Length scale of energy transfer mechanisms in $\text{Er}^{3+}$-$\text{Yb}^{3+}$ co-doped waveguides

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The development of high performance integrated optical circuits requires materials with specific and improved properties. One crucial aspect is the development of active waveguides for all-optical gain devices. Specifically, $\text{Er}^{3+}$-doped materials are of great interest in optical communications as they operate efficiently as gain medium at the standard telecommunication wavelength of 1.5 µm. Co-doping $\text{Er}^{3+}$ with $\text{Yb}^{3+}$ ions is a widely used means to enhance the absorption of $\text{Er}^{3+}$ ion in the 910-980 nm range. However, the performance of waveguides on Si platforms compared to their fibre counterparts is still low due to limited material performance. In an earlier work, it has been demonstrated that nanostructuring the ion distribution in the nanoscale is essential to enhance its performance. The aim of this work is to determine the length scale of energy transfer mechanisms between $\text{Er}^{3+}$ and $\text{Yb}^{3+}$ ions in order to improve the performance of waveguides.

Nanostructured $\text{Er}^{3+}$-$\text{Yb}^{3+}$ co-doped $\text{Al}_2\text{O}_3$ waveguides have been prepared by alternate pulsed laser deposition (PLD) on both porous silicon and $\text{SiO}_2$/Si substrates. The waveguides consist of 100 groups of Yb-Er-Yb layers that are center-to-center separated 5.0-6.0 nm. Within each group, the $\text{Er}^{3+}$ layer has an $\text{Yb}^{3+}$ layer at each side, both been separated the same distance from the Er layer that is varied in the range 0.3 nm to 1.7 nm. Reference samples containing only $\text{Er}^{3+}$ and $\text{Yb}^{3+}$ with the same nanostructure have also been produced. The photoluminescence response at 1.53 µm have been studied under direct excitation of the $\text{Er}^{3+}$ ions at 800 nm and by exciting the $\text{Yb}^{3+}$ ions at 950 nm. The photoluminescence intensity shows a large enhancement (a factor of 3) with respect to that of film doped only with $\text{Er}^{3+}$ for a separation of Er-Yb layers of 1.2 nm. This enhancement is discussed in terms of the $\text{Er}^{3+} \rightarrow \text{Yb}^{3+}$ energy transfer and $\text{Yb}^{3+} \rightarrow \text{Er}^{3+}$ backtransfer mechanisms and the results show the nano-scale distances required to make them optimum.