## §4. Fundamental Study of High Energy Laser System for Plasma Diagnosis and Heating

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Higher performance plasma diagnosis and heating systems are required to prompt the deuterium experiments and the Large Helical Device (LHD) project for fusion research. The advanced high energy laser systems are one of the key technologies to achieve this. Currently, highly transparent laser ceramics represent the rapid progress in solid-state laser development. These ceramics with any required size and dopant concentration make it possible to achieve several to ten kilowatts of average laser output power with Laser Diode (LD) pumping. In terms of the laser materials, Ytterbium (Yb) doped $Y_3Al_5O_{12}$ (YAG) is one of the most promising laser materials for the high power laser systems due to its high stokes efficiency over 90%. Especially, cryogenically cooled (under 100 K) Yb:YAG becomes a true four level laser, and has superior improvements of thermal conductivity, thermal expansion and thermo-optic effects [1]. Therefore, we believe that the cryogenic Yb:YAG ceramics is the most suitable laser material for the next generation high average power and high energy laser systems.

Various laser parameters of single crystal Yb:YAG were widely measured as a function of temperature experimentally. The thermal conductivity of YAG ceramics is lower than that of the single crystal at low temperature because of scattering at grain boundaries [2]. Also, it is well known that the thermal conductivity becomes lower with increasing doping concentration due to the size difference between $Yb^{3+}$ and $Y_3$. However, the doping and temperature dependence of the thermal conductivity of Yb:YAG ceramics has not measured. These characteristics are very important to design and develop high performance laser systems with cryogenic Yb:YAG ceramics.

In this work, we are trying to measure the temperature dependence of thermal conductivity of Yb:YAG ceramics for various doping concentrations. We prepared the undoped YAG ceramic and Yb:YAG ceramics whose doping concentrations of 2%, 7%, 9.8%, and 20%, respectively. Thermal conductivity was measured using a steady state heat flow method as shown in Fig. 1. The temperature of the ceramics was adjusted using a temperature controlled cryostat in NIFS laboratory. The stycast 2850FT which is thermally conductive epoxy glue, was used to attach the ceramic to an oxygen free copper. The cross section of the sample was 5 x 5 $mm^2$, and the thickness *d* were 15 mm, or 20 mm.

Figure 2 shows the experimental results for 9.8% Yb:YAG ceramics. As mentioned above [1], the thermal conductivity increased with decreasing temperature. We found that the thermal conductivity at 100 K is approximately 13 W/mK. There is a slight discrepancy between 15 mm and 20 mm samples. We attribute this to the thermal impedance of the glue. We will measure the thermal conductivity for 10 mm-thick sample, and from the results, we will be able to evaluate the thermal impedance as well in Ref. [3]. In the near future, we will also measure the thermal conductivity of different doping concentration, and we will design high performance laser systems.

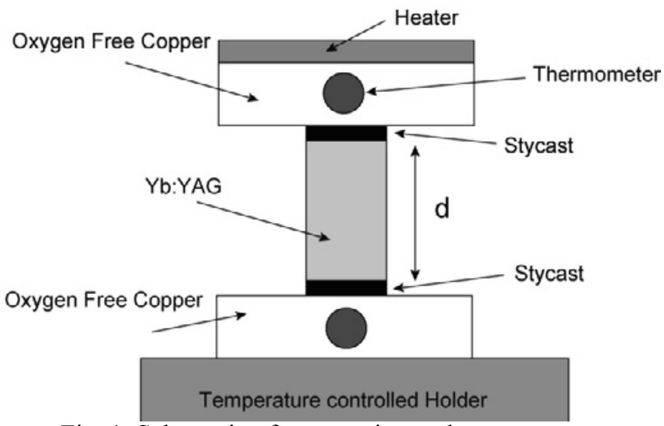


Fig. 1. Schematic of an experimental setup.

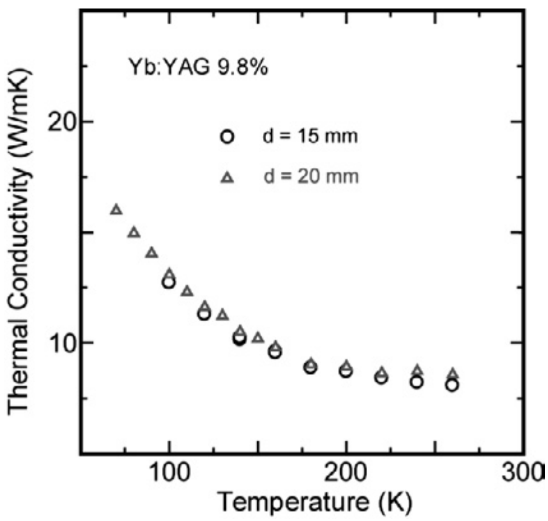


Fig. 2. Experimental results of thermal conductivity for 9.8% doped Yb:YAG ceramics.

1) Fan, T.Y. et al.: J. Sel. Top. Quantum Electron. **13** (2007) 448.
2) Yagi, H. et al.: Ceramics International **33** (2007) 711.
3) Iwamoto, A. et al.: Adv. Cryo. Eng. **49** (204) 643.