The effect of triggering on the output performance of diode direct face pumping for disc laser in pulse mode

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Abstract

The triggering effect for the face pumping of Nd:YVO_4 disc medium of 4×5×0.5 mm was investigated using bulk diode laser at different resonator cavity length in pulse mode and at repetition rate of 1.3kHz. The maximum emitted peak power was found to be 100, 82, and 66 mW for resonator lengths of 10, 13.5, and 17.5 cm respectively, while the threshold pumping power was found to be 41mW. The maximum emitted peak power obtained was 300 mW when using external triggering and 10cm length, with repetition of 3Hz.

Key words
diode pumping, Nd:YVO4, face pumping, bulk diode laser.

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تأثير القدح على مواصفات الخرج لليزر العرضي بالضخ المباشر(بالنمط النبضي)

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الخلاصة

في هذا العمل تمت دراسة تأثير القدح في عملية الضخ المباشر الامامي لعينه القرص (Nd:YVO4) بابعاد (0.5 x5x4 mm) باستخدام ليزرالصمام الثنائي لابعاد مختلفة لمرنان الضخ النبضي بتكرارية 1.3 kHz. ووجد ان اعلى قيمة للقدرة المنبعثة هي بحدود 100,82,66 mW لابعاد المرنان 10,13.5,17.5 cm على التوالي بينما وجد ان قدرة العتبه كانت بحدود 41 mW وان اعلى ذروة قدرة انبعاث كانت 300 mW عند استخدام اشارة قدح خارجية ولطول المرنان 10cm وتكرارية 3Hz للضخ النبضي.

Introduction

Disc-type Solid State Laser (SSL) is enjoy inherently low susceptibility to thermo- optical distortions [1]. Its large-round aperture reduces diffraction and beam clipping losses experienced by other solid diode pumped solid state lasers configurations [2,3]. In a disc laser, transverse temperature gradients are reduced because the waste heat is extracted from the gain medium in a direction parallel to laser beam axis [3].

In the disc lasers the light is amplified by passing through a thin disc active layer [4,5]. Their geometry allows efficient heat sink at small distortions of the wavefront, therefore the scalability to high power is expected [6,7]. In all previous works, the pumping source was in CW mode so, the interest and motivation for this work are to study triggering effect and the effect of resonator length on the output power of diode pumped disc laser.

Experimental Work

As shown in Fig.1, a 4×5×0.5 mm^3 $Nd:YVO_4$ crystal, which was anti-reflection (AR) coated for the 808nm pumping wavelength and 1064nm output laser wavelength at the front side. High-reflection (HR) coated for both wavelengths at the back side to increase the absorption path by meaning of multi-reflection inside the crystal, that is because the small thickens of the crystal [4,5]. The crystal was placed on Al plate from its front surface while this plate contains a central hole of diameter of 4 mm used as an entrance of the pumping beam toward the crystal. This hole makes the crystal acting like a disc. A Cu plate was placed on the crystal back surface with 0.1mm indium material as a thermal adhesive material to remove the heat generated in the crystal to the Cu heat sink. A highly transmissive mirror was placed in front of the crystal and tilted by 45^o, where this mirror has two faces, the first face is high transmission (HT) at 808 nm, while the second face is AR coated at 808 nm and high reflection (HR) coated for 1064 nm at 45^o. All the pumping light (808 nm) is passing through this mirror and the laser output light (1064 nm) is reflected toward the output-coupler mirror to make the oscillator required for any laser system[3]. The output coupler had a radius of curvature (ROC=400mm) and a reflectivity of 90% at 1064 nm. So when the beam radiated from the laser diode at 808 nm emerges from the transmissive mirror after passing through the two lenses and fall upon the crystal. The radiation emitted from the crystal at 1064 nm is then reflected at the 45° mirror towards the output coupler.

Experimental Results

To study the effect of triggering and the repetition rate, two type of triggering system were used; an internal triggering from the build-in diode laser driver with frequency more than 1.3 kHz, and external triggering with repetition rate less than 1.3kHz during that the resonator length was changed to investigate the optimum length with higher output power.

