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THRESHOLD PUMP POWER AND STABILITY ZONE STUDY OF A CW Ti:Sa LASER BASED ON USING TWO DIFFERENT DIELECTRIC BROADBAND HIGH REFLECTIVE CAVITY MIRRORS

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ABSTRACT

The present work study the optical parameters for CW operation in Ti:Sapphire laser system with the focus on stability zone and threshold pump power. The main aim of this study is to explore the influence of a broadband dielectric resonator mirrors used in the laser cavity on the stability zone and threshold pump power. This effect has been determined by using two types of mirrors with different broadband reflection. The experimental results show the dependence of the stability and laser threshold pump on broadband dielectric mirrors. For a broader dielectric mirror, the stability zone shows larger stable distance with respect to the narrower mirror. Moreover, the threshold pump for the broader band is smaller than the narrower. This study allows researcher choosing the appropriate optical components for generating more stable laser with small threshold pump power.

KEYWORDS: Pump power threshold Stability zone, Ti: Sapphire crystal, Broadband dielectric mirrors.

INTRODUCTION

Titanium sapphire (Ti:Sa) laser system is now the most widely used laser technique in the field of science and technology due to its broadband spectrum, high repetition rate and temporal properties. Compared with other pulse lasers such, femtosecond lasers (fs) provide few/cycle pulse duration, an ultrahigh peak power and broadband spectrum. Several types of gain medium have been used to generate femtosecond laser pulses, however, the most attractive gain medium for laser operation in near-infra red spectral range is Ti:sapphire ($Ti:Al_2O_3$), because the fluorescence spans from (680-1100 nm), and also Ti:sa crystal has a much wider emission and band width, high beam quality, good reliability and simple structure(Kerridge-Johns and Damzen 2018). These properties of the fs laser system enable new experimental procedure in the physical environment (Fork, Greene, and Shank 1981). According to that, fs lasers are used for a variety field of applications such as controlling the electronic state of materials (Sarukura 1993), investigation the dynamic of electron in material with a high temporal resolution (Zewail 2000), ultrafast dynamics observation (Guo et al. 2019) and other ultrafast dynamics in chemistry (Grånäs et al. 2019) and biology (Neutzo et al. 2000).

The performance and the implementation of the Titanium sapphire (Ti:Sa) laser system depends strongly on the resonator parameters. Therefore, great efforts have been paid by researchers to understand, improve and devise each of parameters to generate spectral-phase stabilized ultrashort pulses. Since the common used method to generate ultrashort pulses is based on a spatial-dependent nonlinear response of the materials and is called Kerr-lens mode-locked (KLM) method (Spence et al. 1991), KLM in Ti:Sa system takes the most research study and investigation to compensate nonlinear aberration (Christov and Stoev 1998) (Yefe et al. 2013), determine optimum design parameters (Magni, Cerullo, and De Silvestri 1993; Penzkofer et al. 1996) and to explore chirped multilayer mirrors for controlling precise group delay (Razskazovskaya et al. 2017) and broadband (OSA | Chirped multilayer coatings for broadband dispersion control in femtosecond lasers n.d.; Szipöcs et al. 1994) dispersion.

The temperature dependence of CW laser operation of Ti:Sa has been studied (Albers et al. 1986). Researcher investigate power-scaling of green-diode pumped Ti:Sa laser in CW action and they showed that for 2 W pumping of crystal, the generated CW power was almost 440 mW which is high (Gürel et al. 2015). However, the continuous wave (CW) operation in Ti:Sa laser system has not been attracted much attention. Here we study the optical parameters of CW operation in Ti:Sa laser system in term of stability for two different broadband dielectric mirrors. In addition, the threshold pump power for the same mirrors has been measured and compared.

Experiment

The experimental setup of the Ti:Sapphire CW laser is different than the common laser design which is in straight line. Generally, there are two common cavity designs to create Ti:sa laser, which are "X" or "Z" configuration. In this work the "Z" folded cavity design has been used. The configuration of "Z" folded consists from the following steps: for progressing Ti:Sa CW laser, the first step is to align a diode pumped solid state laser (DPSS, Sprout-H) as a P-polarized pumping source, that generate up to 5W of output power at the wavelength of 532 nm. The well-aligned generated pump beam was focused into the Ti:Sa crystal using 100 mm focal length plano convex lens (LA1509, N-BK7). The beams were passed through high reflecting broadband focusing mirrors (M_3 and M_4) having an equivalent effective focal length of about 50 mm (05-BV10UF.20, Newport) to focus laser into the Ti:sa crystal. To ensure that the focused beam enter the crystal at the Brewster angle, the crystal was mounted on a 3-axis micrometer stage and a rotary table. As a result, the loss of energy during pumping process will be minimized. The critical parameters for setting up the resonator are the spacing L_1 and L_2 or their relation to each other. Furthermore, the positioning of the lens for focusing the pump laser is important. This parameter controls the operation of the laser in CW operation. For this reason, the crystal as well as the two resonators mirror R_1 and R_2 and the focusing lens L are mounted on micrometer translation stages for precise positioning. After a perfect alignment all of the elements we mentioned above, M_5 and M_6 were added to the laser cavity. Thus, the propagation of the generated laser beam in the cavity would be from M_3 to M_6 with a distance of (78 cm) and from M_4 to output coupler (OC) with a distance of (78 cm). It is worth to mention that the used OC was 10% transmission at 800 nm center of wavelength (041-1190- EKSMA OPTIC). Finally, the "Z" configuration for Ti:Sa laser completely detected as illustrated in **Fig. (1**.

