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.…

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>
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