Journal of Fundamental and Applied Sciences

ISSN 1112-9867

Available online at http://www.jfas.info

Special Issue

In celebrating the 10th anniversary of JFAS

STUDY OF Nd: YAG SOLAR LASER OUTPUT PERFORMANCE IN END PUMPING AND SIDE PUMPING CONFIGURATIONS

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Received: 01 October 2019/ Accepted: 08 December 2019 / Published online: 01 January 2020

ABSTRACT

Since the report of the first sun-pumped solid-state laser, several pumping schemes have been proposed for enhancing the solar-laser performance.

Although the most efficient laser systems have end-pumping approaches, side-pumping configurations are very suitable for reducing the thermal loading problems and consequently producing higher laser beam quality. Here we report a study of the Nd: YAG solar-lasers performance by using either end-pumping or side-pumping techniques.

The end-pumping configuration provides simultaneously, in multimode regime, the maximum laser power (120 W continuous wave), the highest collection efficiency (32.1 W/m^2), the highest slope efficiency (8.9 %), the lowest threshold pump power (192 W) and in monomode operation the highest fundamental-mode collection efficiency (7.9 W/m^2) the highest solar laser brightness (6.5 W). However, the side-pumping approach is very preferred for achieving high laser beam quality in monomode operation ($M^2 < 1.05$).

Keywords: Solar irradiance; parabolic mirror; Fresnel lenses; solar-pumped laser; end-pumping configuration; side-pumping method; solar-laser power.

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doi: http://dx.doi.org/10.4314/jfas.v12i1S.4

1. INTRODUCTION

As the natural sunlight does not provide power density sufficient enough for lasing, additional focusing systems are usually required to convert solar power into laser radiation. Since the report of the first solar-pumped solid-state laser [1], researchers have been exploiting parabolic mirrors, Fresnel lenses, heliostats to attain enough solar flux at the focal point. The utilization of the compound parabolic concentrators (CPC) as secondary pumping cavities further boosted up the solar laser power level [2, 3]. To increase the spectral match between the emission spectrum of the pump radiation and the absorption spectrum of the laser medium, crystals of different active materials were tested [4]. Several pumping architectures have been proposed for solar-pumped lasers [5]. Although the most efficient laser systems have end-pumping approach, side-pumping is an effective configuration for producing high laser beam-quality as it allows uniform absorption distribution along the laser rod axis and spreads the absorbed power within the laser medium, reducing the associated thermal loading problems [6].

Renewable lasers have a large potential for many applications. Some of these applications require operation of the laser system with end-pumping method since it produces the highest performances, as well as other applications can be feasible with side-pumping configuration because it leads to obtain a high laser beam-quality [7]. Therefore, it is highly desirable to study the performance of the solar-laser systems with end-pumping and side-pumping configurations.

Aiming to show the pumping configurations performances, we report here a study of research carried out on Nd: YAG solar-laser systems by using either end-pumping or side-pumping techniques.

A brief description of the solar-laser systems with end-pumping and side-pumping configurations will be firstly introduced in Section 2. A citation of the record results of the laser-systems with end-pumping configuration, along with the most important results on continuous wave solar laser oscillation systems using side-pumping method will be given in Section 2-1 and Section 2-2, respectively, followed by discussions in Section 3 and conclusions in Section 4.

2. PERFORMANCE STYDY OF THE SOLAR LASER SYSTEMS

The collection efficiency is generally regarded as a primary figure of merit for solar-lasers. The second is thermal problem worsening the efficiency as well as the beam quality [8]. The research that have been marked by record results in solar-laser field are summarized below in order to show, first that the end-pumping solar-laser systems are the most efficient; however, the thermal load effects caused by non-uniform distribution of pump light, typical in these pumping configurations, lead to a poor solar-laser beam quality [9]. Second, that the side-pumping systems are the most effective for producing high solar-laser beam quality and stability as they give uniform absorption within the laser medium, reducing the associated thermal loading problems [9].

