2 µm Ho:YAG and Cr:ZnSe Thin Disk cw Lasers

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Summary

A Thulium fiber laser pumped Ho:YAG thin disk cw laser with an output power of 15 W at a 2% Ho in YAG concentration and 7 W at 1.6% as well as a Thulium fiber laser pumped Cr:ZnSe thin disk cw laser with an output power of 0.4 W will be presented. Comparison of the output power to a Rigrod formula with Boltzmann occupation factors will be shown.

Introduction

Holmium- or Cromium-doped crystals emit in the 2 µm 'eye-safe' wavelength range and are therefore attractive for use in remote sensing, laser material processing as well as laser surgery or therapy [1]. In the present report a single mode Thulium fiber laser at 1.908 µm will be used to pump a Ho:YAG thin disk laser [2] with two different Ho concentrations in a multi-pass pumping scheme via a multimode transfer fiber to generate a flat pump intensity distribution on the disk. With a 24 pump pass concept an efficient absorption of the pump light in the Ho:YAG disk material will be achieved. Furthermore, the same multi-pass pumping concept will be used to pump a Cr:ZnSe thin disk cw laser [3], but in this case, directly with the single mode Thulium fiber laser.

Experimental results of the Ho:YAG and Cr:ZnSe thin disk cw lasers

The single mode Tm fiber laser (IPG, 50 W) is focussed into a 600/660 µm polyimide transfer fiber before entering the Ho:YAG disk laser module (Dausinger + Giesen GmbH) [4, 5]. The Ho concentration of disk 1 is 2% (thickness of 500 µm). The disk 2 has a 1.6% Ho concentration (thickness of 500 µm). The pump beam spot size for the Ho:YAG disk is adjusted to a diameter of approximately 2 mm. The transmission of the output mirror has been changed between 1 and 5%. The output power of the Ho:YAG thin disk cw laser is shown in figure 1 for a optimized output transmission between 2 and 3%. For a pump power of 47 W the output power reached 15 W with a maximum efficiency of 37%. It can be recognized that the output power still shows a linear power scaling dependence in contrast to the 1.4% Ho concentration disk.

For the Cr:ZnSe thin disk cw laser with a disk thickness of 250 µm the pump spot size has to be reduced to 0.75 mm to reach threshold. An output power of 0.4 W with an emission close to 2.35 µm and a linewidth of 30 nm has been accomplished so far.

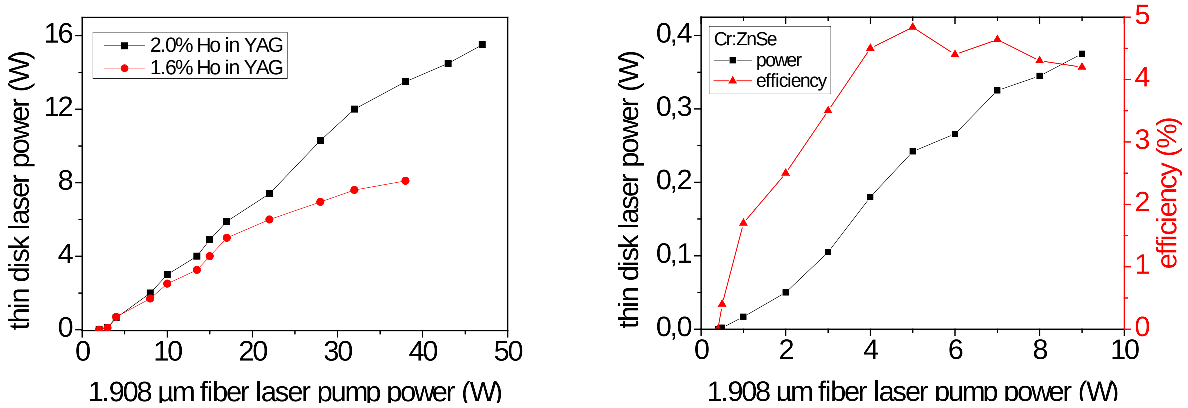

Fig 1. Output power of Ho:YAG (left) and Cr:ZnSe (right) thin disk cw laser versus pump power

