Thermal-Lens-Free Heat Capacitive Active Mirror

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Thermal-lens problem is one of the most serious problem for the solid state lasers because the high beam quality is the key for the power scaling of coherent beam combining. Today we have two possible solution, one is the athermal laser material, and another is the thermal-lens-free design concept. We propose athemal fluoride mixed solid solution like Yb:CaF2-LaF3 as a possible candidate[1)]. We demonstrated high efficiency lasing performance I found a new design concept HCAM, Heat Capacitive Active Mirror has a potential of significant thermal-lens reduction less than 1/1000 through the systematic calculation.

Lawrence Livermore National Lab. demonstrated 67 kW output thermal-lens-free operation of Heat Capacity Laser using Nd:YAG ceramics under the no-cooling condition. But the operation time is quite limited, only 10 sec. This is not so available for the scientific and industrial applications. We need thermal-lens-free solid state laser available for CW and high rep. rate pumping scheme. I found a new solution for the steady state thermal-lens-free laser scheme, Heat Capacitive Active Mirror HCAM. This is the first proposal of a thermal-lens-free solid state laser containing efficient cooling thermal flow. Thermal lens reduction is a result of phase-shift compensation of heat capacitive volume at unpumped outer edge of an active mirror laser. A systematic calculation of the temperature profile and the thermal induced phase shift have been carried out on 0.25 - 5 mm thick active mirrors of 10 mm diameter with 5 mm area pumping. When the bottom cooling area is smaller than the pumping area, the heat/cool gap induces a thermal barriers against the lateral thermal flow. The unheated outer edge works as a heat capacitive volume. The thermal-lens-effect of a heat capacitive active mirror becomes less than 1/1000 without any additional heating control over a wide range of disk thickness. The temperature and phase shift profile of an 1-mm thick HCAM laser is shown in Fig.1. The maximum temperature is independent under the thin disk condition (T<0.3mm). The thermal-induced phase shift has a plateau over the heat capacitive volume because there is no heat generation and heat sink there. The calculation results are summarized in Fig.2. Thermal lens effect, that is the integrated phase shift along the optical axis, decreases 1/50 at 50% bottom cool and <1/1000 for constant T control for heat capacitive volume. These effect is available for wide range of thickness. Not only for the thin disk, but also for the relatively thick disk (T>1mm) the thermal lens reduction rate is almost constant. When the relatively thick active mirror is available, the requirement for the active ion concentration is significantly relaxed.

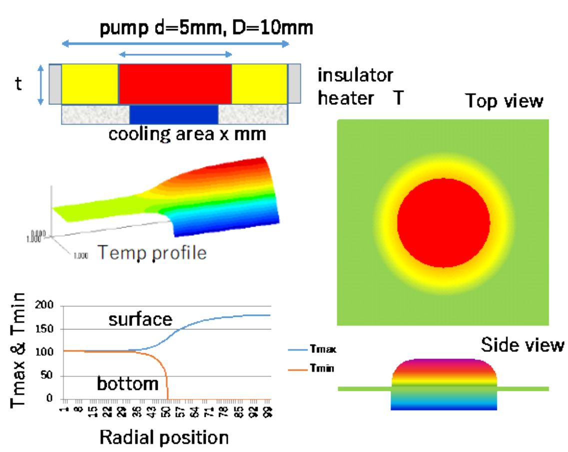

Fig.1 Temperature profile of HCAM laser (t=1mm).

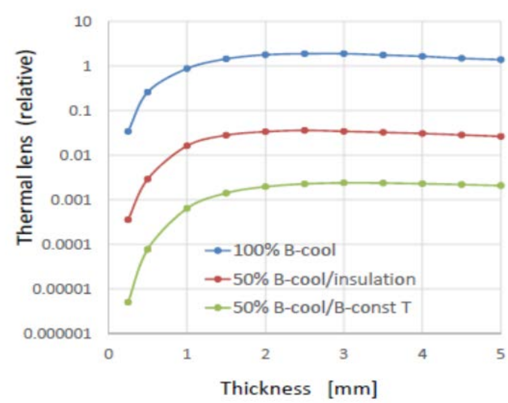

Fig.2 Thermal-lens reduction by 50% bottom cooling and constant T condition.

HCAM should be the new generation of solid state lasers available for the coherent beam combining. It means HCAM is so promising for the high average power laser for industrial application and even ultra-high intensity laser for scientific application. The detailed characteristics of HCAM are discussed in the presentation.

This work is partially supported by Toyota Physical & Chemical Research Institute and Mega Grant Program of Russian Federation.

1) Sh. Kitajima, A. Shirakawa, K. Ueda et. al. Opt. Lett. 42, 1724 (2017).