

Beam shaping of high power diode laser stack into homogeneous line

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Abstract In this paper, analysis of beam shaping and homogenization of high power diode laser stack into a line focus with dimension of $10\text{ mm} \times 0.5\text{ mm}$ was reported. The beam shaping and homogenization was simulated by using ZemaX-ray tracing technique. The results have shown that intensity distribution after beam shaping and homogenization at the work piece is a flat top for the slow axis with homogeneity over 95% and a Gaussian distribution for the fast axis.

Keywords beam shaping, homogenization, high power diode laser stack, homogeneity, pumping applications

1 Introduction

Diode laser stack systems have gained increase interest for their successful application in a number of different fields, such as pumping applications, materials processing, and medical applications. Among these, a major application of high-power diode laser stacks is the pumping of solid-state lasers, which can offer the advantages of much higher electrical-to-optical efficiency, lower thermal gradients induced inside the active materials, higher system lifetime and reliability, and higher beam quality.

The main drawback of diode laser stacks is the non-homogeneous intensity distribution in the far field. To overcome this problem, the beam shaping optics are combined with the diode laser system in order to transform the non-homogeneous intensity distribution into a homogeneous intensity distribution with specific dimension

that should be independent from fluctuations and non-homogeneities of the original laser beam. The laser beam shaping techniques can be categorized into two types, namely filed mapper and beam integrator [1]; both can be implemented with diffractive elements based on wave theory or refractive and reflective elements based on geometrical optics. The technique of beam integrator used for this aim is homogenization by waveguide [2–4] or micro optical arrays [4–11].

In this paper, we reported on the beam homogenization and beam shaping of diode laser stack in a line focus with dimension of $10\text{ mm} \times 0.5\text{ mm}$ by means of waveguide technique. The simulation of the optical setup was carried out by using ZemaX-ray tracing software that operated in a non-sequential mode.

2 Homogenization principle of waveguide

Due to higher independency from original diode laser intensity distribution, high power handling capability and better conservation of beam quality, the optical waveguide is frequently used for both one dimensional and two dimensional homogenization of diode laser stacks. Diode laser stacks offer a Gaussian intensity profile for the fast axis, while the slow axis intensity profile has neither a top hat shape nor a Gaussian distribution. Thus, the slow axis distribution is needed to be homogenized and transformed to a top hat distribution.

The basic principle of this homogenization and beam shaping technique is shown in Fig. 1(a) where the light of a diode laser stack source is focused into an optical waveguide and the beam field distribution is coupled into the different transverse modes of the waveguide, based on the theory of the different phase shift for the different waveguide modes, the output field of the waveguide will

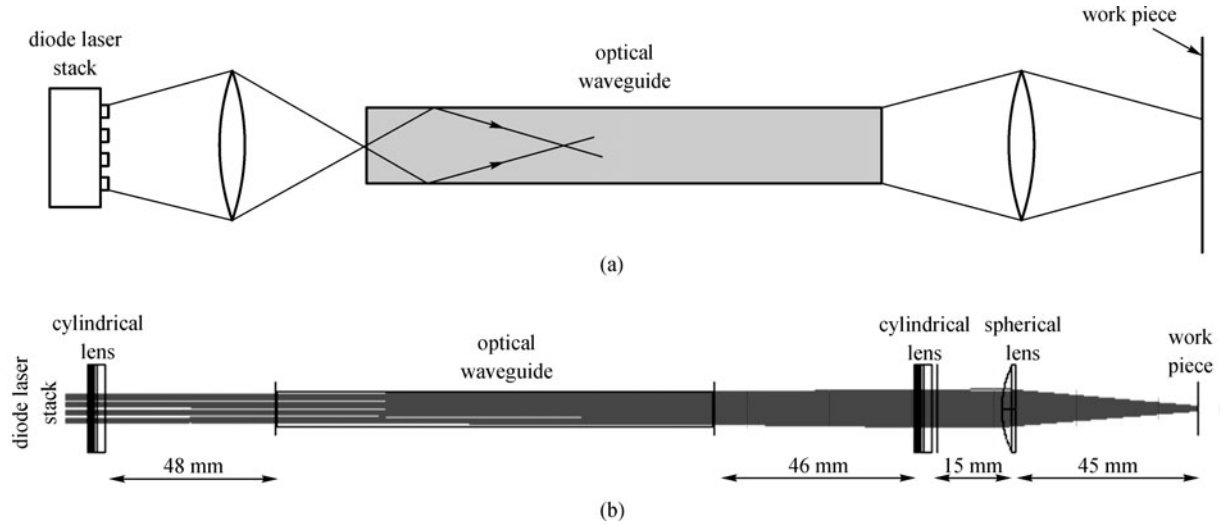


Fig. 1 Optical setup. (a) Homogenization principle of waveguide; (b) fast axis ray tracing

be recomposed by the different waveguide transverse mode with the different phase shift, by the proper design the waveguide length, the uniformity of the output field of the waveguide will be improved.

