Study Of The Temperature Distribution In Diode-End-Pumped Solid State-Lasers

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Abstract—The main problem of bulk crystals for the realization of powerful lasers is their poor management of thermal effects. Optical pumping is associated with the heat generation in solid state laser materials. Moving of heat toward the surrounding medium which is mostly designed for the cooling management causes thermal gradient inside the medium. This is the main reason of appearance of unwanted thermal effects on laser operation. Thermal lensing, thermal stress fracture limit, are some examples of thermal effects. In this work an investigation of heat generation inside the rod crystal during optical pumping was carried out. The Finite Difference Method (FDM) was used to resolve the heat differential equation in order to calculate the temperature generated in Yb:YAG with diode-end-pumped configuration. The effect of the conductance was studied by using two methods of the cooling system. In the first method the crystal is directly in contact with water. In the second method the crystal is surrounding by a copper to keep the cylindrical surface at the define temperature. The temperature generated reduced to half by using the second method and we can conclude that it is the best choice for high power end pumping system.

Keywords—Solid-state laser, end-pumping, cooling schemes, Finite difference method (FDM)

I. Introduction :

To reduce the thermal effect, the rod of crystal laser must be cooled efficiently. Studies on laser cooling were conducted by several researchers [1]. In this work, we have used the finite difference method (FDM) to solve the differential equation of heat to calculate the temperature distribution in an end-pumped laser crystal. We also investigate the effect of the conductance to optimize the cooling system, so as to reduce the thermal effects.

II. RESULTS :

In this paper, the crystal laser has a cylindrical shape. The material used is Yb:YAG (1at. %). The heat differential equation used in rod shape lasers with the end pumped configuration is given by [2]:

$$\frac{1}{r} \frac{\partial}{\partial r} \left( r \frac{\partial T}{\partial r} \right) = \frac{Q_{th}}{k_c}$$

Where $T$ temperature in K, $k_c$ the thermal conductivity in W/m.K, $Q_{th}$ the thermal power per unit volume in W.m$^{-3}$.

This equation has been discretized using (FDM). The equation takes a polynomial form. So, the (TDMA) Algorithm is appropriate to solve the discretized equation [3].

This method allows us to draw the radial temperature profiles for the two cooling configuration (water cooling or cooper surrounding the laser rod).

To study the effect of thermal conductivity of the Yb:YAG (1at. %) on the temperature variation in this crystal, we used these properties: radius of the rod 1.5 mm with length L of 3 mm, total pump power 30 W and absorption coefficient 1.02 cm$^{-1}$ [4]. Figure below shows that when the thermal conductivity increase, the temperature decrease with the same profile in both cases of cooling. Nevertheless the temperature generated reduced about a half if the crystal is surrounded by a copper heat sink.

REMARKS