Tuesday
22 May 1990
SANTA ANA ROOM A9

MORNING
JTUA

8:00 AM Joint Symposium on Doped Fiber Lasers

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8:45 AM

JTUA3 Absorption-emission cross-section ratio for Er^{3+} doped fibers at 1.5 μm

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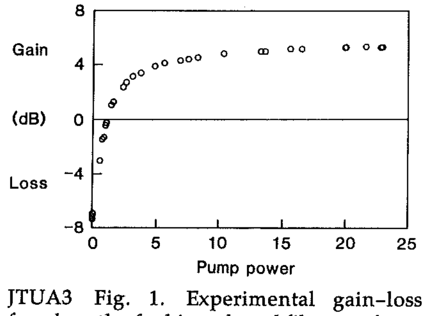
Erbium doped optical fibers have been demonstrated to be both efficient and practical optical amplifiers in the 1.5-μm region.[1] Research is now concentrated on optimizing the performance of such amplifiers. Accurate modeling allows possible routes to optimization to be readily evaluated. The ratio of absorption cross section σ_A to that for emission σ_E, both at the gain peak and across the band, is crucial to such a model, particularly for in-band (e.g., 1490-nm) pumping.

Several determinations of the absorption emission cross sections have been made for the $^4I_{13/2}\leftrightarrow{}^4I_{15/2}$ transition of Er^{3+}.[2-4] All report that at the gain peak the ratio σ_A:σ_E is less than one, values typically being 0.8. Initial experiments on fiber optimization for amplifiers[1] showed us that the magnitude of the gain never exceeded that of the ground state absorption, even in conditions of very strong pumping. This brings into question the quoted values for the cross-section ratio. Specific experiments were undertaken to examine this in more detail.

The loss of a length l of fiber is given by $\eta Nl\sigma_A$, where N is the number of ions per unit volume in the fiber and η is the transverse overlap between the dopant and optical field. Under high pumping at 980 nm the gain asymptotically approaches $\eta Nl\sigma_E$. The ratio of gain and loss for a given fiber length thus provides a measure of the ratio σ_A:σ_E. Such measurements were performed at the gain peak on several fibers, and an example is shown in Fig. 1. The ratio σ_A:σ_E is found to be (1.2 ± 0.1):1 and applies to both GeO_2 silica and Al_2O_3 silica fiber types.

Previous estimates of σ_A and σ_E have been based on the Fuchtbauer-Ladenburg (FL) equation in which the cross sections are evaluated from the shape of the absorption and emission spectra, the radiative lifetime of the upper level, and the manifold degeneracies. This analysis was conducted on our fibers, and σ_A:σ_E was found (at the gain peak) to be ~0.8:1, in broad agreement with previous reports. Thus there is a discrepancy between the gain-loss and spectroscopic techniques. The FL equation approach involves several assumptions, one of which is that the process of absorption follows the same path as that of emission: we believe this to be a false assumption in the present case. In reality emission involves transitions predominantly from the lower Stark levels of the upper manifold ($^4I_{13/2}$) to all levels of the ground state manifold. Absorption, on the other hand, is dominated by transitions from the lower Stark levels of the ground state manifold to all those of the upper state.

The two processes would still be equivalent if the probability of transition between any two Stark levels was the same. Recent fluorescent line narrowing work suggests that such probabilities are not equal.[5] As a result the assumptions of the FL equation are inappropriate for the analysis of the erbium system. The gain loss technique reported here thus provides a more reliable measure of the cross-section ratio and will be useful in modeling the erbium amplifier. Further data on the spectral variation of the cross-section ratio are also presented.



JTUA3 Fig. 1. Experimental gain-loss for a length of erbium doped fiber as a function of pump power. The pump wavelength was 980 nm, the signal wavelength was 1535 nm, and the fiber was of the Ge silica type.

1. For example, R. S. Vodhanel *et al.*, Electron. Lett. **25,** 1386 (1989).
2. W. J. Miniscalco, L. J. Andrews, B. A. Thompson, T. Wei, and B. T. Hall, in *Technical Digest, Topical Meeting on Tunable Solid State Lasers* (Optical Society of America, Washington, DC, 1989).
3. E. Desurvire and J. R. Simpson, IEEE/OSA J. Lightwave Technol. **LT-7,** 835 (1989).
4. C. G. Atkins, J. F. Massicott, J. R. Armitage, R. Wyatt, B. J. Ainslie, and S. P. Craig-Ryan, Electron. Lett. **25,** 910 (1989).
5. S. Zemon, G. Lambert, W. J. Miniscalco, L. J. Andrews, and B. T. Hall. Proc. Soc. Photo-Opt. Instrum. Eng. **1171,** paper 23 (1989).