

Thermal focal length of Nd: YLF laser rod crystal at 797nm and 792nm diode-end pump

Khalid A. Yahya^{*}, Oday A. Hussein and Ola H. Mustafa

Department of Physics, College of Science, Al-Nahrain University, Iraq

ABSTRACT

A theoretical studied are carried out to study the thermal focal length in a-cut Nd: YLF laser rod crystal at 20W Diode- end-pumped. Different thermal lensing effects for π and σ polarizations have been theoretically analyzed .Our results show that the values for thermal focal length are positive for σ polarization and negative values for π polarization for end pump laser wavelength 797nm and 792 nm respectively.

Keywords: thermal effects, Nd: YLF laser crystal, thermal focal length, diode- pump, heat dissipated power in crystal.

INTRODUCTION

The thermal loading per unit volume due to heat generation within a laser rod due to some of the absorbed pump light being converted to heat leads to cause the deterioration of the laser beam quality. However, the heat load accumulated in crystal is responsible for occurrence of cracks and changes to the population distribution and for the vibrations [1]. To reduce the thermal effect it is normally use a laser material which have characteristic better suited to operation at high powers. The crystal Nd:YLF has a number of attributes that offer an advantage and it has a much lower thermal fracture limit than other laser crystal such as, Nd:YAG [2]. The Nd:YLF have important advantages that increase it used as fallow ,the natural birefringence and long storage time of the upper laser level (480 μ s) make it attractive for generating high energy Q-switched pulses and high power lasers, its negative temperature dependence of the refractive index dn/dT , a good thermo-optical characteristic creates a weak or even negative thermal lens under lasing conditions . This makes Nd:YLF crystal a good candidate for use in high power laser source .[2-8].

Nd:YLF is crystal with two main lasing line in the 1 μ m wave length region namely 1047 nm and 1053 nm on both the π and σ polarized with good quality of beam .The a-cut Nd:YLF crystal shows different thermal lensing effects in the π and σ polarizations. .

The purpose of this paper is study the different thermal lensing effects for the 1047 nm and 1053 nm polarizations in an a-cut Nd:YLF crystal theoretically, with used diode end –pump power at 20 W for 797nm and 792nm.

2. Proposed Geometry and basic equation

The model consists of Nd:YLF crystal rod, whose axis corresponds to the pump symmetry axis, with a radius r_0

which is surrounded by a cylindrical with water for cooling, which leads to conduction heat transfer from rod surface to the ambient medium. The schematic figure of the rod and cooling system geometry are depicted in figure (1).

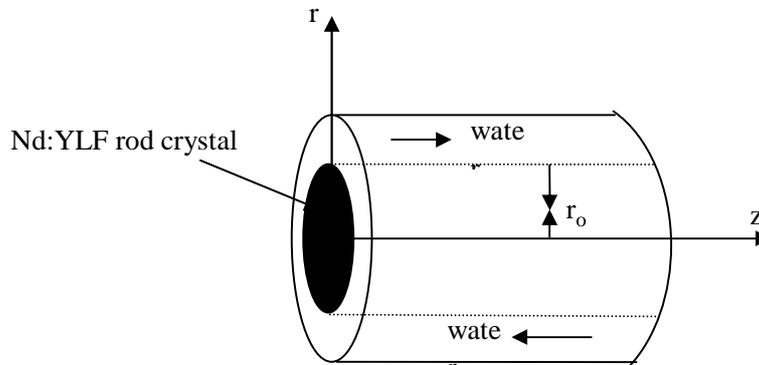


Figure (1) A simple drawing of Nd:YLF rod crystal and cooling system geometry.

In a solid state laser, a fraction at the pump energy is converted to heat, which acts as heat source inside the crystal rod. If η_a is the absorption efficiency which is the fraction of optical input power P_{in} , the power is absorbed by crystal P_a given by [2].

$$P_a = \eta_a P_{in} \dots\dots\dots (1)$$

For the diode pumped laser, the absorption efficiency can be approximately by

$$\eta_a = 1 - e^{-\alpha L} \dots\dots\dots (2)$$

where α is the absorption coefficient of the laser crystal at a wavelength emitted by the laser diode, L is the crystal length and P_h is the heat dissipated power in crystal given by

$$P_h = \eta_h P_a \dots\dots\dots (3)$$

where η_h is the fractional thermal load given by

$$\eta_h = 1 - \frac{\lambda_p}{\lambda_L} \dots\dots\dots (4)$$

where λ_p is the pump wavelength and λ_L is the laser wavelength.

