Fig. 3 compares the ratios of PL decay times for 4I11/24I15/2 and 4I11/24I15/2 emission bands for different glasses. It shows linear dependence in a form

|  |  |
| --- | --- |
|  | (1) |

where *a* is a slope with values listed in Table 1.

Suppose excited ions may relax through two independent processes with characteristic times **1 and **2. In this case, the decay of *Ni* after switching-off the excitation may be described by a simple rate equation

|  |  |
| --- | --- |
|  | (2) |
|  | (2a) |
|  | (2b) |
|  |  |

which corresponds to a characteristic time

|  |  |
| --- | --- |
|  | (3) |

Experimentally, **(0) may be observed in fine powders where the influence of RT has been proven to be negligible. However in a presence of RT some modifications of Equation (2) are required. First of all, we note that the radiative transition becomes “less efficient” because part of emitted PL photons is reabsorbed by Er3+ ions. Therefore, Equation (2) should be corrected as

|  |  |
| --- | --- |
|  | (4) |

here *p*esc(*L*) is the probability of photon to escape the sample with the size *L* without being reabsorbed. Obviously, the parameter *p*esc depends on the sample size. Thus, in fine powders, *p*esc(*L*)→1 due to small size of powder particles and the inefficiency of reabsorption. On the other hand, in large samples *p*esc(*L*)→ 0 meaning that nearly all photons are being reabsorbed within a huge volume of the sample. The solution of Equation (4) gives again a single exponential decay but with a different characteristic time

|  |  |
| --- | --- |
|  | (5) |

which is observed in bulk samples with *effective geometrical size* *L* as PL decay time. Dividing Equation (3) by (5) we find a ratio of two characteristic PL decay times in powdered and bulk materials as

|  |  |
| --- | --- |
|  | (5a) |
|  | (6) |

Equation (6) is a general one that can be applied to some particular cases. Let us start with the 4I13/24I15/2 relaxation of Er3+ ions. Usually, relaxation from 4I13/2 level (it is referred to as level 1 in this paper) to ground level 4I15/2 (level 0) occurs by radiative emission which is known to be the dominant relaxation process in many glasses. In other words, there is only one relaxation mechanism and hence equation (6) may be reduced to

|  |  |
| --- | --- |
|  | (7) |

here the index (1) shows that Equation (7) refers to the first emission/absorption band, i.e. 4I13/2  4I15/2.

Er3+ in second exited state 4I11/2 may relax either directly to 4I15/2 ground state or through intermediate excited 4I13/2 state. The first 4I11/24I15/2 relaxation is purely radiative and may be strongly affected by RT due to the presence of matching 4I15/24I11/2 absorption band. The presence of RT is supported by Fig. 1 and reported earlier for some other glasses. Let us assume that 4I11/24I15/2 radiative lifetime is **20.

The relaxation from 4I11/2 to 4I13/2 state may be radiative or non-radiative. Obviously, for non-radiative relaxation there is no RT. However, for 4I11/24I13/2 radiative relaxation the RT influence is also negligible because detectable 4I13/24I11/2 excitation stimulated absorption appears only at very high pumping levels far exceeding those used in present paper. Assuming that radiative lifetime is  and non-radiative relaxation time is we get an effective time of relaxation from 4I11/2 to 4I13/2 as **21 = (1/+1/)1 and in case of relaxation of 4I11/2 level equation (6) may be presented as

|  |  |
| --- | --- |
|  | (8) |

By combining experimental results presented by equation (1) with equations (7) and (8) it is easy to derive the relation between and as

|  |  |
| --- | --- |
|  | (9) |

In very big samples (*L*→∞) as we already mentioned earlier the escape becomes improbable, i.e. *p*esc→0 for both bands giving us a simple relation between **20 , **21 and experimental value of *a*

|  |  |  |  |
| --- | --- | --- | --- |
|  | or |  | (10) |

Equation (10) is the final result of our simple model and it shows that the slope of the linear dependence (*a*) in Equation 1 may be used to evaluate **20 and **21 as

|  |  |  |  |
| --- | --- | --- | --- |
|  | and |  | (11) |

The results of these calculations for four different glasses doped with Er3+ ions are summarized and presented in Table 1. The validity of these conclusions is presented in Table 2 which compares the predicted values of **20 with calculations using Judd-Ofelt model. In overall, Table 2 shows quite good agreement of 4I13/24I15/2 radiative recombination times  with experimental values of PL decay times in fine powders **10(0) confirming the applicability of JO model to our case. Table 2 also shows a reasonable agreement of values of 4I13/24I15/2 radiative recombination times  and **20 which are calculated in present paper.