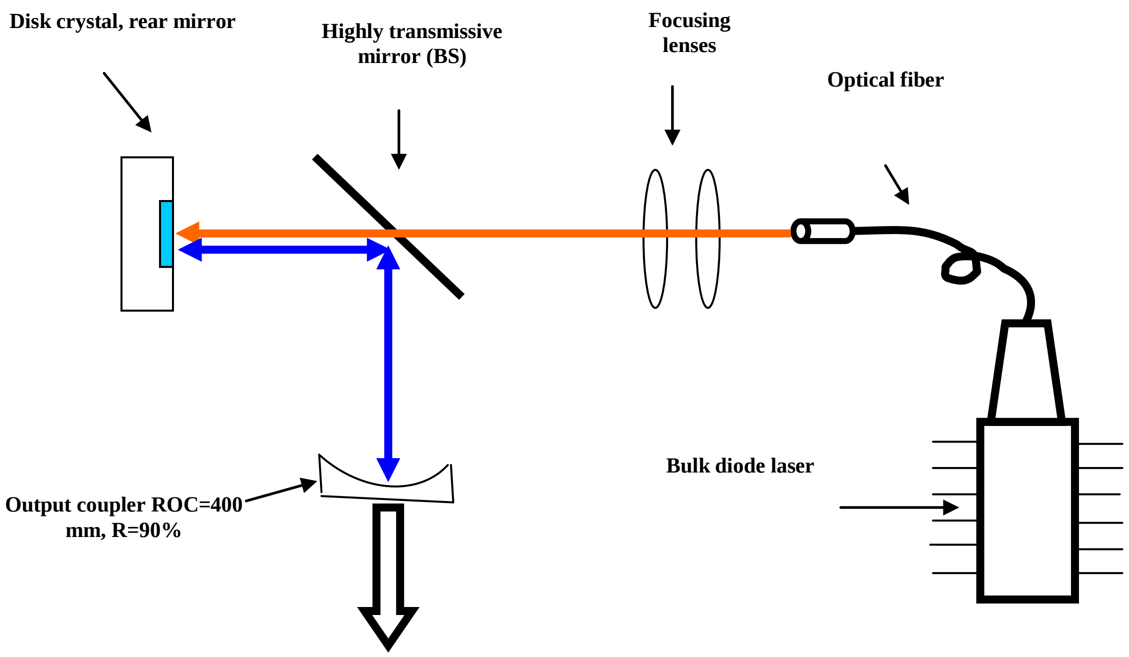

Fig.1: The experimental setup. The ray propagation of pumping.

1- Internal Triggering

Using the pumping configuration for direct face pumping as shown in Fig.1 and using internally triggering bulk diode laser at a repetition rate of 1.3kHz to pump the disc system the following results were found. As in the Figs. (2 to 8). Fig.2 shows the power emitted from the Nd:YVO_4 disc medium with and without the output coupler at fixed repetition rate of 1.3kHz as a function of the driving current of diode laser at resonator length of L=10 cm. The first curve represents the output from the Nd:YVO_4 disc medium while the second curve represents the 1064 nm output laser from the system only. It is clear that the output of the disk without the output coupler mirror was higher than that with the output coupler mirror because the spontaneous emission is shearing in the value of the output, while in the second curve all the free running output is shearing without selection [7]. From this figure it can be seen that the maximum peak power gained from this system was found to be less than 100 mW at a fixed peak pumping power of 1030 mW with the presence of R2 and about 175mW without the presence of R2. The optimal resonator length was 10 cm where the higher output power was found at 100 mW where Fig.3 shows the relation between the peak pumping power and the peak output laser power using internal triggering of repetition rate 1.3kHz using an output coupler of R=90% with different resonator lengths. From these curves it was found that Pth is increased with increasing resonator length and depending on the satisfying of the resonator conditions to create the laser output [8]. To study the effect of output coupler reflectivity on the output power of the disc system, different mirror reflect ivies (R2=99%,90%,30%) were used. The relation between the operating current and the laser output peak power at a resonator length of L=13.5 cm with these reflectivity values was found. Different output powers at the same pumping power were found from the curves and maximum output peak power was obtained at R=90%, Fig.4. The maxium peak output power obtained was approximately 82 mW at R=90%. The effect of optical elements within the whole system configration was investegated. Fig.5 shows the relation between the operating current and the peak pumping power of the bulk diode laser transmitted through the two focusing lenses of focal lengths f=5, and 4.5 cm in the first curve these tow lenses are removed, while the second curve was drawn between the operating current and the peak power obtained after the highly transmissive mirror which placed at 45°. From the first curve it was found that the measured transfer efficiency η_t from these two lenses was equals to 28%. This efficiency is relatively small which is due to using not antireflection coated mirror.