The result of the homogenization depends on the number of reflections inside the waveguide [12,13], which is defined by the aspect ratio of the waveguide L/h , the divergence of the incident beam θ and the refractive index of the waveguide n .

$$\text{No. reflections} = \frac{L}{h} \tan \left(\arcsin \left(\frac{1}{n} \sin \theta \right) \right) \approx \frac{L}{h} \frac{\theta}{n}$$

It is often debated that one major drawback of the optical waveguide is the loss due to multiple reflection [2]. However, in proposed setup, a fit optical waveguide is required to mix the light from the source to obtain a uniform intensity distribution at the outlet, and therefore this drawback can be minimized.

3 Optical setup and simulation results

The optical setup illustrated in Fig. 1(b) consists of diode laser stack with 4 bars that offer in total an output power up to 1.2 kW at wavelength of 808 nm, two cylindrical lenses ($f=50$ mm), optical waveguide (100 mm \times 10 mm \times 8 mm) and spherical lens ($f=45$ mm). The optical waveguide size is chosen for the following reasons: high power diode laser beam size, minimize loss by means of multiple reflections [9] and compact size in the experimental realization.

As mentioned above, the slow axis of the diode laser stack (see Figs. 2(a) and 2(b)) is focused onto the entrance

surface of the waveguide by cylindrical lens (see Figs. 2(c) and 2(d)). The slow axis is homogenized by multiple internal reflections inside the waveguide. At exit surface of the waveguide, we used cylindrical lens to focus the beam on the slow axis. In the end of the optical setup, we used spherical lens to focus both slow and fast axis on the work piece.

It can be seen in Figs. 2(a) and 2(b) that the output beam intensity distribution of the diode laser stack is not uniform along slow axis direction; and the uniformity of the beam intensity distribution cannot be improved by simply optical focusing as shown in Figs. 2(c) and 2(d).

The beam intensity distribution at the focus point after passing through the waveguide is shown in Fig. 3, where the optics generates a line with dimension of 10 mm \times 0.5 mm.

It can be seen that the intensity distribution at the focus point is an almost perfect top hat profile for the slow axis with homogeneity over 95% and a Gaussian distribution for the fast axis as depicted in Fig. 4. The optical efficiency (output power of the optics divided by the power of the diode laser) amounts to 86%.

4 Conclusions

This paper presented the beam homogenization and shaping of high power diode laser stack light into homogeneous line with specific dimension by using optical waveguide technique. The simulation yields the intensity distribution of a top hat shape in the slow axis with homogeneity over 95% and a Gaussian distribution in the fast axis.