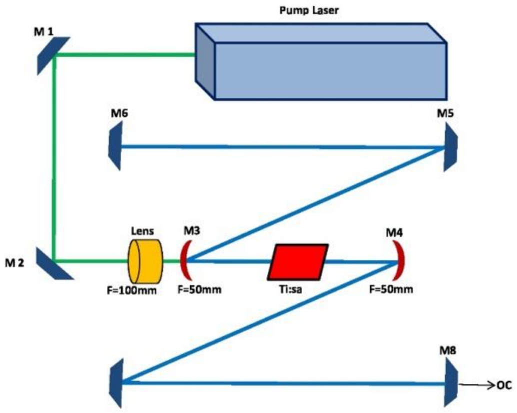


Fig. (1): A "Z" shape setup of the continuous wave laser.

RESULTS AND DISCUSSION

In this work we want to compare between two types of mirrors to find the leaser threshold difference and stability zone between them. The types of the mirrors are ultrafast mirror with wavelength 720-880 nm (082-7288, EKSMA OPTICS) and wavelength 750-1100 nm (BB1E03, Thorlabs).

First, we focus on the demonstrating the threshold behavior for both mirrors. In the laser system, a power meter was used for output power measurement as a function of the laser threshold pump power.

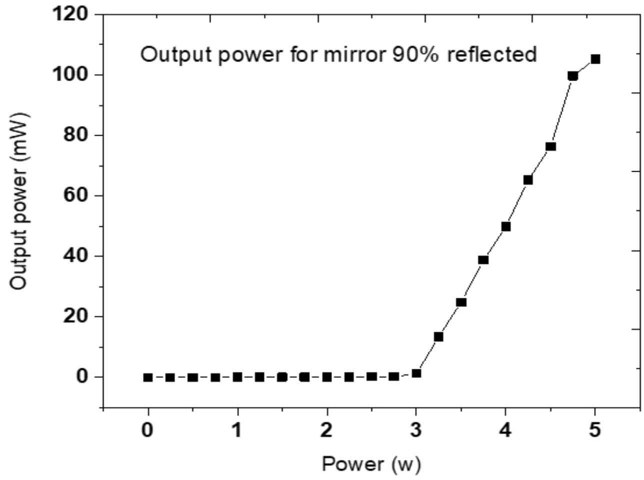


Fig. (2.1): Lasing thresholds for out-put coupler 90% turns back to the cavity laser and transmitted 10% of the light for ultrafast mirrors.

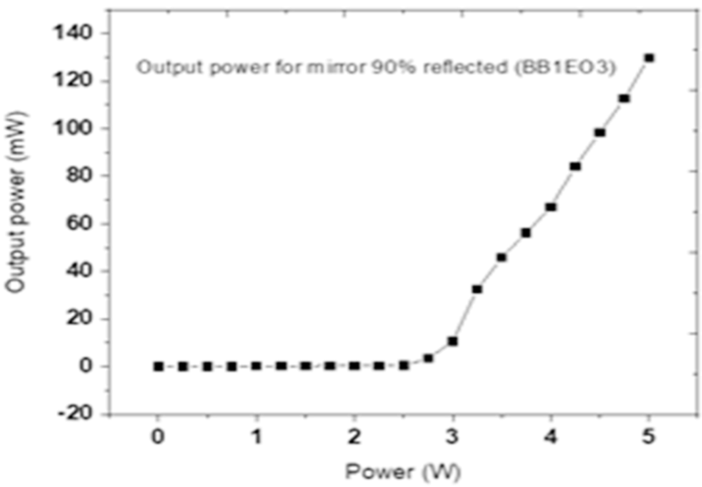


Fig. (2.2): Laser thresholds for out-put coupler 90% turns back to the cavity laser and transmitted 10% of the light for BB1EO3 mirrors.

As one can see from the **Fig. (2.1**, for the mirror (720-880, wavelength range centered at 800 nm) nm, the threshold pump power was about 3 W. Then we change the mirrors with (750-1100) nm and do the same measurement without changing anything. The dotted line in **Fig. (2.2** shows that the threshold pump power is around 2.75 W. Since both mirrors show different bandwidth spectrum as well as central wavelength, the explanation of the threshold pump power is complicated. It is well known that the gain bandwidth of the active medium defines the spectrum of the oscillated laser. The generated cavity modes lie within the gain bandwidth will be amplified. It is the result of interacting of the gain bandwidth with the generated multimode resonance. Moreover, the Threshold pump power depends mainly on the losses inside the cavity. Higher loss requires larger pumping power to obtain lasing. Another complexity arises because each generated mode has its own losses and mode profile. Thus, we will not seek to deal with these complexities.