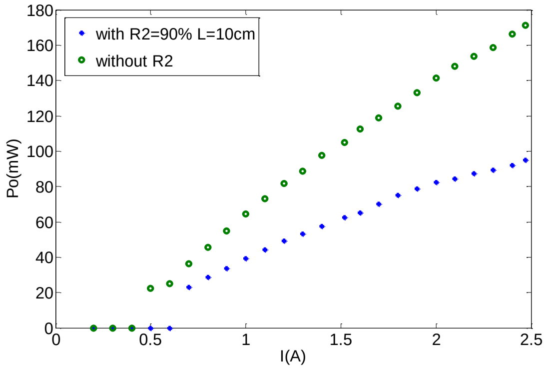

Fig.2: The driving current vs. the output power at 1.3 kHz.

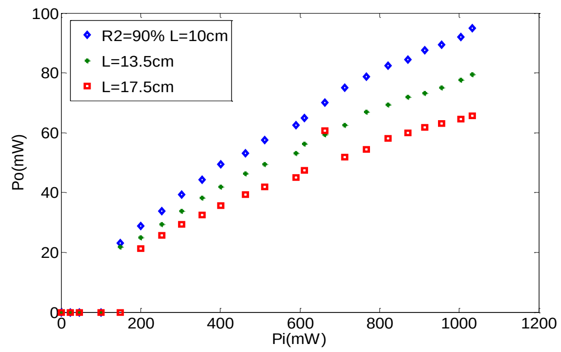

Fig.3: The peak pumping power vs. the laser output peak power at different resonator lengths, R2= 90%.

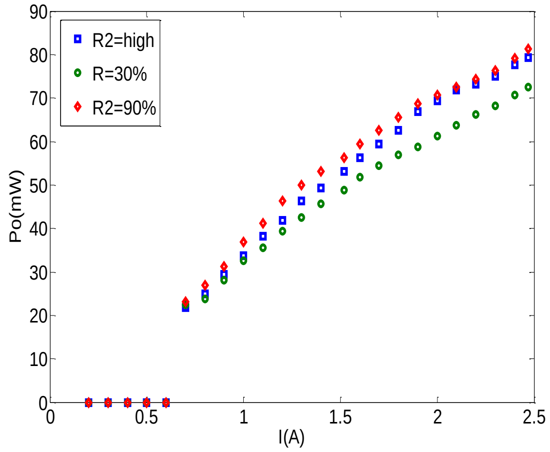

Fig.4: The peak output laser power vs. the driving current at different reflectivity, L=13.5 cm.

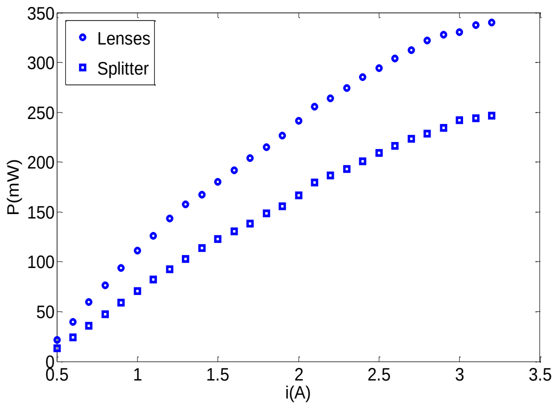

Fig.5: The operating current and the peak pumping power of the bulk diode.

2- External Triggering

Decreasing of repetition rate of the bulk diode laser was found to increase the emitted peak power [9], and since our laser unit has the opportunity to be internally triggered, thus the same system configuration was used but with externally triggered bulk diode laser this time (below 1kHz), and the effect of such change was investigated. It is necessary to mention that the duty cycle D.C. in external triggering cannot be changed unlike the case of internal triggering. Operating at a current of 3.2A, temperature of 18.1°C and duty cycle of 7.69, Fig.6 shows a plot between the repetition rate and the energy obtained from the bulk laser diode using external triggering, it is obvious from the fitted

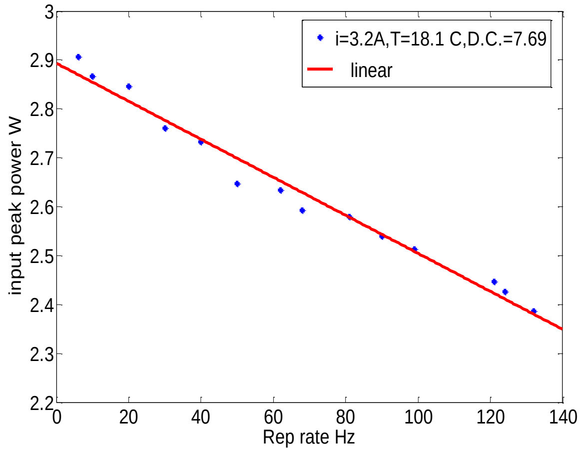

Fig.6: The repetition rate vs. the emitted peak power from the bulk diode laser.

