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SINGLE PULSE AND CW MULTIPLY DOPED Ho:YAG AND Ho:YLF LASER

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Abstract

A comparison of the laser performance of the $^5I_7 \rightarrow ^5I_6$ transition at 2.1 micron in multiply doped Ho:YLF and Ho:YAG both in CW and pulsed operating modes is reported. CW operation was carried out at liquid nitrogen temperature, while the pulsed laser was operated in the temperature range from 86K to 220K. In both YAG and YLF, the laser threshold shows a fast rise with temperature. The total laser power at high pumping levels gradually decreases with temperature in YAG. In YLF, however, the laser output is peaked around 150K. The laser performance as a function of temperature, pumping energy and coupling mirror will be presented.

Introduction

The importance of laser emission of various rare earth ions doped in crystal matrix in the spectral range of 1.3-2.5 μ m is well established. In particular, the 2.1 μ m laser line of Ho³⁺ appears to be an attractive potential candidate as a source for rangefinders, target illuminators, parametric oscillators and for medical applications⁽¹⁾. Ho³⁺ exhibits a relatively long lifetime of the emitting level 5I_7 , which results in a high energy storage capability and efficient Q-Switched operation⁽²⁾. As a result, several studies of CW and pulsed Holmium laser operation and spectroscopic studies of some Ho doped crystals have been conducted and reported⁽³⁻⁴⁾, with emphasis on YLF and YAG doped Ho³⁺. Although YLF exhibits a negative change of its refractive index versus temperature (thus implying lower thermal lensing in YLF than in YAG), it also shows a lower thermal conductivity than YAG, which limits the operation to relatively low average power applications. The thermal load on the crystal can be minimized by employing a pulsed pumping source. Since YAG is much easier to handle than YLF, it is useful to compare the two hosts and find out which one is better for CW and for pulsed operation at 2.1 μ m. It is also important to investigate solarization effects, which are considered as a limitation factor in the operation of rare earths doped YAG laser materials⁽⁵⁾.

Experimental

The experimental set-up has been described recently⁽⁶⁾. Briefly, the laser pumping head was a water cooled elliptical reflector coated by gold for CW operation or silver for pulsed operation. The pumping source for the CW Holmium laser is a tungsten-halogen lamp with input electrical power levels (at 50Hz) of up to 1500W. A xenon flashtube (3mm bore diameter, 450 torr), pumped in the range of 30J - 290J was employed in the pulsed version. The evacuated laser head is sealed by two antireflection coated IR-quartz windows, thus allowing laser operation with external mirrors. The laser rear reflector is a 2m concave mirror coated for maximum reflectivity at 2 μ m. The front

mirrors used were in the reflectivity range of between 50% to 95%. All the rods (supplied by Litton Airtron, by Sanders Associates and by the crystal growth unit at NRCN) were of 75mm in length, 5mm in diameter, with plane parallel AR coated ends. Both YLF and YAG crystals were highly doped with Er^{3+} and Tm^{3+} and with a low concentration of Ho^{3+} . The strong and broad absorption bands of Er^{3+} and the consequent energy transfer through Tm^{3+} ions to Ho^{3+} ions, leads to an increase of the cavity transfer efficiency and thus contributes to the overall laser efficiency⁽²⁾. The laser rods were tested for lasing performance in the same cavity. With each laser rod, the laser output emission was measured as a function of the lamp input power, and from that measurement the laser slope efficiency was obtained.

Results and Discussion

We first deal with the CW laser working mode. Working with Ho:YLF, more than 10 rods from three different boules were dynamically checked in the laser cavity. Two of the boules were of identical nominal concentration (namely, 0.1% at. of Ho^{3+}), while the third boule was grown with 0.2% at. of Ho^{3+} . The laser power versus lamp power is quite linear up to the 1.5KW input power used. The slope efficiencies measured for Ho:YLF ranged from 2.6% to 4.7% (using an output coupler of R=80% in all cases). Laser power above 60W (with a slope efficiency of 4.75%) was achieved in some of the rods (see Fig. 1) at both two holmium doping levels in YLF. It is worth while to note that no clear difference in slope efficiency or performance between the two different doping levels was observed. The loss value in the laser rod was obtained from a measurement of the laser output power as a function of lamp electrical power, for different output couplers.⁽⁴⁾ A representing value of the loss is 0.7%/cm for the Ho:YLF rods⁽⁷⁾. Working with Ho:YAG, five rods from the same boule were systematically compared in the laser system as above. Fig. 2 presents the results of the laser output power versus lamp power for rod #3 (with a nominal concentration of 0.5 %at of Ho^{3+}). As is clearly seen from the figure the laser threshold in Ho:YAG is sensitive to the magnitude of the output coupling. The average slope efficiency obtained for Ho:YAG with the 80% mirror is $3.4 \pm 0.2\%$ with 0.4% standard deviation, while the round trip loss in the rods was found to be around 1%/cm⁽⁷⁾.

Single pulse Holmium YLF and YAG laser was operated at various temperatures (86K-220K) and at different input electrical energies. In both Ho:YLF and Ho:YAG, the laser threshold increases sharply with the increase of the temperature. As expected, the laser threshold and slope efficiency depend on the value of the output coupler. At R=50% (the lowest available mirror), the best laser performance, with up to 2.4J/pulse in YLF was obtained.

Figure 1.

CW laser power versus lamp electrical power for $\alpha\beta$ Ho:YLF

Figure 2.

CW laser power versus lamp electrical power for $\alpha\beta$ Ho:YAG with three output couplers

In YAG, the laser output was decreased with temperature. In YLF, at high level of xenon lamp pumping, the laser output energy was increased with the increase of temperature from liquid nitrogen temperature up to about 150K, and then gradually decreased. This unexpected phenomenon which was observed only at high lamp excitation energy will be explained and modelled shortly.

References

1. See for example: D. Aravot, E. Lachman, S. Giler, I. Kaplan, D. Sagie, J. Kagan and Y. Kalisky, The Holmium Laser in Tissue Welding, 7th Congress of the International Society for Laser Surgery and Medicine, Munich, 22-26 June (1987).
2. E.P. Chicklis, C.S. Naiman, R.C. Folweiler, D.R. Gabbe, H.P. Jensen and A. Linz, Appl. Phys. Lett. **19**, 119 (1971).
3. R. Beck, K. Gurs, J. Appl. Phys. **46**, 5225 (1975).
4. N. P. Barnes, and D.J. Gettemy, IEEE J. Quantum Electron. **QE-17**, 1303 (1981).
5. L.F. Johnson, K.A. Ingersoll, J. Appl. Phys. **44** 544 (1973).
6. W. Koechner, Solid State Laser Engineering, Chapter 3, Springer-Verlag New York, Heidelberg, Berlin, (1976).
7. Y. Kalisky, J. Kagan, H. Lotem and D. Sagie, submitted to Optics Communications (1987).