Excitation Cross-Section of Erbium in Semiconductor Matrices under Optical Pumping

Authors

T. Gregorkiewicz
University of Amsterdam, Van der Waals-Zeeman Institute
Amsterdam

O.B. Gusev
Russian Academy of Sciences, Ioffe Physical-Technical Institute
St.-Petersburg

M.S. Bresler
Russian Academy of Sciences, Ioffe Physical-Technical Institute
St.-Petersburg

M. Forcales
University of Amsterdam, Van der Waals-Zeeman Institute
Amsterdam

P.E. Pak
Russian Academy of Sciences, Ioffe Physical-Technical Institute
St.-Petersburg

N.Q. Vinh
University of Amsterdam, Van der Waals-Zeeman Institute
Amsterdam

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Excitation Cross-Section of Erbium in Semiconductor Matrices under Optical Pumping

O.B. Gusev[1], M.S. Bresler[1], P.E. Pak[1], I.N. Yassievich[1], M. Forcales[2], N.Q. Vinh[2] and T. Gregorkiewicz[2]

[1] A.F.Ioffe Physico-Technical Institute, Russian Academy of Sciences, Polytekhnicheskaya st. 26, RU-194021 St.-Petersburg, Russia

[2] Van der Waals-Zeeman Institute, University of Amsterdam, Valckenierstraat 65, NL-1018 XE Amsterdam, The Netherlands

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Abstract. Based on a detailed consideration of excitation mechanisms of erbium in crystalline and amorphous matrix we present an analysis of the physical meaning of the Auger excitation cross-section of Er^{3+} ions in semiconductor. It is demonstrated that large values of Auger excitation cross-sections under optical pumping in semiconductor matrices are due to large values of band-to-band absorption coefficient exceeding by several orders of magnitude the absorption coefficient of erbium in dielectric SiO_2 and Al_2O_3 matrix. The Auger excitation cross-section of Er^{3+} in semiconductor matrices is roughly given by the ratio of the matrix absorption coefficient to concentration of Er^{3+} ions. While the analysis of the effective excitation cross-section is carried out for Er-doped crystalline and amorphous silicon, the results are expected to be applicable to the other rare-earth doped semiconductors. Based on low-temperature experimental results for crystalline silicon we get the Auger excitation coefficient of $c_A \approx 7 \times 10^{-10}$ cm^3s^{-1} and the effective cross section $\sigma_{eff} = 4 \times 10^{-12}$ cm^2. For amorphous silicon at 100 K we obtain $\sigma_{eff} = 1.4 \times 10^{-14}$ cm^2.

Introduction

Semiconductor matrices doped with rare earth ions are of great interest for optoelectronics. In contrast to dielectric matrices in which erbium ions are excited by direct absorption of photons, excitation of erbium in semiconductor matrices occurs mainly by free carrier recombination in an Auger process [1] or via impact excitation by hot electrons for the case of electroluminescence from reverse-biased p-n junctions [2].

The efficiency of erbium excitation under direct optical pumping in dielectric matrix of SiO_2 and Al_2O_3 is determined by the excitation cross-section of erbium σ, which enters into the rate equation

$$\frac{dN_{Er}^*}{dt} = \sigma\Phi(N_{Er} - N_{Er}^*) - \frac{N_{Er}^*}{\tau}, \qquad (1)$$

where Φ is the photon flux, N_{Er} and N_{Er}^* are total concentrations of erbium ions and of excited erbium ions, respectively, and τ is the lifetime of erbium in the excited state. This equation describes the processes of excitation and de-excitation of erbium in a two-level scheme and σ is a real cross-section of photon absorption by an erbium ion. For erbium in SiO_2 the experimentally determined value of σ is 8×10^{-21} cm^2 [3].

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