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Analytical model of transient temperature and thermal stress in continuous wave double-end-pumped laser rod: Thermal stress minimization study

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Abstract. A time-dependent analytical thermal model of the temperature and the corresponding induced thermal stresses in continuous wave double-end-pumped laser rod are derived from the first principle using the integral transform method. The aim of the paper is to study the effect of increasing the pumping powers while the laser crystals are still in the safe zone (i.e. far away from failure stress) and to suitably choose a crystal that achieves this task. The result of this work is compared with a well-verified finite element solution and a good agreement has been found. Some conclusions are obtained: Tm:YAP crystal, which has high thermal conductivity, low expansion coefficient, low absorption coefficient, low thermal factor and low product of $\gamma E/(1-\upsilon)$, is the best choice to reduce induced stress although it is responded and brought to thermal equilibrium faster than the other types of crystal usually used in the end-pumped solid-state laser.

Keywords. Integral transform method; double end-pumped; laser rod; thermal stress.

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1. Introduction

Diode-end-pumped solid-state lasers are widely used because of their high compatibility, high efficiency, high output power, good stability and good beam quality. The most determinate factor that limits the increase of their output power is the part of the absorbed power that converts to heat. It may cause thermal stress, stress birefringence and thermal lens effect which may degrade the optical properties of the laser medium, reduce the laser output and beam quality and at excessive thermal stress, it may lead to medium break [1,2].

The reduction of thermal effects which causes a temperature gradient across the laser medium is an important factor in designing high-average-power systems. In order to reduce heat effects, many procedures were followed [3–6]. The most noticeable one is to use a double-end pumping where the pumping power is divided over two ends of the laser

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