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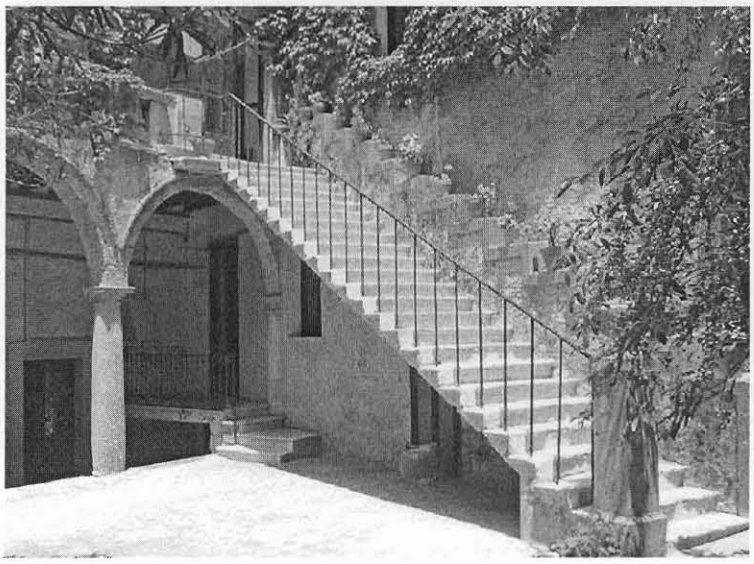

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PROCEEDINGS

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Upconversion Luminescence Transients

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Abstract
Inhomogeneous active-ion distributions in laser materials lead to strong deviations of upconversion versus direct luminescence transients from the quadratic law of energy-transfer upconversion. Measured luminescence decay curves in $LaSc_3(BO_3)_4$:Nd^{3+} and $GdVO_4$:Nd^{3+} confirm experimentally the predicted deviations. Differences in energy migration within the metastable level of Nd^{3+} are identified.

For several decades, energy-transfer upconversion (ETU) in rare-earth-ion doped systems has been studied intensively, partly because of the fundamental interest in the physical nature of this process, but also because of the availability of near-infrared pump sources for the ETU excitation of visible luminescence and laser emission and because ETU can introduce a loss channel for devices emitting in the infrared region.

We investigate fundamentally the behavior of infrared luminescence emitted directly from a metastable level after excitation by a short laser pulse and visible luminescence emitted after ETU from this metastable level to higher-lying levels [1]. Although these two luminescences are connected by the same metastable level and influenced by the same ETU process, they probe different classes of ions. Whereas the infrared luminescence probes all ions, the visible luminescence probes only the class of ions susceptible to ETU [2]. A simple analytical model predicted that such luminescence decay curves exhibit a super-quadratic dependence of upconversion on direct luminescence decay [3].

The Nd^{3+} ion can serve as a model system for such investigations. It exhibits strong ETU from the metastable $^4F_{3/2}$ level (Fig. 1). When doped into oxide matrices, the $^4F_{3/2}$ level is the only metastable level within the 4f subshell. The Nd^{3+} energy levels excited by ETU decay by fast multiphonon relaxation and, hence, the weak visible fluorescence emitted from these levels represents a quasi instantaneous reaction on the dynamics of the $^4F_{3/2}$ metastable level.

$LaSc_3(BO_3)_4$ and $GdVO_4$ crystals with different Nd^{3+} concentrations were provided by the University of Hamburg, Germany, and the General Physics Institute, Moscow, Russia, respectively. Experimental results obtained after short-pulse laser excitation near 800 nm (for an example, see Fig. 2) show that the upconversion (VIS) decay is much faster than the square of the direct (IR) decay, indicating the superquadratic behavior of ETU that fundamentally derives from the inhomogeneous active-ion distribution in the host. The experimental decay curves are described in a new model taking into account isolated, paired, and clustered ions. Comparison between $LaSc_3(BO_3)_4$ and $GdVO_4$ shows that static ETU in $LaSc_3(BO_3)_4$ [4] leads to a more

superquadratic behavior, in agreement with model predictions. These findings question many interpretations of upconversion luminescence in solid-state laser materials.

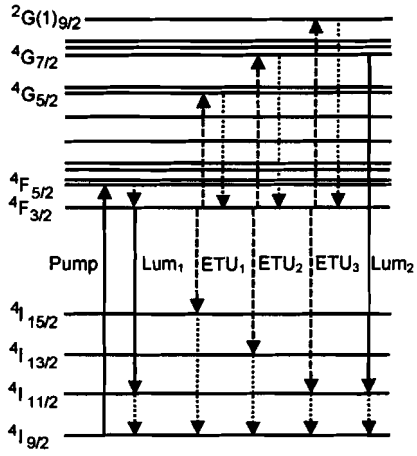

Fig. 1. Partial energy-level scheme of Nd^{3+} indicating the relevant processes: pump excitation at 800 nm, direct (LUM_1) and upconversion (LUM_2) luminescence, ETU processes, and fast multiphonon relaxation (dashed arrows).

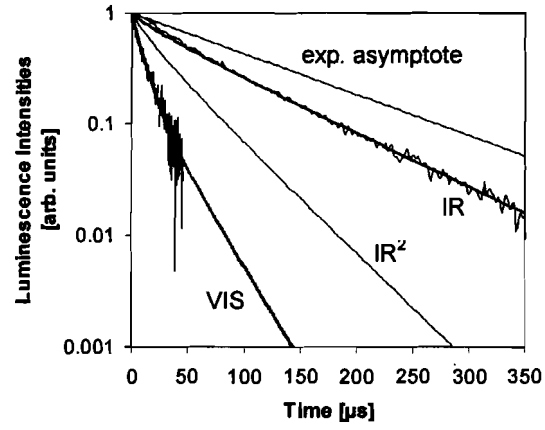

Fig. 2. Measured direct (IR) and upconversion (VIS) luminescence intensities in $LaSc_3(BO_3)_4$:(10%)Nd^{3+} together with model results (solid lines) for direct (IR) and upconversion (VIS) decay as well as the exponential asymptote and the square of direct (IR) decay [1].

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