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طراحی سامانه ۴۴ بار عبوری برای دمش لیزر دیسک

حمیدرضا شهرکی، محسن جمشیدی سرشت و شهرام کاظمی

مرکز ملی علوم و فنون لیزر ایران

چکیده- در لیزرهای دیسک نازک به دلیل ضخامت کم دیسک، درصد کمی از انرژی باریکه دمش در یک‌بار عبور جذب می‌گردد. یکی از روش‌ها برای بهبود بازده جذب، افزایش تعداد عبور نور دمش از داخل دیسک است. متداول‌ترین روش برای دمش، قرار دادن دیسک در کانون سامانه‌های تصویرساز 4f بازتابی با بزرگنمایی واحد بوده تا نور دمش جذب نشده مجدداً از داخل دیسک عبور کرده و جذب گردد. افزایش تعداد عبور سبب بهبود بازده و امکان استفاده از دیسک با آلاییدگی کمتر را میسر می‌سازد که در نتیجه کیفیت باریکه خروجی لیزر بهبود می‌یابد. در این مقاله سامانه ۴۴ بار عبوری شبیه‌سازی و طراحی‌شده است که با استفاده از آن بازده اپتیکی نسبت به سامانه ۱۶ بار عبوری ۱۲ درصد افزایش‌یافته است.

کلید واژه- سامانه ۴۴ بار عبوری، دمش لیزر دیسک نازک، سامانه تصویرساز

Design of a new 44-pass system for using in thin-disk lasers' pumping module

Hamid Reza Shahraki, Mohsen Jamshidi Seresht and Shahram Kazemi

Iranian National Center for Laser Science and Technology

Abstract-In thin disk lasers, a few percent of pump energy is absorbed when it passes through the disk due to its low thickness. One method to enhance absorption efficiency is increasing the number of pump light's passes. The most common procedure providing multi-pass is placing disk in the focal plane of a reflective 4f-imaging system with unitary magnification. In that case, unabsorbed light transmits through disk repeatedly to rise absorption efficiency. More pump passes, also, open the way for usage of active material with low absorption which results in better beam quality of disk laser. Here, a 44-pass system has been simulated and designed able to improve optical efficiency about 12 percent compared to 16-pass system.

Keywords: 44-pass system, thin-disk pump system, imaging system

1. Introduction

The active medium of thin-disk lasers is a disk with typical thickness of 100-500 µm and diameter up to a few cm. In most structures, lasing and cooling processes occur along the disk axis, while pumping is ensued in a quasi-end-pumped configuration. The rear side of the disk is acting as a high-reflective mirror (HR) for pump and laser wavelengths, and it is thermally coupled to a heat sink [1].

Because of low thickness of thin-disk, only a small fraction of pump light is absorbed in one pass. The rest of light is reflected by the HR coating onto a second pass in the active medium. Even so, the absorption in the resulting double pass is too small. This shortcoming can be compensated using a multi-pass scheme for the pump light by redirecting the unabsorbed pump beam into the disk several times.

To generate an appropriate pump profile which minimizes radial tails, the optical multi-pass system has to redirect the various pump passes, with sharp boundaries, at “exactly” the same position on the disk’ surface. A relay 4f telecentric imaging system with unitary magnification is often used for this purpose [2].

Increasing the number of passes has influential benefits. Firstly, it reduces the thin-disk thickness and doping concentration, while pump light absorption does not change. Reduction of thin-disk thickness can decrease thermal lens effects and improve laser beam quality by making smaller heat resistance and lower overall temperature. Secondly, a larger number of passes enhances the optical efficiency of laser by increasing the absorbed energy and supressing the unabsorbed pump power [1], [3].

In this paper, a 44-pass system has been reported which rises the optical efficiency more than 12 percent [4] in comparison with 16-pass system in the same operation conditions like pump power and spot diameter, doping and thickness of disk, and etc.

