

The Efficiency of the Quantum-Splitting Process in $\text{SrAl}_{12}\text{O}_{19}:\text{Pr}^{3+}$

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Commercial phosphor materials have a quantum efficiency of less than 100%, although Piper et al. demonstrated already in 1974 a quantum efficiency of 140% in $\text{YF}_3:\text{Pr}^{3+}$ [1]. This achievement was based on the sequential emission of two photons after optical excitation of the Pr^{3+} ion. More recently, an efficiency of close to 200% was demonstrated by Meijerink's group [2] in a more complicated system involving a combination of energy transfer and relaxation processes.

Sequential emission of photons in $\text{SrAl}_{12}\text{O}_{19}:\text{Pr}^{3+}$ has been reported Srivastava and Beers [3]. However, the quantum efficiency of this system was found to be well below unity. Here we report on the origin of the apparent luminescence quenching in this system.

Pr^{3+} based quantum-splitting phosphors are optically pumped via the $4f^2$ to $4f^15d$ transition, followed by a non-radiative relaxation to the $^1\text{S}_0$ state. Radiative relaxation leads to the emission of the first photon in the UV spectral region, and one of the possible decay channels populates the $^3\text{P}_0$ level. Radiative relaxation from this level leads to the emission of the second, blue photon, completing the quantum-splitting process.

A quantum efficiency of less than 100% implies that the $^1\text{S}_0$ is depopulated in part non-radiatively. To verify this implication we measured the relaxation dynamics after pulsed excitation ($\lambda_{\text{ex}} = 193$ nm, pulse width 2.5 nsec) of both the $^1\text{S}_0$ and $^3\text{P}_0$ emission in $\text{SrAl}_{12}\text{O}_{19}:\text{Pr}^{3+}$ at 403 nm and 488 nm, respectively. The $^1\text{S}_0$ signal shows the expected exponential decay, a decay that is reflected in a corresponding rise of the $^3\text{P}_0$ fluorescence. However, we observe an initial rapid rise of the $^3\text{P}_0$ signal, which cannot be attributed to the $^1\text{S}_0$ decay, but must involve non-radiative relaxation via the 5d or host conduction band.

The work was supported by a grant from The Department of Energy.

References:

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