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

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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

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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
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Conclusion

In this report, a new 44-pass scheme was presented and 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.

References