2. Design Method

In the most popular pumping method of thin-disk lasers, the radiation of a fiber-coupled diode laser or a number of laser-diode stacks are fed into a glass rod used as beam homogenizer. The rays of beam are experienced multiple reflections on the walls of the rod and mixed together. Finally, an uniform intensity profile is produced at rod’s output face, which can be considered as an uniform source in thin disk pumping [2]. In our simulation (was done by Zemax OpticStudio™ software, version 16) a light of a fiber-coupled diode laser is coupled in a 120 mm rod with hexagonal cross-section which delivers acceptable uniformity.

In the next step, the imaging system, which includes a set of lenses and a parabolic mirror, makes an image of uniform source on a disk, which is located at the middle of the parabolic focal plane (Fig. 1a).

The next stage is related to providing 44 passes for pump beam. This is the duty of HR on the rear side of disk, parabolic mirror, 10 folding mirrors (HR coated prism-pair) and one flat mirror. The pump beam routing in the multi-pass and before that is shown in Figure .1. The sequence of flat mirrors, which are executed for directing by pump beam, is indicated by the numbering. A semi-collimated pump beam enters into multi-pass from circular window (number 1). It is, then, converged by parabolic mirror into its focal plane where disk (shown with orange circle) is placed to transmit through the disk for the first time. After absorption a few percent of pump beam at one-pass, it is redirected toward parabolic mirror by HR coating on the rear side of disk (this is the second pass). The parabolic mirror collimates beam and sends it toward first folding mirror (number 2 and 3). This is used for changing the position of beam when it comes back to the parabolic mirror. The pump beam travels toward disk again after reflecting from surface of parabolic mirror to transmit through the disk for two times more. Other folding mirrors operate like the first one and this illustrated process

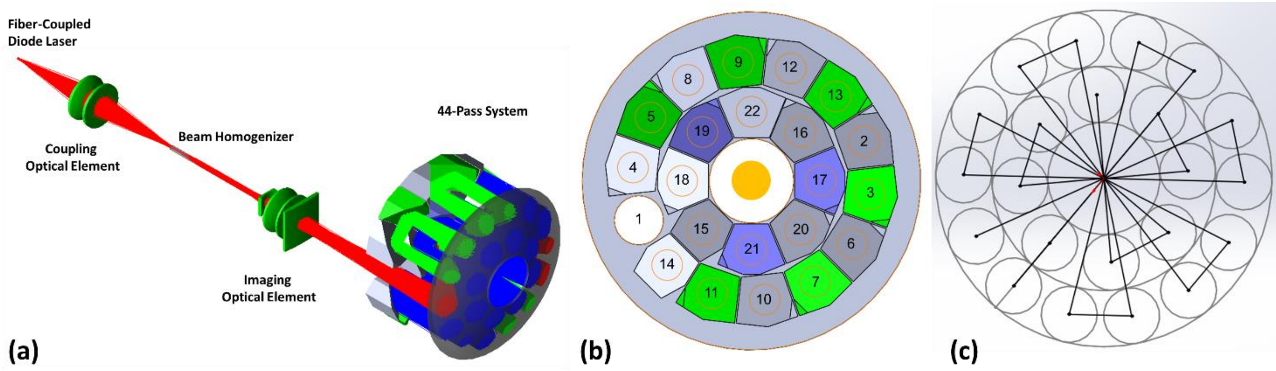

Figure 1.a) Schematic of the designed pumping optical system. b) The sequence of used flat mirrors. c) Propagation of pump beam in 44-pass system

continues until beam arrives to flat mirror (number 22). Here, the beam is back-reflected giving rise to a propagation in opposite direction which results in a doubling of the number of pump passes on the disk. Finally, this designed structure provides 44 passes for our pumping system.

