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Excited-State Absorption in ZBLAN:Er^{3+}: Implications for a Diode-Pumped 3-μm Fiber Laser

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Erbium-doped fluorozirconate (ZBLAN) fibers are promising candidates for the construction of compact and efficient all-solid-state 3-μm laser sources for surgical applications. Excited-state absorption (ESA) was found to have a major influence on the lasing properties of the erbium 3-μm transition in ZBLAN fibers. An approach has been suggested recently [1], which aims to avoid pump ESA and requires only low pump intensity, thus enabling high-power double-clad diode pumping of the erbium 3-μm fiber laser. However, the values of the relevant ESA cross-sections could not be determined experimentally so far, because the pump excitation is distributed between two metastable levels of erbium in ZBLAN, and ESA transitions from these two levels overlap in the spectral region of interest.

We have measured ESA spectra of ZBLAN:Er^{3+} in the wavelength range 780-840 nm of ground-state absorption (GSA), using a pump- and probe-beam technique. The investigated fiber (Er^{3+} conc. 1000 ppm mol) is pumped by a Ti:sapphire laser at 990 nm. The effective excited-state cross-sections of transitions from the $^4I_{11/2}$ and $^4I_{13/2}$ metastable levels are derived by calculating the population densities of these levels under the chosen pump conditions and by fitting Gaussian curves to the measured spectra. The resulting values of the peak cross-sections are 1.4×10^{-21} cm^2 at 793 nm (from $^4I_{13/2}$), 2.3×10^{-21} cm^2 at 808 nm (from $^4I_{11/2}$), and 0.9×10^{-21} cm^2 at 831 nm (from $^4I_{11/2}$). ESA from either the $^4I_{11/2}$ or the $^4I_{13/2}$ level is present over the whole wavelength range of GSA, with ESA cross-sections being generally larger than that of GSA. Measured spectra will be presented at the conference.

The implications of the present data for possible double-clad diode pumping of a 3-μm ZBLAN:Er^{3+} laser are as follows. When trying to operate the 3-μm ZBLAN:Er^{3+} laser as a simple four-level system. ESA losses cannot be avoided by choosing a different pump wavelength within the 800-nm pump band. A dominance of GSA over ESA and operation as a four-level system can only be established by, firstly, effectively repopulating the ground state by quenching the lifetime of the $^4I_{13/2}$ lower laser level via energy transfer to a co-doped rare-earth ion, secondly, using a high dopant concentration and, thirdly, applying a low pump intensity [1].

If the lifetime of the lower laser level is effectively quenched by co-doping, the pump band around 980 nm may be superior for pumping a double-clad ZBLAN:Er^{3+} laser operating at 3 μm. From the spectra of Ref. [2] it is apparent that pumping at 979 nm does not only provide a GSA cross-section which is twice as large as at 799 nm and, hence, will strongly support absorption in a double-clad fiber as long as ground-state bleaching can be avoided. It also reduces the ESA cross-section at 979 nm to one third of the GSA cross-section at the same wavelength. In addition, pumping directly into the $^4I_{11/2}$ upper laser level provides a higher Stokes efficiency of the system than pumping into the $^4I_{9/2}$ level. Our computer simulation predicts that the output power of the fiber laser will be 1.5 W when pumping with 7 W of incident power at 979 nm. With increasing diode pump power and with corresponding adjustment of fiber parameters, even higher output powers will be achievable. A wavelength of 979 nm will, therefore, be the pump wavelength of choice for a high-power diode-pumped double-clad erbium 3-μm fiber laser.

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11.00 CFF3

Gain cross section measurements on the 2.8 μm laser transition of Er^{3+} doped BaY_2F_8 single crystal

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Summary

The ~2.8 μm laser transition of Er^{3+} ions is interesting for medical application. The transition takes place between the two excited states $^4I_{11/2}$ and $^4I_{13/2}$. In the fluoride crystals this emission is efficient due to low nonradiative processes between these two levels. The Er^{3+}:BaY_2F_8 [1] is one of the most interesting crystals for 2.8 μm emission because the lifetime ratio between $^4I_{11/2}$ and $^4I_{13/2}$ is closed to one and the phonon energy is low compared to $LiYF_4$. Some strong excitation transfer processes make difficult the prediction of the efficiency by a population rate equations model. It's important to know the gain cross section and population inversion rate to predict the laser properties.

In our experiment, the gain cross section of this transition in Er^{3+}:BaY_2F_8 is directly obtain by a pump-probe technique. The incident pump intensity is closed to the threshold condition of the laser emission. The probe is a white lamp. The first step is to estimate the excited state absorption cross section of $^4I_{13/2} \rightarrow {}^4I_{11/2}$ in a low concentrated sample with a pumping in the $^4I_{13/2}$ level. In the second step we measured the gain cross section for the other pump wavelengths and different crystal concentrations. From these experiments, the population inversion ratio are deduced. All these results can be easily compared together and with other materials [2]. It's possible to predict the best condition for laser emission and at which wavelengths around 2.8μm the laser emission appears.

References :

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