Further studies of radiation trapping in Er^{3+} doped chalcogenide glasses

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Absorption and emission bands in trivalent erbium ions Er^{3+} are known to strongly overlap, which means that in heavily doped samples, it is possible to observe the effects of sequential radiation absorption and re-emission processes that involve the Er^{3+} ions. In particular, this effect of “radiation trapping” (RT) or “radiation/ excitation diffusion” is responsible for the dependence of the measured photoluminescence (PL) lifetime and PL spectrum shape in Er^{3+} chalcogenide glasses on the rare-earth doping concentration and sample size.[1,2]. It is worth mentioning here that the original name “excitation diffusion” originates from Milne’s paper where he pointed out the formal similarity of equations describing the effect with those for normal diffusion [3].

In present paper we present the results of experiments which are design to maximize the effect of RT by passing the light along the bulk of a chalcogenide glass sample as shown in Figure 1 (b-d). We carry out experiments on samples having regular cylindrical shape, which allows us to do some simple calculations predicting the shape and lifetime of PL (see Equations (1-3) in Figure 1). The results of these predictions appear to be in a very good agreement with experimental data as shown in Figure 1(a). These results show that RT effectively “stirs” the excitation inside of sample, evenly distributing it throughout the whole volume of the sample.

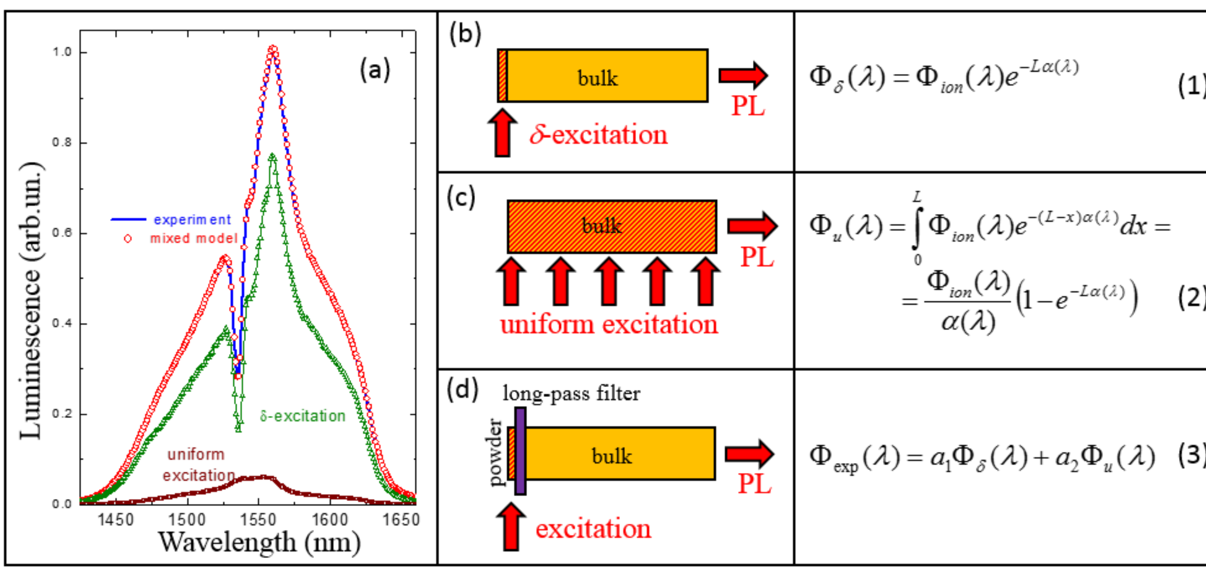

Figure 1. The design of experiment is shown in (d). The excitation light interacts with a fine powder of material and PL of the powder is filtered by a long-pass filter allowing only $^4I_{13/2}$–$^4I_{15/2}$ emission to reach the bulk sample. The PL coming out from the other side of the bulk sample (blue line in (a)) is a combination of emission of powder partially absorbed by bulk (green line in (a)) and radiation trapped inside of bulk sample (maroon line in (a)). The spectra of both contributors $\Phi_\delta(\lambda)$ and $\Phi_u(\lambda)$ are calculated using Equations (1) and (2) where $\Phi_{ion}(\lambda)$ is the emission spectrum of isolated Er^{3+} ion, $\alpha(\lambda)$ is the absorption coefficient and L is the length of the bulk cylindrical sample. The results of calculations using Equation (3), shown in (a) by open red circles, demonstrate a very good agreement with experimental data.

It is worth noting that the results in Figure 1(a) refer to the $^4I_{13/2}$–$^4I_{15/2}$ emission band. In the present paper, we also investigate the effect of RT on the PL of the upper $^4I_{11/2}$–$^4I_{13/2}$ emission band and demonstrate the effect of competition of RT with non-radiative relaxation. We build a Monte Carlo model of the effect and discuss how RT can be used to extract useful information concerning the material properties.

References

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