The absorbed pump power generates a temperature profile across the gain medium .This temperature profile gives rise to variation of refractive index across the gain medium .The combined effects of temperature and stress-dependent variation of the refractive index and the distortion of end-face curvature of the laser crystal lead to the thermal lensing with focal length f ,which can be calculated by [2].

$$f = \frac{K A}{P_h} \left(\frac{1}{2} \frac{dn}{dT} + \alpha_T C_{r,\phi} n_o^3 + \frac{\alpha_T r_o (n_o - 1)}{L} \right)^{-1} \dots\dots\dots (5)$$

where K is thermal conductivity ,A is the surface area at the crystal rod, dn/dT is Thermo-optical coefficient , α_T is thermal expansion coefficient, n_o is refractive index of the active medium at the center point in the absence of the pumping radiation and $C_{r,\varphi}$ are functions of the elasto –optical coefficients.

The stress-induced birefringence, namely, the photo elastic effect, is of minor importance in Nd:YLF because of its strong natural birefringence. Hence, by ignoring the photoelastic effects, so the thermal focal length can be approximately given by [9]

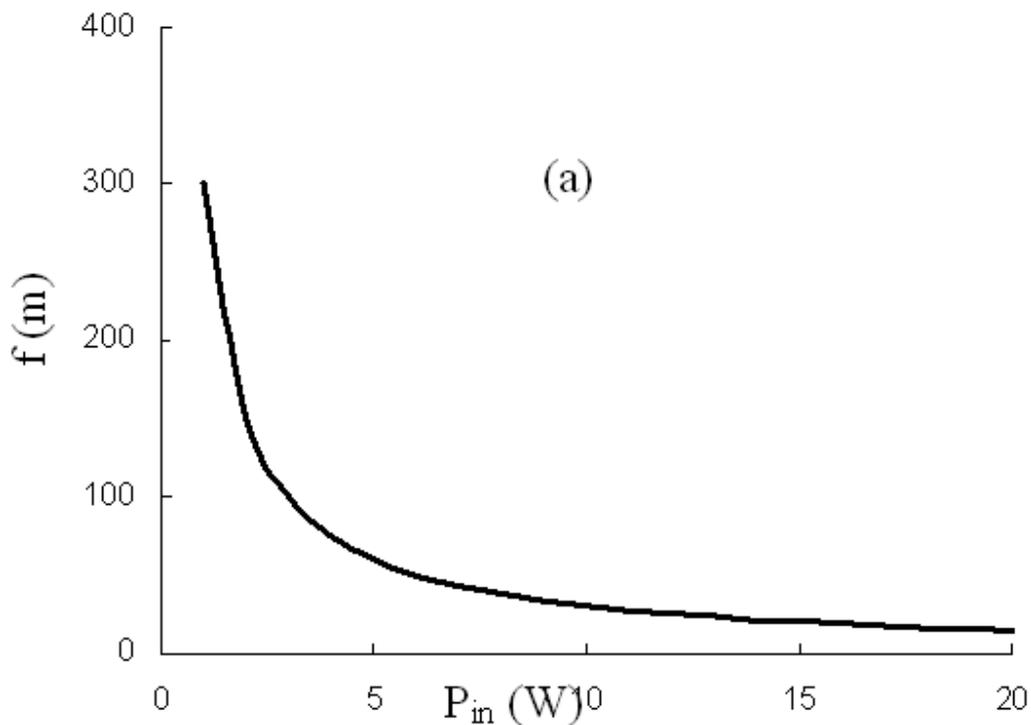
$$f = \frac{KA}{P_h} \left(\frac{1}{2} \frac{dn}{dT} + \frac{\alpha_T r_o (n_o - 1)}{L} \right)^{-1} \dots\dots\dots(6)$$

where r_o , L are the radius and length of crystal respectively.

RESULTS AND DISCUSSION

The numerical calculations of thermal focal length in a-cut Nd: YLF crystal for1047 nm (π) and 1053 nm (σ) polarization are calculated by using equation (2) with adoption basic parameters in table (1) shown in figure (2).

It can be seen from figure (2) , that the values of thermal focal length are negative for π and positive for σ polarizations .The Nd:YLF laser operation on the 1053 nm is over all weak thermal lens ,this is due to the combined effect of a negative change in refractive index with temperature dn/dT and a positive contribution to the thermal lens from the bulging of the end face of the laser rod ,and the 1047 nm has strong thermal lens ,which is an agreement with [9].