Another interested parameter is measuring the stability zone of the proposed setup. We attempt to study the stability zone for both type of mirrors it is one of the important parameters for constructing continues wave leaser and even short pulses. The stability zone in the laser cavity depends on the distance between concave mirrors. To make the stability measurement for both mirrors, we use equal arms which is known as a symmetric design (single stable region).

Fig. (*3* represents the setup used to measure the stability zone for both type of mirrors. Since the stability zone depends on the distance between the focusing mirrors (M_3 and M_4), both mirrors were placed on a micrometer stage to adjust the separation between both focusing mirrors. The measurement procedure was done as follows: First, M_3 was fixed while M_4 was moved from its original position toward and away from the Ti:Sa crystal each time 0.5 mm and simultaneously measure the output power for each positions until the power become zero.

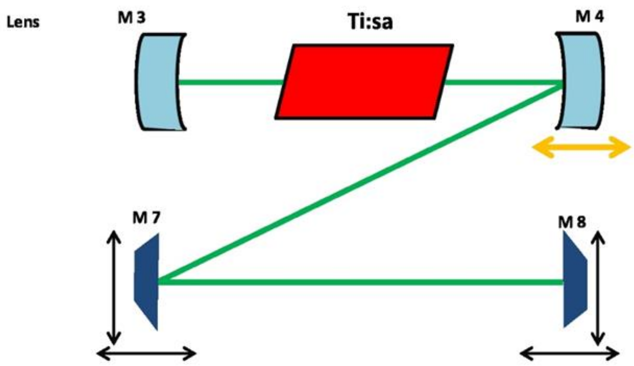


Fig. (3): Schematic diagram of stability zone measurement setup.

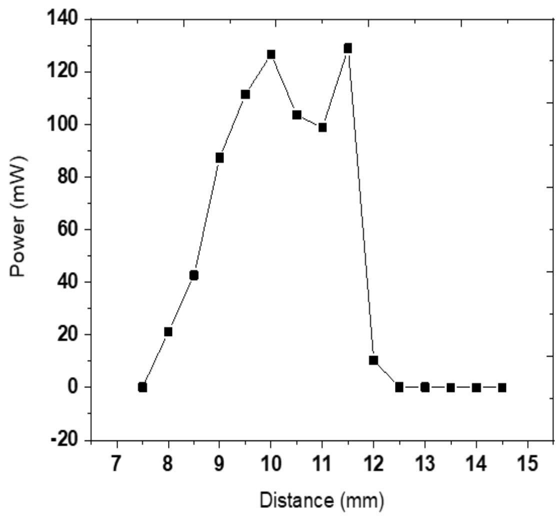
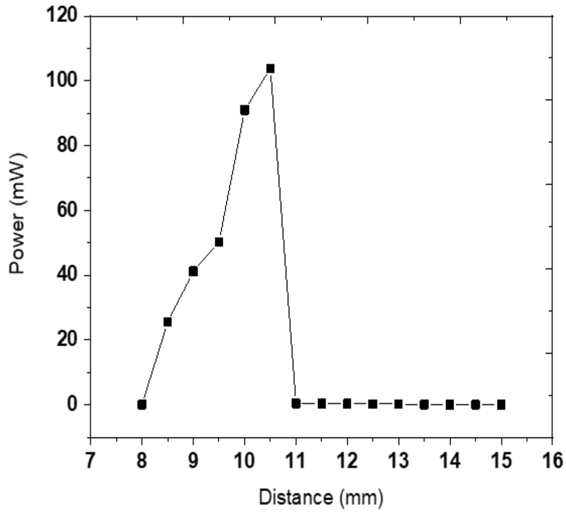


Fig. (4): Stability zone for 750-1100 nm dielectric mirror.



Fi.e (5): Stability zone for 720-880 nm dielectric mirror.

Fig. (4 and **Fig. (4** show the stability zone of a resonator for (750 nm- 1100 nm) and (720 nm-880 nm) mirrors, respectively. As one can see clearly from the figures, the stability zone for (750 nm- 1100 nm) mirror show wide stability area comparing with (720 nm-880 nm) mirror. Moreover, the (750 nm-1100 nm) mirror has larger maximum power comparing with the (7200 nm- 880 nm) mirror.

CONCLUSION

Threshold pump power and stability zone have been studied of a CW Ti:Sa laser based on using two different dielectric broadband high reflective cavity mirrors. Our results clearly show that the two parameters behave differently for the different dielectric broadband high reflective cavity mirrors. The broader broadband dielectric mirrors (750 nm-1100 nm) shows lower threshold pump power comparing with the dielectric broadband mirrors (720 nm-880 nm). Furthermore, the measurements results show that the broader broadband dielectric mirrors (750 nm-1100 nm) shows larger stability zone with respect to the dielectric broadband mirrors (720 nm-880 nm). These demonstrations can be further proved by using more than three different broadband dielectric mirrors.

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