Optical properties of the quantum splitting phosphor YF_3: Pr^{3+}

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YF_3 doped with Pr^{3+} was the first phosphor material found to have a quantum efficiency more than 100% in the visible (Piper et al. in 1974 [1]) after it had been shown in 1957 by Dexter that this process is experimentally feasible [2]. Under UV excitation, photon cascade emission (PCE) or a quantum splitting process is observed, where a single photon of high energy is converted into two visible photons. The cascade emission is a consequence of the Pr^{3+} energy level diagram. If the lowest energy component of the Pr 4f5d is located well above the $4f^2[^1S_0]$ state, emission can take place in two steps via the transition $^1S_0 \rightarrow {}^1I_6$ followed by a radiative decay from the $^3P_0$ level.

Fluoride based host materials are not stable under Hg discharge excitation used in fluorescent lighting, thus considerable work has been devoted to quantum splitting phophors (QSP) based on non-fluoride host materials since the initial report by Piper et al [1]. This has come at the expense of a thorough investigation of the Pr^{3+} doped YF_3 system.

We report investigations on YF_3:Pr^{3+} powder samples and single crystals in order to explore the unique properties of this material which lead to a quantum efficiency of 140% at room temperature as reported by Piper et al.[1]. Excitation measurements show that the $^1S_0$ is located at 214 nm, well separated from the 4f5d band (the rise of the 4f5d starts at 202 nm), which prohibits thermally induced quenching processes involving the 5d levels. The absence of non-radiative processes is confirmed by measurements of the $^1S_0$ decay times as a function of temperature.

The work was supported by in part by GE and the Department of Energy under contract DE-FC26-99FT40632.

References:

[1] W. W. Piper, J. A. DeLuca and F. S. Ham, J.Lumin. **8** (1974) 344.

[2] D. L. Dexter, Phys. Rev. **103** (1957) 630