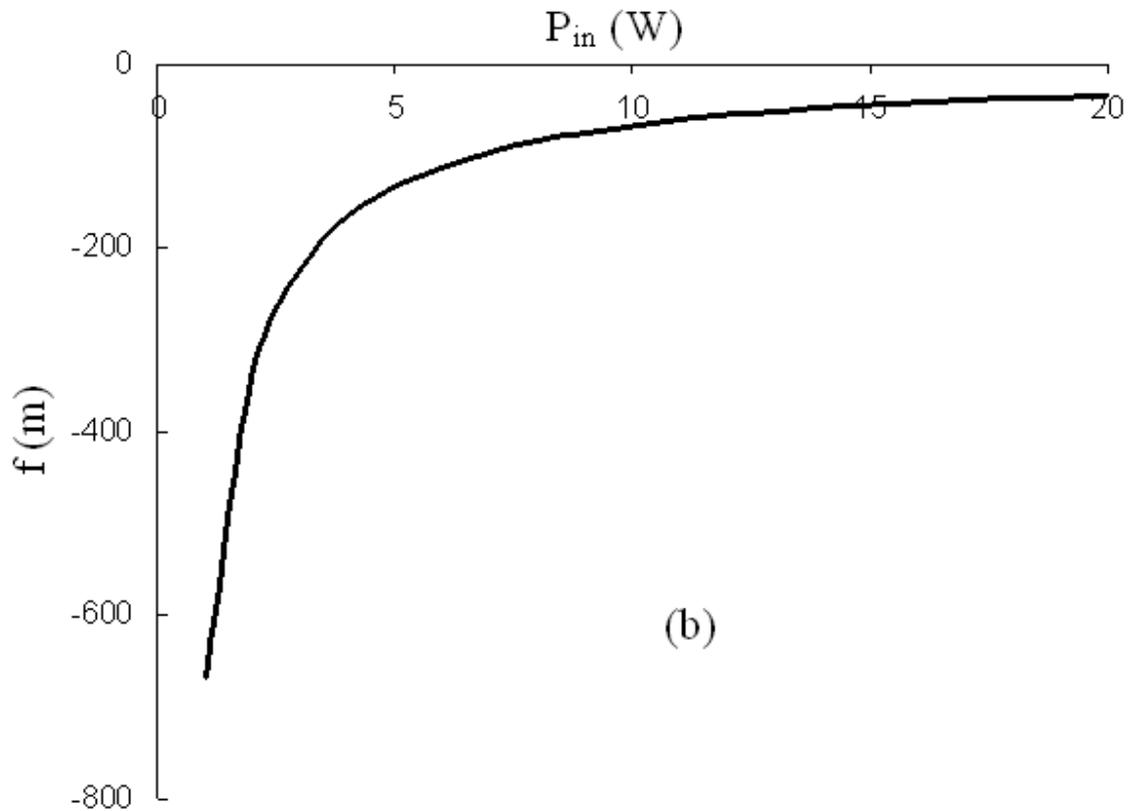


Figure (2) Thermal focal length as a function of the input pump power in Nd: YLF crystal (a) for the σ polarized laser. (b) for the π polarized laser

Table (1) The basic parameters and information of Nd: YLF laser crystal [2].

Thermal conductivity K	0.063 (W/cm.K)
Thermal expansion coefficients α_T	$13.3 \times 10^{-6} \text{ K}^{-1}$
Refractive indices n_o	$\pi : 1.477; \sigma : 1.448$
Thermo –optical coefficient dn/dT	$\pi : -4.3 \times 10^{-6} \text{ K}^{-1}; \sigma : -2.0 \times 10^{-6} \text{ K}^{-1}$
Peak absorption coefficient α for 1% Nd	$\pi : 10.8 \text{ cm}^{-1}; \sigma : 3 \text{ cm}^{-1}$
Crystal radius r_o	0.15 cm
Crystal length L	0.5cm

CONCLUSION

From the theoretical calculations, it is found that fraction power converted into heat are 18.8%, 24.2% for σ and π respectively at 20W input power. The positive focal length for σ (1053nm) polarization in a-cut Nd:YLF is inversely proportional with pumping power . On the other hand, the negative focal length for π (1047 nm) is directly proportion .Furthermore, the 1053 nm is weaker thermal lens than 1047 nm. Therefore , for both σ and π polarizations, with the difference that σ - polarized light experience a converging lens , while π - polarized light experience a diverging lens.

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