2.1 Research carried out on solar laser systems using end pumping method and characterized by record-high results

For clearly exhibiting the results of research carried out on solar-laser systems using end-pumping method, performance details of these systems will be given afterward. Divers literatures were made for the solar-laser performance improvement. Research details will be given for both multimode and monomode solar-laser operations, respectively.

In multimode regime, by using the end-pumping method, the maximum laser power of 120 W continuous wave [10], the highest collection efficiency of 32.1 W/m^2 [11], the highest slope efficiency of 8.9 % [12] and the lowest threshold pump power of 192 W [13] were attained. In monomode operation the highest fundamental-mode collection efficiency of 7.9 W/m^2 [12] and the highest solar laser brightness of 6.5 W were achieved [14].

2.2 Research carried out on solar laser systems with side pumping configuration and marked by record-high results

The researches carried out on solar-laser systems with side-pumping configuration show that these systems provide simultaneously, in monomode operation, high solar-laser beam quality and stability.

The beam quality factors (M^2_x and M^2_y), which are defined by the ratio between laser beam divergence and divergence of diffraction-limited Gaussian beam, characterize the solar-laser beam quality.

M^2_x and M^2_y less than 1.05 are reached by using the side-pumping method. More importantly, a fundamental mode solar-laser with 1.7% laser power stability is produced, being significantly more stable than the previous monomode solar lasers [8].

3. DISCUSSIONS

Since the first report of “A sun-pumped c w one-watt laser” in 1966 [01], several pumping architectures have been proposed for solar-pumped laser ystems to improve their performance [08]. These laser systems can have either side-pumping or end-pumping configurations.

The most efficient laser systems have end-pumping approaches because of the high absorption efficiency of the pump-light by the laser crystal. In turn the thermal loading effects caused by nonuniform distribution of pump-light in these pumping configurations affect negatively the laser beam quality [9].

In multimode regime, by using the end-pumping method, high collection efficiency of 32.1 W ⁄ m^2 was attained by pumping a large Nd: YAG rod through a large Fresnel lens. However, very large $M^2_x = M^2_y = 61$ factors have been associated with this approach, resulting in very poor beam quality [11].

For the fundamental-mode operation, record-high collection efficiency of 7.9 W ⁄ m^2 with only 1.2 as M^2 factors was reported [12].

Side-pumping is an effective configuration for producing high laser beam-quality and stability as it allows uniform absorption distribution along the laser rod axis and spreads the absorbed power within the laser medium, reducing the associated thermal loading problems of the end-pumping method [9].

In contrast to the end-pumping configuration, the side-pumping method leads to low collection efficiency but also to very low M^2 factors. Record-low M^2 factors less than 1.05 have been achieved [8].

4. CONCLUSION

To improve solar-laser performance, several pumping architectures have been proposed. These pumping architectures can be either side-pumping or end-pumping configurations.

The most efficient laser systems have end-pumping configurations because of the high absorption efficiency of the pump-light by the laser crystal, the thermal loading effects caused by nonuniform distribution of absorbed pump-light typical in these pumping configurations affect negatively their laser beams quality.

In multimode regime, the maximum laser power (120 W continuous wave), the highest collection efficiency (32.1 W/m^2), the highest slope efficiency (8.9 %), the lowest threshold pump power (192 W) were achieved. In monomode operation, despite the highest solar laser brightness (6.5 W) obtained, the M^2 beam quality factors less than 1.2 could not be obtained because of the negative thermal loading effects characterizing these pumping methods.

As mentioned above, the most efficient laser systems have end-pumping configurations; the side-pumping approach is very preferred for achieving high laser beam quality in monomode operation, $M^2 < 1.05$ was obtained. In addition to the high solar-laser beam quality, the side-pumping configuration presents the advantage to be able to produce a stable fundamental-mode solar-laser power. Maximum output power variation being <1.7% was obtained. The Gaussian fundamental-mode profile was also found stable during the process.

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How to cite this article:
Hamrouni N., Mehellou S. and Rehouma F. Study of Nd: YAG solar-laser out put performance in end-pumping and side-pumping configurations. J. Fundam. Appl. Sci., 2020, *12(1S), 49-55*.