Experimental study of the efficiency of a multi-pass pumping scheme for solar lasers

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Приведены результаты исследования целесообразности многопроходной схемы накачки в лазерах с солнечной накачкой. Разработан вторичный концентратор, способствующий многократному прохождению солнечных фотонов через активную среду. При использовании многопроходной схемы накачки наблюдается увеличение на 12.5% спектров люминесценции Nd:YAG в окрестности линии генерации на длине волны 1064 нм.

Ключевые слова: Лазеры с солнечной накачкой, многопроходная схема накачки, Nd:YAG, вторичный концентратор.

Here we present the results of our study on the feasibility of a multi-pass pumping scheme in solar lasers. A secondary concentrator has been developed to ensure the multiple passage of solar photons through the active medium. When using a multi-pass pumping scheme, an increase of 12.5% in the luminescence spectra of Nd:YAG is observed in the vicinity of the lasing line at a wavelength of 1064 nm.

Keywords: Solar lasers, multi-pass pumping scheme, Nd:YAG, secondary concentrator.

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I. Introduction

It is obvious that one of the many factors influencing laser performance is the pumping scheme, regardless of the type of optical laser. Since the first realization of the celebrated Ruby laser using a flashtube, diverse types of pumping methods and schemes are being used. Laser engineering requires important considerations for pumping schemes such as stability, efficiency, and convenience.

Pumping efficiency is more critical in solar pumped lasers. Because, firstly, solar lasers usually use a primary concentrator for focusing solar radiation, meaning concentrated radiation energy. Secondly, the solar spectrum is very wide in comparison with absorption spectra of the currently existing active media. There are mainly three categories of pumping schemes in solar lasers: end-pumping [1, 2], side-pumping [3, 4] and end-side pumping schemes. Obviously, each has advantages and disadvantages in a particular circumstance. A noteworthy advantage of the end-pumping (or combined end-side pumping) is a relative longevity of optical path length inside an active medium ensuring efficient absorption of solar photons. However, when end-pumping scheme is used, the possibility of solving scaling up problems is severely limited [3], in addition, control of the cavity layout becomes more difficult. These two are essential features required to generate powerful, high-quality beams. The indicated problems of end-pumping easily attainable in side-pumping schemes due to the lower pump efficiency due to the small value of the optical path inside the

active medium. However, this leads to low efficiency when using a side-pumped scheme. However, the latter leads to a low conversion efficiency of lasers using a side-pumped scheme.

Recently, we proposed a way to mitigate the lower pump efficiency problem in the side-pumping scheme where the effectiveness of multi-pass scheme is demonstrated using a simulation model based on Monte-Carlo photon tracing method [5]. In this paper, our aim is to experimentally study the feasibility of a multi-pass pumping scheme under solar illumination using a Fresnel lens. In next section, we briefly describe the experimental setup.

II. Experimental setup

We developed a new chamber with a retro-reflector [6, 7] for side pumping. Figure 1 shows a photo of the developed camera for multi-pass transverse pumping. The camera was made of aluminium and the interior surfaces were polished and silver coated. The internal dimensions of the camera are 14mm×30mm×35mm.

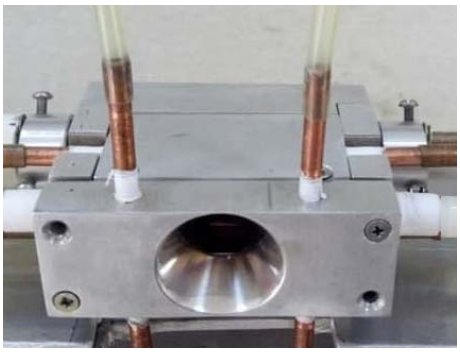


Figure 1. Chamber for multi-pass side pumping.

Concentrators based on a Fresnel lens [8], in contrast to parabolic solar concentrators, have a more smeared spot with a relatively large diameter with the same dimensions of the Fresnel lens due to dispersion in the material from which the lens is made. In this regard, to reduce losses at the chamber inlet, we designed a secondary concentrator with a cone shape. The reverse side was coated with silver and served as a retro reflector providing multi-pass pumping. The reflection coefficient of the inner walls of the pump chamber as well as of the retro-reflector was about 90%. Using this camera, the experimental setup shown in Figure 2 was developed.

To measure the luminescence spectrum, an ASP-150T spectrometer is used, which allows measurements in the spectral range 170–1100 nm, which covers the luminescence spectra of Nd:YAG. As a source of excitation, we used solar radiation concentrated by a small Fresnel lens with dimensions of 18×24 cm^2 with a focal length of about 30 cm and a transmission of ~75%. The power at the focus of the solar concentrator could reach up to 30 W with solar radiation intensity of 950 $W \cdot m^2$, and the focal spot diameter was ~5 mm. In the experiments, the active element was cooled with distilled water to prevent unwanted thermal effects.

