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Energy-Transfer-Upconversion Models, Their Applicability and Breakdown in the Presence of Spectroscopically Distinct Ion Classes: A Case Study in Amorphous Al_2O_3:Er^{3+}

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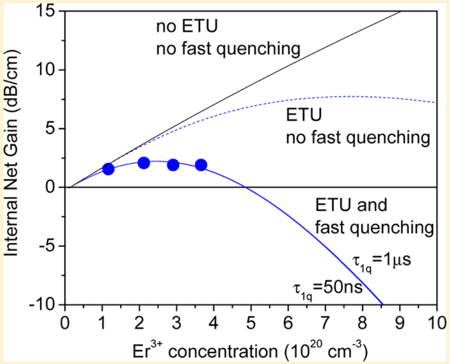

ABSTRACT: The influence of energy migration and energy-transfer upconversion (ETU) among neighboring Er^{3+} ions on luminescence decay and steady-state population densities in Al_2O_3:Er^{3+} thin films is investigated by means of photoluminescence decay measurements under quasi-CW excitation. The experimental results are analyzed by several models. As expected from the basic physical assumptions made by these models, only Zubenko's microscopic model provides good agreement with the experimental data, while other donor−acceptor treatments found in the literature are unsuccessful and the macroscopic rate-equation approach provides meaningful results only when misinterpreting the intrinsic lifetime as a free fit parameter. Furthermore, a fast quenching process induced by, e.g., active ion pairs and clusters, undesired impurities, or host material defects such as voids, that is not revealed by any particular signature in the luminescence decay curves because of negligible emission by the quenched ions under quasi-CW excitation, is verified by pump-absorption experiments. This quenching process strongly affects device performance as an amplifier. Since Zubenko's microscopic model treats all ions equally, it is unable to describe a second, spectroscopically distinct class of ions involving a fast quenching process. The model is extended to take into account the fraction of quenched ions. This approach finally leads to excellent agreement between the luminescence-decay, pump-absorption, and small-signal-gain experiments within the frame of a single theoretical description.