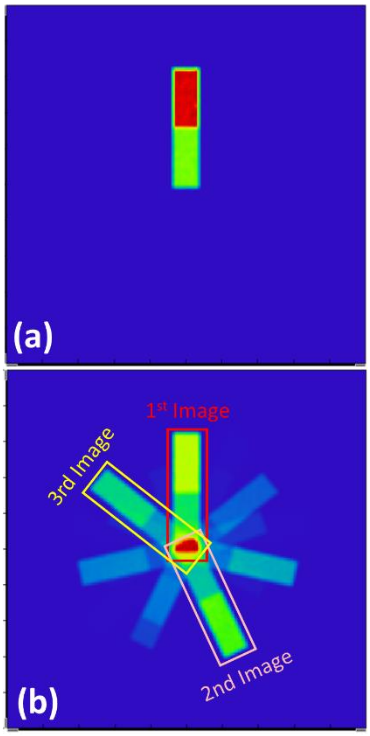

Figure 2. Irradiance distribution: a) step-shaped rectangular source, b) multi-pass profile.

A noticeable point about multi-pass is that the folding mirrors change the incidence position of the pump beam on the parabolic mirror by rotating the beam around the parabolic axis such that the adjacent spots do not overlap each other on the parabolic mirror. Therefore, second image on the disk is rotated around disk's axis compared to the first one. The rotation angle of the image is equal to the rotation angle of the pump beam around the parabolic mirror axis. For clarifying this image rotation, a rectangular source having step-shaped distribution was used as the bottom of that was placed on disk' axis (Fig. 2a). As shown in multi-pass intensity distribution (Fig. 2b), the images of source were rotated around disk's axis with constant angle. The bottom of images was overlapped because of that the central position had more intensity.

3. Results

In this article, an imaging system with magnification of 2.5 was used in order to make an image of homogenizer's output surface. The homogenizer had a hexagonal cross section circumscribed about a circle with a diameter of 5 mm. For analysing the profiles, Detector Rectangle Object in Zemax OpticStudio™ with area of 20× 20 mm^2 and 200 × 200 pixels was executed. Figure 3 shows the absorption profiles of pump irradiance in a 0.2 mm thick Yb:YAG disk with 7% doping concentration, for both cases of one-pass and 44-pass by using designed pumping configuration. The obtained spot diagrams in one-pass were 12.9 and 12.7 mm in X and Y directions, respectively while that of for 44-pass were 12.6 and 12.5 mm.

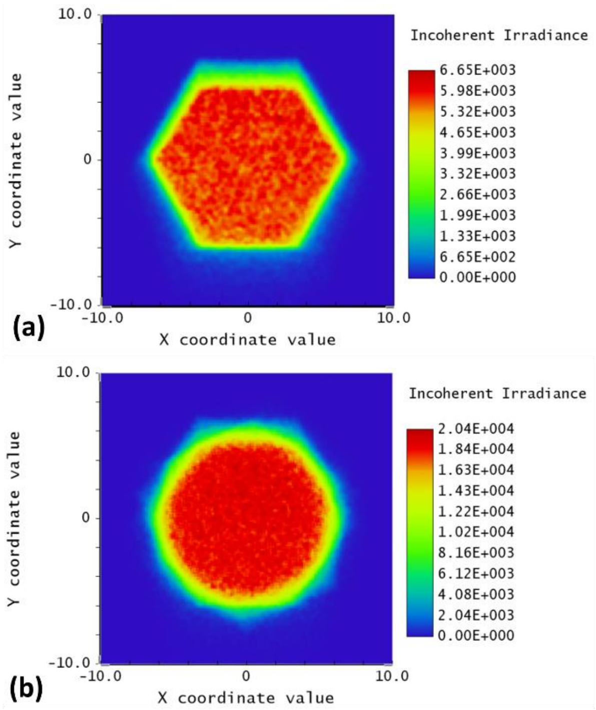

Figure 3.Numerical irradiance of pump beam on disk surface in both cases of one-pass (a) and 44-pass (b)

Conclusion

In this report, a new 44-pass scheme was presented yields an increased optical efficiency. This structure is particularly important for active media having small single pass absorption due to lower disk thickness, lower doping, lower active medium absorption cross section, and smaller absorption bandwidth. By numerical investigation, 73 percent of optical efficiency was obtained for this designed structure in contrast to 61 percent for 16-pass in the same operation condition.

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