Simplified Rigrod simulation for the Ho:YAG system

For the Ho^{3+}-ions only two transitions in the two $^5I_7$ and $^5I_8$ manifolds are necessary to describe the absorption and amplification processes. With the Boltzmann occupation factors of the involved Ho^{3+}-Stark levels and the reflection coefficients R of the crystal facets, the laser output intensity normalized to the saturation intensity will be calculated for a disk with a relatively large thickness [6]:

$$I_{laser} = (1-R_s^l)\cdot\sqrt{R_m}\cdot\frac{g_o\cdot(\alpha_o^{-1}\cdot I_p^+(0)\cdot(1-\Gamma)\cdot(1+R_m^p\cdot\Gamma)-\mathrm{f}_1\cdot L)+\ln\sqrt{R_m^l\cdot R_s^l}}{(1-\sqrt{R_m^l\cdot R_s^l})\cdot(\sqrt{R_m^l}+\sqrt{R_s^l})}\,; \qquad \Gamma = (R_m^l\cdot R_s^l)^{\alpha_o/2g_o}\cdot\exp(-\alpha_o\cdot(\mathrm{f}_2-\mathrm{f}_1)\cdot L) \qquad (1)$$

The Boltzmann population factors for the Ho^{3+}-laser and pump levels are taken from the literature: $f_a = 0.154$, $f_l = 0.017$, $f_u = 0.0994$, $f_b = 0.0994$ [7] with $f_1 = f_a/(f_a+f_b)$, $f_2 = f_l/(f_l+f_u)$. The gain and absorption can be calculated from the products of the cross-sections (eff. pump absorption $5*10^{-21}$ cm^2, eff. stimulated emission $12*10^{-21}$ cm^2), the Ho in YAG concentration and the Boltzmann factors. The 2% Ho concentration is set to $3*10^{20}$ cm^{-3}. In figure 2 the laser output intensity is depicted for the 2% and 1.6% Ho concentration with $I_p(0) = 1$ and a disk thickness of L = 400 µm. For the 2% of Ho concentration case the experimental laser intensity of 0.5 kW/cm^2 (power 15 W, beam diameter 2 mm) is shown in figure 2, too.

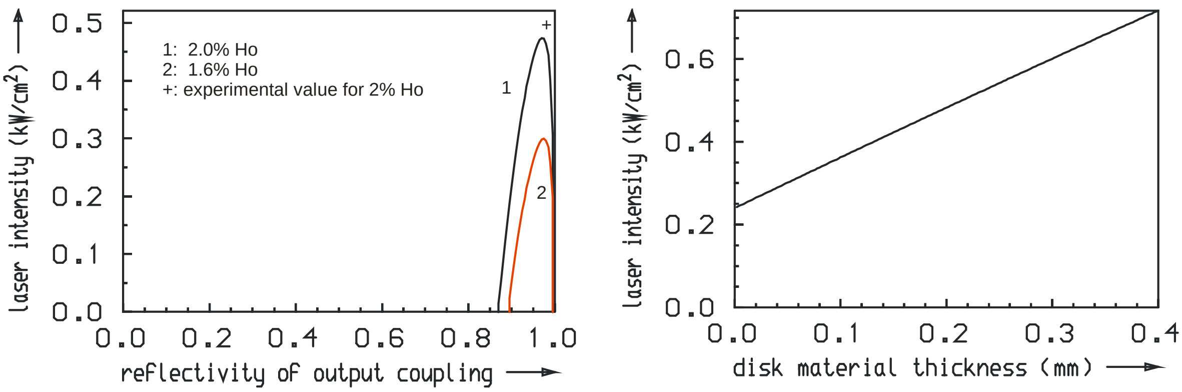

Fig 2. Simulation of laser intensity versus reflectivity of output coupling coefficient (left diagram) for 2% and 1.6% Ho in YAG concentrations and laser intensity versus disk thickness (right diagram) for the 2% Ho in YAG concentration and a 2% output coupling coefficient

Conclusions

Holmium doped YAG and Cromium doped ZnSe are promising laser materials for thin disk laser concepts in the 2 µm range. A cw laser output power of 15 W has been achieved with an efficiency of 37% for a Ho in YAG concentration of 2% with scaling opportunities to higher power. For the Cr:ZnSe thin disk cw laser an output power of 0.4 W at 2.35 µm has been realized so far.

Acknowledgements: The authors would like to express their gratitude to I. Sorokina (University of Trondheim) and E. Sorokin (University of Wien) for the support of the Cr:ZnSe disks as well as to M. Schellhorn (ISL) for the Ho:YAG disks.

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