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SPECTROSCOPIC PROPERTIES AND OPERATION OF PULSED HOLMIUM LASER

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Abstract Absorption sprctra measurements and detailed analysis of Er:Tm:Ho:YLF absorption lines at 4 K were carried out. Laser induced fluorescence was utilized to study energy transfer dynamics of three different laser crystals namely, Cr→Tm→Ho in YAG, Tm→Ho:YAG as well as Tm→Ho:YLF.

Pulsed, free runninng laser performance of a freon-cooled Er:Tm:Ho:YLF laser at -10°C and -50°C at different current densities with maximum laser energies of 1.5 J/pulse and 2.25 J/pulse, respectively were obtained.

1. Introduction.

Holmium laser with laser emission peaking at 2.1 μm is an important laser source./1,2/ It's main disadvantage is that it behaves at room temperature as a quasi-three-level system./3/ It requires cryogenic cooling in order to achieve population inversion and efficient laser operation.

It was found that codoping Ho:YAG with sensitizers such as Cr^{3+} and Tm^{3+} have improved CW and pulsed laser performance at ambient temperature. When higher repetition rates are required, we have to use a cooling system to eliminate thermal effects in the laser rod and to maintain laser beam quality. In these cases one would use YLF as a host crystal due to its better optical properties.

Therefore, we have investigated laser operation of pulsed αβHo:YLF using freon as a coolant liquid in a closed cycle cooling system in temperature of -10°C and -50°C.

We have also conducted a comparative study on the routes of energy transfer leading to population of $Ho^{3+}(^5I_7)$ level doped YLF, and compared the results with those of Cr:Tm:Ho:YAG.

2. Experimental

The experimental set up for low temperature absorption spectra and fluorescence decays was described in details./4/ Shortly, samples of the following nominal concentrations (in % at.) were supplied by Litton Airtron: Er^{3+} (30%), Tm^{3+}(10%), Ho^{3+}(0.3%):YLF; Cr^{3+}(1%), Tm^{3+}(5.76%), Ho^{3+}(0.36%):YAG and Cr^{3+}(1%), Tm^{3+}(2.9%):YAG.

Pulsed laser operation of αβHo:YLF and the experimental set-up namely, laser head, resonator, pumping source and the closed cycle cooling system was the same as described in previous publications /4,5/ in details. In this experiment the current density was controlled by varying the temporal pulse width and the charging voltage. Laser output was coupled via 50% reflectivity output coupler and was trasmitted through an AR coated IR grade quartz windows.

3. Results

3.1 Absorption spectra

It is important to identify the excited state levels of Tm^{3+} and Ho^{3+} which are responsible for feeding the $^5I_7$ lasing level of Ho^{3+}. However, at ambient temperature there is an overlap between energy levels of the doped ions which prohibits a proper identification of the energy levels of a multiply doped system. The overlap between the higher Stark components of the electronic levels of of such system can be minimized by lowering the temperature whereas only the low lying Stark components of the energy levels are populated. Absorption spectra and spectroscopic identification of the electronic states of αβHo:YLF at 10 K in the spectral range 380nm to 2 μm was performed and presented recently./4/ From the absorption spectra we were able to excite selectively the energy levels of rare earth ions participating in energy transfer processes which will be described below.

3.2 Excited state dynamics

Laser induced fluorescence was used to study the dynamics of Er:Tm:Ho:YLF and Cr:Tm:Ho:YAG excited states participated in the energy transfer processes at ambient temperature. In all cases, direct excitation into Tm^{3+} or Cr^{3+} levels yielded Ho^{3+} ($^5I_7$) emission. A schematic description of the energy levels in Cr:Tm:Ho:YAG and the various routes of excitation and deexcitation are presented in Fig. 1.

Er:Tm:Ho:YLF

The lifetime of $^5I_7$ level of Ho^{3+} doped YLF excited via $^3F_4$ level of Tm^{3+} was obtained from an exponential decay curve with a value of τ=6.8msec. The built-up of Ho^{3+} ($^5I_7$) level upon Tm^{3+} ($^3F_4$) excitation was also observed, with a rise time, (defined by the time interval from 10% to 90% of the maximum amplitude) of 44μsec. The rise time became larger, up to 72μsec, as we excited into higher levels of Tm^{3+}, namely, into $^3H_4$ level. Tm^{3+} ($^3F_4$) electronic level decyed exponentially with τ=6.4msec and 7.2msec for αβHo:YLF and Cr:Tm:Ho:YAG, respectively. $^3F_4$ level of Tm^{3+} showed a relatively fast built-up (τ=1.8μsec and 1.6μsec for YLF and YAG, respectively) while excited into higher levels of Tm^{3+}.

Cr:Tm:Ho:YAG

Holmium emission originating from $^5I_7$ level could be obtained upon excitation to higher levels of Tm^{3+} ($^3H_6$ $^3H_4$ or $^3H_6$ $^3H_5$) transition, as well as excitation into Cr^{3+} ($^4T_2$) level, peaking at 593.7nm. In all cases the $^5I_7$ level exhibited an average built-up time of 60-77μsec with a typical exponential decay time of $\tau\approx$7.8msec.
The role of Tm^{3+}($^3F_4$) in transferring energy directly to $^5I_7$ was further studied by comparing the fluorescence of $^3F_4$ level in the

presence of Ho^{3+} and without holmium ions. The details will be discussed in the talk.