data that the laser diode peak power decreases with increasing repetition rate, hence it is expected that decreasing the repetition rate will increase the output laser peak power obtained from the system. The effect of the operating temperature on the output power was also investigated. Fig.7 shows the relation between the operating current of the bulk diode laser externally triggered at repetition rate of 3Hz and the output laser peak power with a resonator length of 10cm at different operating temperatures (5-50°C). It was found that lowering the temperature of the diode laser increases the peak pumping power obtained but these causes to a shift in the emission wavelength of the diode laser, i.e. reducing the portion of the absorbed power and thereby reducing the laser output peak power of the system, so there is a compromistion between T, Pin, and Po. Fig.8 shows the relation between the operating current of the diode laser in external triggering and the obtained laser output peak power at different repetition rates using L=10cm. From the measured values of the laser output peak power as it was expected that reducing repetition rate will increase the obtained pumping power from the diode laser and in turn the laser output peak power, but far from the expected. It was found that maximum output peak power can be obtained at repetition rates of 45 and 50Hz.

Conclusions

It is necessary to use external triggering to lower the repetition rate of the diode laser, which in turn will need less cooling than operating in high repetition rates, and will increase the optical slope efficiency of the system due to the increased peak pumping power. Reducing of repetition rate will increase the obtained pumping power from the diode laser hence the laser output peak power. Maximum output peak power was found at repetition rates of 45 and 50Hz. It was found that lowering the temperature of the diode laser, increases the peak pumping power obtained, leads to a shift in the emission wavelength of the diode laser.

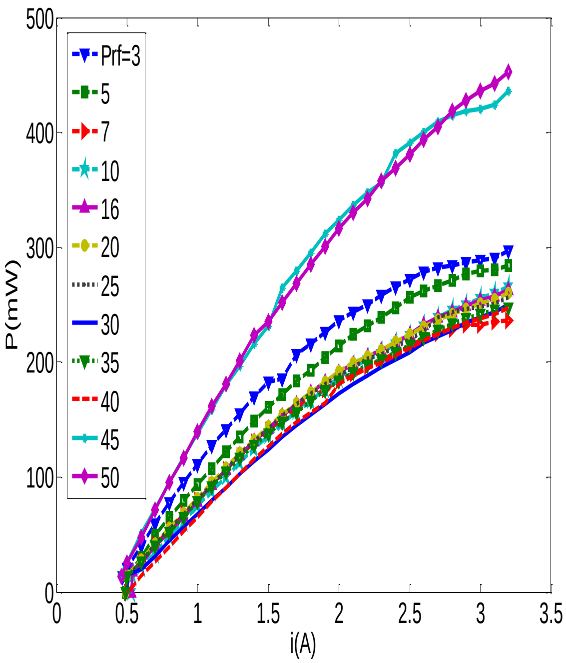

Fig.7: The current vs. the laser output peak power at different operating temperature, L=10 cm, prf=3Hz.

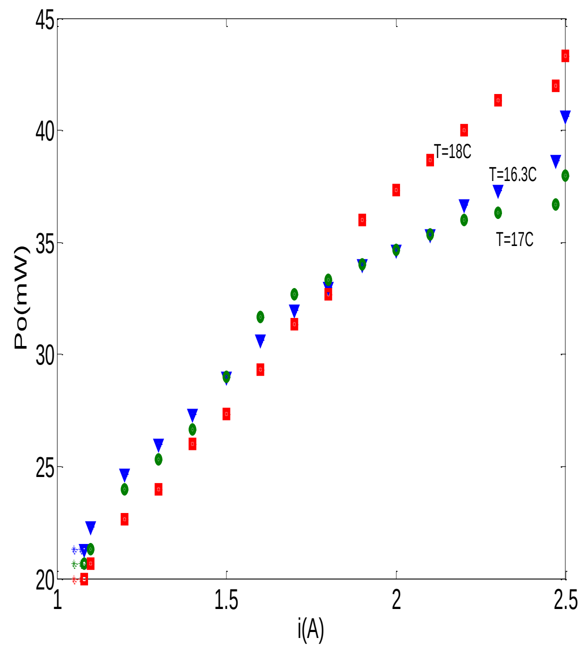

Fig.8: Obtained laser output peak power at different repetition rates.

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