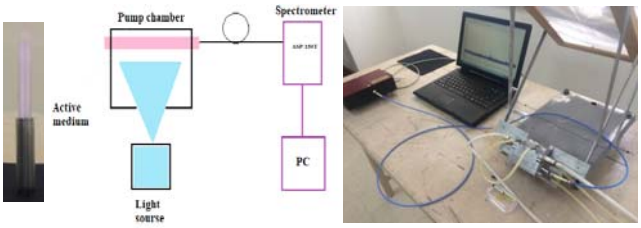


Figure 2. Block diagram of the experimental setup and a real image of the active medium.

III. Results and discussions

The experimental setup was used to measure the luminescence spectra of the Nd:YAG laser medium under excitation with concentrated solar radiation in turn with and without the use of a retro-reflector (front wall of the chamber with a conical secondary concentrator, see Fig. 1) and compared the results. Based on these comparisons, the effect of enhancement of Nd: YAG luminescence due to the process of multi-pass transverse pumping was estimated.

The following figures (Figs 3 and 4) show the obtained luminescence spectra of Nd: YAG in the vicinity of the 1064 nm lasing line. As can be seen from these spectra, when using a retro reflector (the front wall of a chamber with a conical secondary concentrator), an increase in luminescence is observed in comparison with the spectrum obtained in the absence of a retro reflector. Calculation of the line area ratios in the wavelength range of 1050–1080 nm for cases with and without a retro reflector showed that it was 1.125, that is, an increase of 12.5% is observed when using a retro reflector, which confirms our idea of multi-pass pumping to increase the efficiency of lasers with solar pumping. As for the not very large magnitude of the amplification effect, this can be explained by the not sufficiently high reflection coefficient of the pump chamber walls, which was about 90%. An increase in the reflection coefficient to 97–98%, we assume, may al-

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low further improvement in the results of measuring this amplification effect.

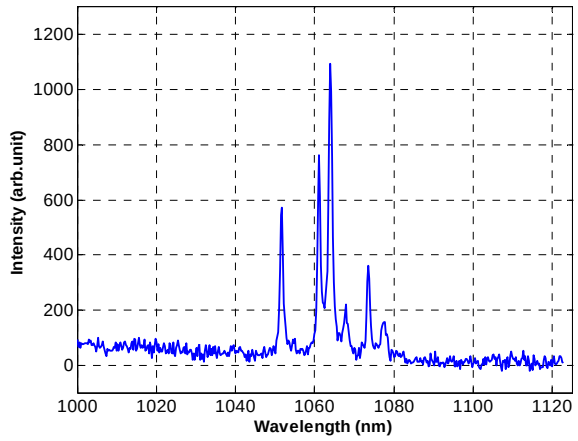


Figure 3. Nd:YAG luminescence spectrum in a scheme without a retro reflector.

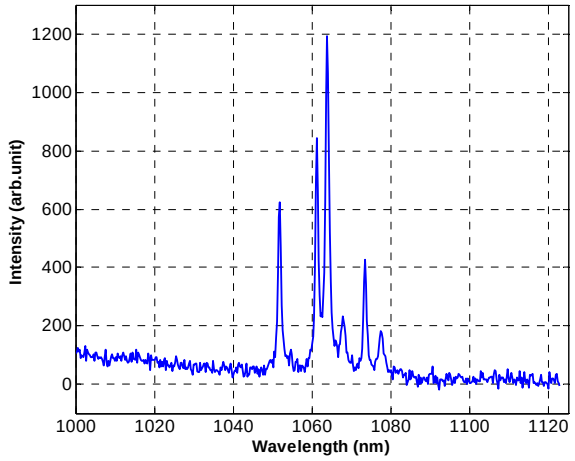


Figure 4. Nd:YAG luminescence spectrum in the scheme with a retro reflector.

IV. Conclusion

A new multi-pass pumping camera – a laser head for transversely pumped solar lasers has been developed and created. An experimental study of the luminescence spectra of Nd:YAG under excitation by concentrated solar radiation has been carried out. Application of a multi-pass pumping scheme enables an increase of 12.5% in the luminescence spectra of Nd:YAG is observed in the vicinity of the lasing line at a wavelength of 1064 nm when the reflection coefficient of the inner walls of the pump chamber is about 90% confirming the practicality of the proposed scheme in solar lasers

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Қуёш лазерлари учун кўп-ўтишли оптик дамлаш схемаси эффективлигини экспери-ментал ўрганиш

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Қуёш лазерларида кўп-ўтишли дамлаш схемасини қўллаш мақсадга мувофиқлиги бўйича ўтказилган тадқиқот натижалари келтирилган. Қуёшдан келаётган фотонларнинг фаол муҳит орқали кўп марта ўтиш имконини яратиб берувчи иккиламчи концентратор ишлаб чиқилди. Кўп ўтишли дамлаш схемасидан фойдаланилганда, тўлқин узунлиги 1064 нм бўлган генерация чизиғи яқинида Nd:YAG луминесценсия спектрининг 12.5% га ошиши кузатилди.

Калит сўзлар: Қуёш лазерлари, кўп-ўтишли дамлаш схемаси, Nd:YAG, иккиламчи концентратор.

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