A Study on the Luminescence of Unconventional Visible Quantum-cutting Phosphors by Using Synchrotron Radiation

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We have discovered and investigated unconventional non-fluoride quantum-cutting phosphors, such as $KCaGd(PO_4)_2:Tb^{3+}$, $Gd_3Al_5O_{12}:Eu^{3+}$ and $Gd_3Al_5O_{12}:Tb^{3+}$. Based on the analysis of the experimental photoluminescence (PL) and PL excitation (PLE) spectra, the theoretical quantum efficiencies were found to be 146.1% and 172.4% for $KCaGd(PO_4)_2:Tb^{3+}$(9mol%) and $Gd_3Al_5O_{12}:Eu^{3+}$ (1.5 mol%), respectively. Plausible mechanisms and energy level diagrams involving Gd^{3+}-$Tb^{3+}$and Gd^{3+}-Eu^{3+} energy transfer were proposed to rationalize the QC processes. In this report, we described the investigation on the $KCaGd(PO_4)_2:Tb^{3+}$ phosphor.

Figure 1 shows the PLE spectra of $KCaGd(PO_4)_2:Tb^{3+}$ (5 mol%) monitoring the $^5D_3 \rightarrow {}^7F_J$ emission of Tb^{3+} at 543 nm (red line) and the $^5D_4 \rightarrow {}^7F_J$ emission of Tb^{3+} at 416 nm (black line), both at 300K. The spectra are scaled on $^8S_{7/2} \rightarrow {}^6I_J$ excitation intensity.

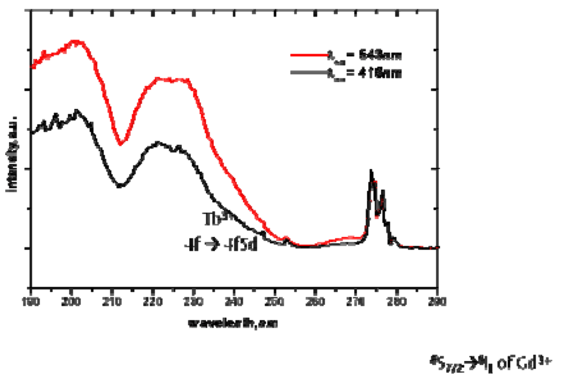

Fig. 1: PLE spectra of $KCaGd(PO_4)_2:xTb^{3+}$ monitored at (a) 543 nm, and (b) 416 nm.

Figure 2 shows the PL spectra of $KCaGd(PO_4)_2:Tb^{3+}$ (5 mol%) upon excitation in the ^6I_J level of Gd^{3+} at 274 nm (black line) and upon excitation in the $4f^75d$ band of Tb^{3+}

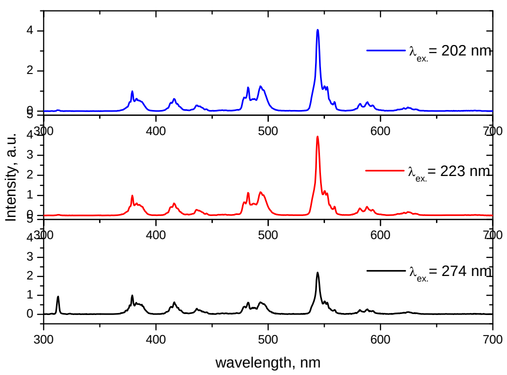

Fig. 2: PL spectra of $KCaGd(PO_4)_2:xTb^{3+}$ under excitation at (a) 202 nm, (b) 223 nm, and (c) 274 nm.

at 223 nm (red line) and 202 nm (blue line), both at 300K. The spectra are scaled on the $^5D_3 \rightarrow {}^7F_J$ emission (416 nm) intensity.

Figure 3 represents the energy level diagram of the Gd^{3+}-Tb^{3+} system, showing the possible of visible quantum cutting by cross-relaxation (dotted line) from Tb^{3+} to Tb^{3+}. ① and ② denote cross relaxation and direct energy transfer.

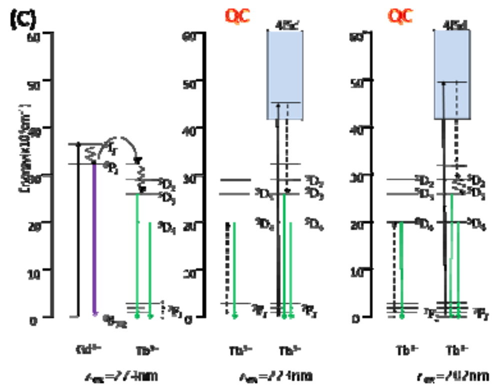

Fig. 3: Schematic energy levels of $Gd(PO_3)_3:Tb^{3+}$ showing possible mechanisms for visible QC under excitation of VUV with $_{ex}$ = (a) 273 and (b) 217 nm; ① and ② denote cross relaxation and direct energy transfer, respectively.

Figure 4 indicates the variation of the calculated quantum efficiency of $KCaGd(PO_4)_2:Tb^{3+}$ with doped Tb^{3+} concentration.

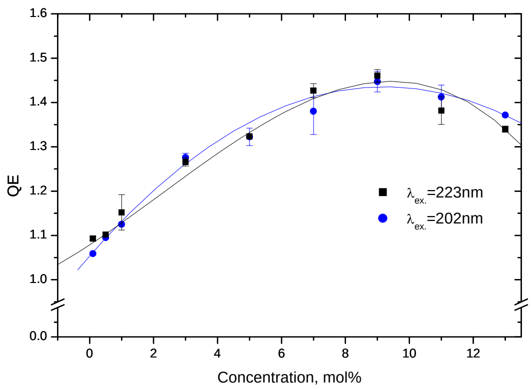

Fig. 4: QE as a function of Tb^{3+} contents of $KCaGd(PO_4)_2:xTb^{3+}$

We have investigated the $KCaGd(PO_4)_2:xTb^{3+}$ phosphors which shows QC via a down conversion mechanism with QE of 146.1% under the excitation at 202 and 223 nm, respectively.