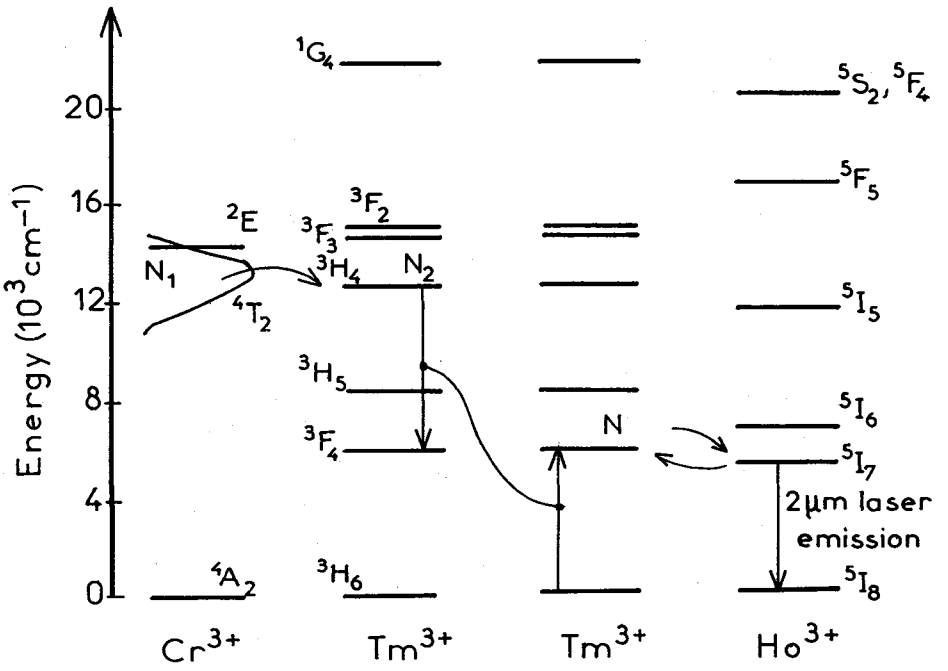

Figure 1. Energy level and pumping routes for Cr^{3+}, Tm^{3+}, and Ho^{3+}.

3.3 Laser performance

Laser operation of αβHo:YLF at −10°C and −50°C at differnt current densities is reported with maximum energy of 1.5 J/pulse (1.28% slope efficiency) at −10°C. (Fig 2). An increase in laser output energy to 2.5 J/pulse and in total efficiency was obtained upon lowering the operating temperature to −50°C. The effect of current density on laser performance at −10°C and −50°C was studied and will be further discussed. It indicates a sharp decrease in laser efficiency as the current density decreases.

4. Conclusion

A comparative spectroscopic study of holmium doped YLF and YAG as well as pulsed, free running laser performance studies of holmium doped YLF crystal, was carried out.

By controlling the current density and the amount of UV radiation of the Xe pumping flashlamp, we were able to operate the laser more efficiently and at higher temperatures, up to −10°C with 1.5 J/pulse.

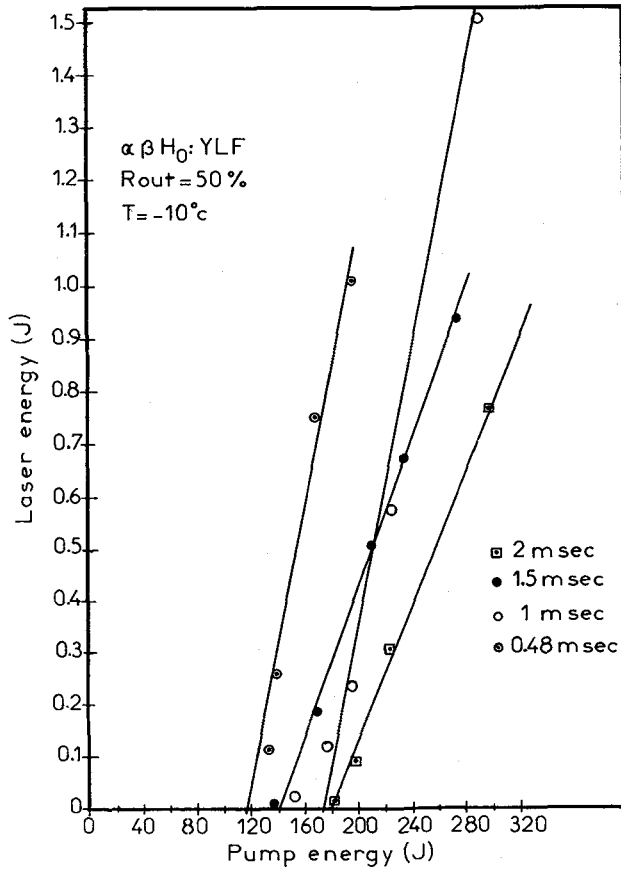

Figure 2. Laser output energy vs. electrical energy deposited in the flashlamp for αβHo:YLF at -10°C with the following pulse widths:
⊗ 0.48 msec. ○ 1 msec ● 1.5 msec ⊡ 2 msec

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