Republic of Iraq-Baghdad

Ministry of Higher Education and Scientific Research

University of Technology

Laser and optoelectronics Engineering Department

Laser Engineering Branch

Mitigation Of Thermal Effects In Nd:YAG Laser Rod Utilizing Ring-Shaped Beam Profile

A Thesis

Submitted to the Department of

Laser and Optoelectronics Engineering/University of Technology in a Partial Fulfillment of the Requirements for the Degree of Master Science in Laser Engineering

Presented by

Zinah Adil Khazal

(B.Sc. 2010)

Supervised by

Prof. Dr. Mohammed Jalal AbdulRazzaq ***Assist Prof. Dr. Raed Khalid Ibrahim***

2024 A.D **1445 A.H**

ABSTRACT

Mitigating thermal effects within the solid-state laser is critical to improving the laser performance. The thermal effects on the laser rod were reduced by using a double-end pumping configuration with ring-shaped beam profile. A mathematical expression of the temperature distribution within a cylindrical laser rod was derived by solving the general heat equation using Kirchhoff's transformation method to convert the non-linear heat equation to a solvable linear equation. An Nd:YAG laser rod with 2.5 mm in diameter and 5 mm in length was used as a case study. The temperature distribution was simulated on a double-end pumped Nd:YAG laser rod with an annular pump beam profile using MATLAB software. The simulation results were enhanced compared to top-hat pumping owing to the presence of an un-pumped central region with no heat dissipation. Thus, the temperature distribution was more uniform when using an annular pump profile. A reduction in temperature difference of approximately 28.58% was obtained compared to the top-hat intensity profile. Compared to a single end pumped configuration under the same operating parameters, the pumping power was reduced by half, resulting in lower thermal effects on the laser rod end faces.

The thermal lensing effect can pose a significant performance challenge. However, by implementing effective mitigation techniques, it is possible to overcome this challenge and improve overall laser performance. Based on the temperature distribution equation and, in the case of temperature-independent thermal conductivity, the expression of thermal lensing was derived for solid-state laser rods in a double-end pump cavity with an annular pump beam profile. Using the same simulation condition but with different pump power, the results demonstrate that a pump light with an annular shape has an even better distribution for reducing the thermal lensing effect with a slope of 0.09 m^{-1}/W as compared to a 0.07 m^{-1}/W slope for the top-hat distribution. Additionally, there is no thermal lensing in the inner region and a much longer focal length in the pumped region compared with the top-hat pump beam. In other words, the overall thermal lensing was considerably reduced for the annular-shaped pump beam. These results confirm that the annular-shaped pump beam can significantly reduce detrimental thermal effects, including thermal lensing, which is beneficial for high-power laser operations.