SPECTROSCOPIC PROPERTIES AND ORANGE-TO-BLUE UPCONVERSION OF Pr^{3+} IONS IN A SODIUM GERMANATE GLASS

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Germanate glasses are of interest as hosts for rare earth ions as they possess maximum phonon energies, which are lower than any of the other common oxide glasses such as; silicates, phosphates, and borates. The luminescence efficiency of these glasses doped with rare earth ions is obviously higher due to the lower vibrational energies thus they are attractive for certain optical applications such as fiber and planar waveguides. The optical properties of the praseodymium dopant ion have been extensively studied in many crystalline and non-crystalline hosts as it is an excellent optical probe to study the dynamics of radiative and non-radiative processes due to the numerous transitions from the emitting energy levels.

Following one photon excitation of the Pr^{3+} ion with 457.9 nm (Figure 1), emission was observed from the $^3P_1$, $^3P_0$ and $^1D_2$ excited states. Emission from the $^3P_1 \rightarrow {}^3H_5$ transition was observed centered at 527 nm while emission from the $^3P_0$ state to the $^3H_{4,5,6}$ levels was observed centered at approximately 490, 540, and 620 nm, respectively. Emission from the $^3P_0 \rightarrow {}^3F_2$ and $^3P_0 \rightarrow {}^3F_{3,4}$ transitions was observed centered at 645 and 730 nm, respectively and emission from $^1D_2$ to the $^3H_{4,5}$ states was observed centered at 605 and 700 nm, respectively. Selective excitation into the $^1D_2$ energy level (582.9 nm) was used to aid in the transition assignments reported using an excitation wavelength of 457.9 nm (Figure 1, inset). Following excitation with 582.9 nm, emission from the $^1D_2$ state is predominant.

Blue upconverted emission was observed from the $^3P_0 \rightarrow {}^3H_{4,5}$ and $^3P_1 \rightarrow {}^3H_5$ transitions following excitation using 582.9 nm (Figure 2). A power dependence study of the $^3P_0 \rightarrow {}^3H_4$ transition was performed and the blue emission was shown to obey a quadratic dependence on the pump power (Figure 2, inset). Upconversion therefore occurs via a two photon process. No inflection point was observed in the power study thereby ruling out photon avalanche (PA) as the mechanism of upconversion. Excited state absorption (ESA) or energy transfer upconversion (ETU) are therefore the likely candidates.

In this paper, we report on the optical properties of a praseodymium doped sodium germanate glass as well as discuss the mechanism(s) for the orange-to-blue upconversion following excitation into the $^1D_2$ state.

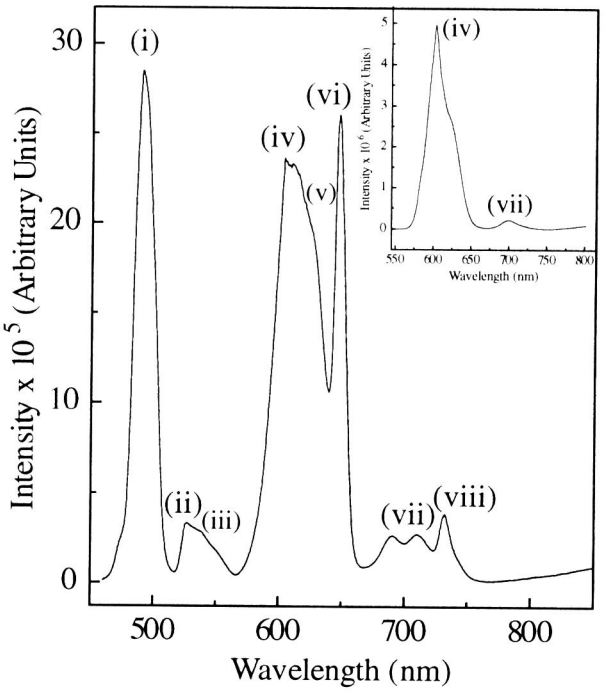

Figure 1: Emission spectrum of sodium germanate glass doped with Pr^{3+} following excitation with 457.9 nm at room temperature, showing (i) $^3P_0 \rightarrow {}^3H_4$ (ii) $^3P_1 \rightarrow {}^3H_5$ (iii) $^3P_0 \rightarrow {}^3H_5$ (iv) $^1D_2 \rightarrow {}^3H_4$ (v) $^3P_0 \rightarrow {}^3H_6$ (vi) $^3P_0 \rightarrow {}^3F_2$ (vii) $^1D_2 \rightarrow {}^3H_5$ (viii) $^3P_0 \rightarrow {}^3F_{3,4}$ transitions.
Inset: Emission spectrum of sodium germanate glass doped with Pr^{3+} following excitation with 582.9 nm at room temperature, showing (iv) $^1D_2 \rightarrow {}^3H_4$ and (vii) $^1D_2 \rightarrow {}^3H_5$ transitions.

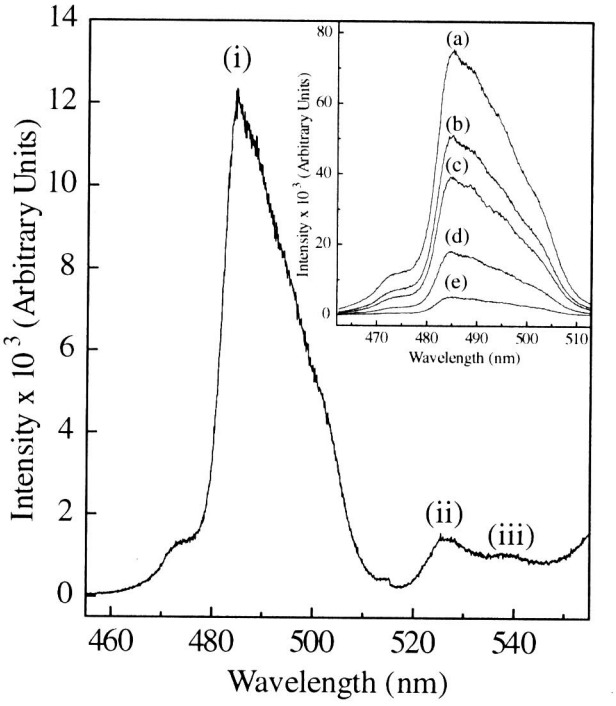

Figure 2: Blue upconverted emission spectrum of sodium germanate glass doped with Pr^{3+} following excitation with 582.9 nm at room temperature, showing (i) $^3P_0 \rightarrow {}^3H_4$ (ii) $^3P_1 \rightarrow {}^3H_5$ (iii) $^3P_0 \rightarrow {}^3H_5$ transitions.
Inset: Upconversion of the $^3P_0 \rightarrow {}^3H_4$ transition as a function of pump power: (a) 800 mW (b) 640 mW (c) 600 mW (d) 500 mW (e) 270 mW.