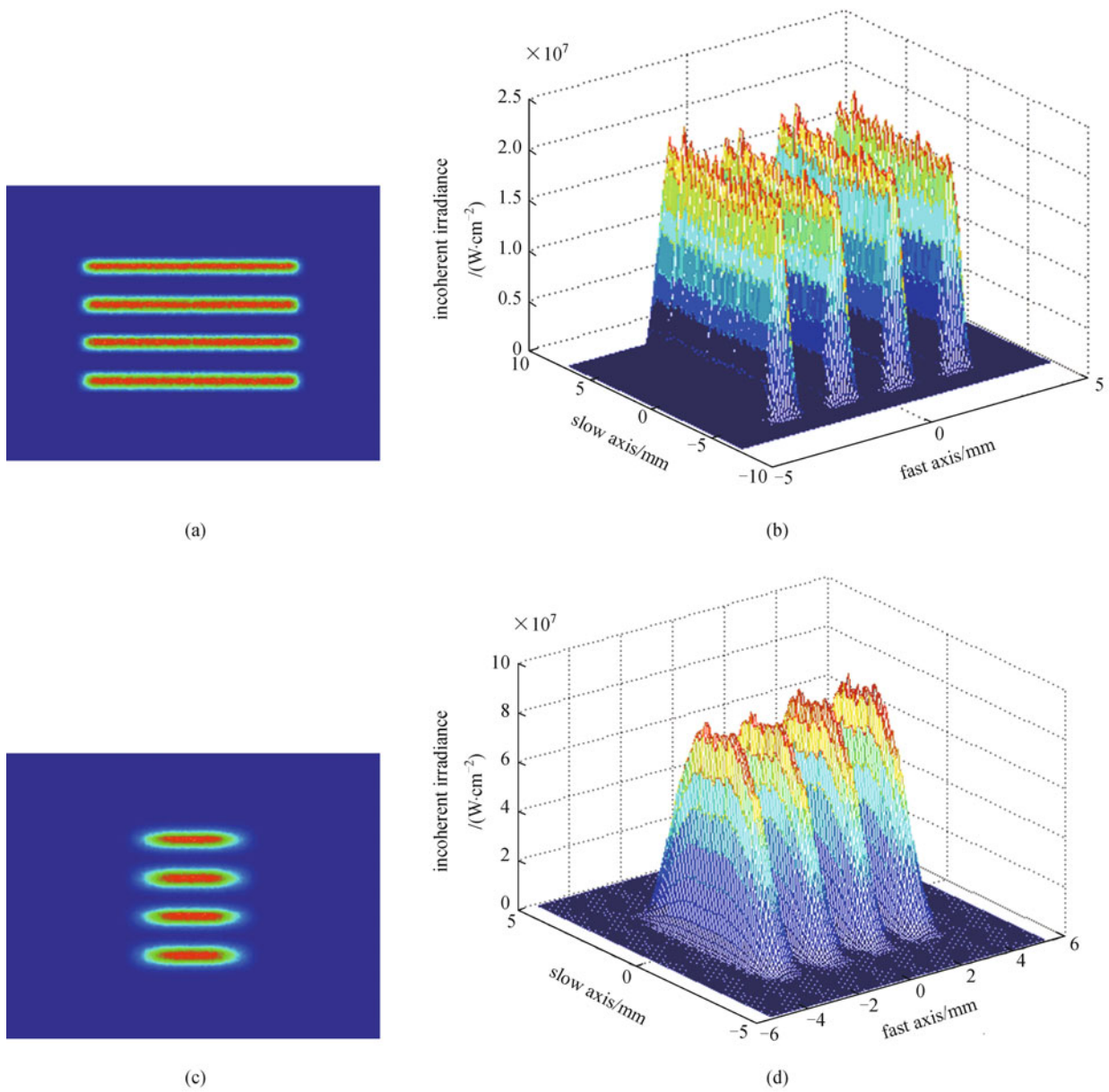


Fig. 2 Diode laser stack beam profile. (a) and (b) Beam profile before focusing; (c) and (d) beam profile after focusing onto waveguide's entrance

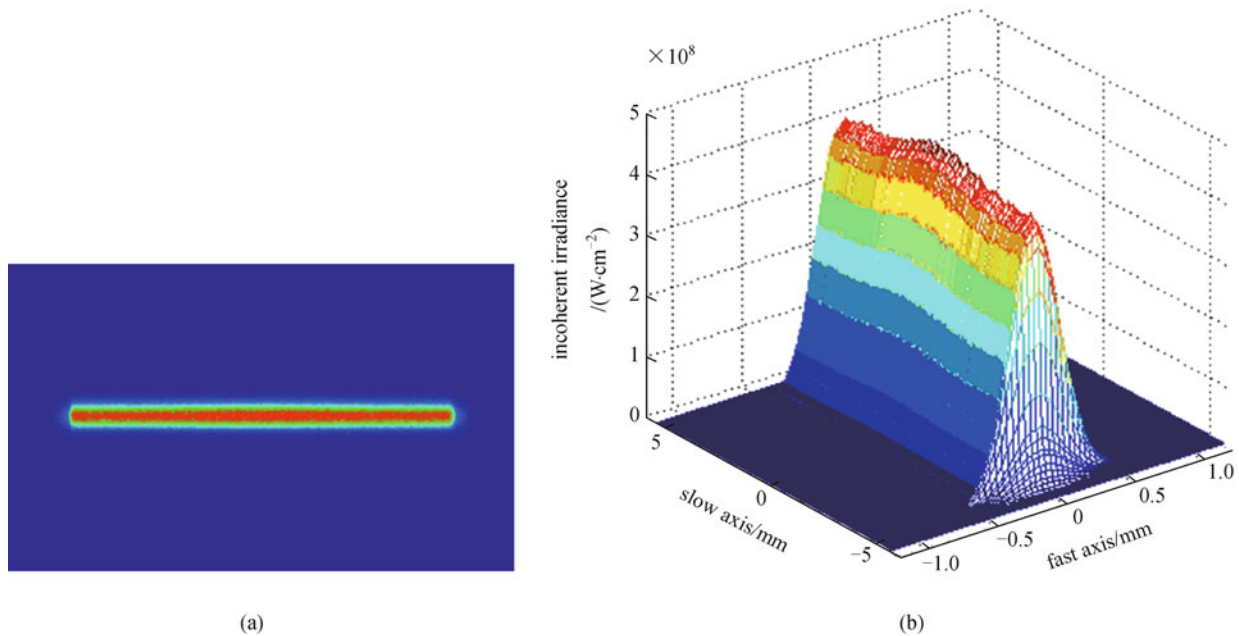


Fig. 3 (a) Spot size at work piece; (b) three dimensional diagram of spot size

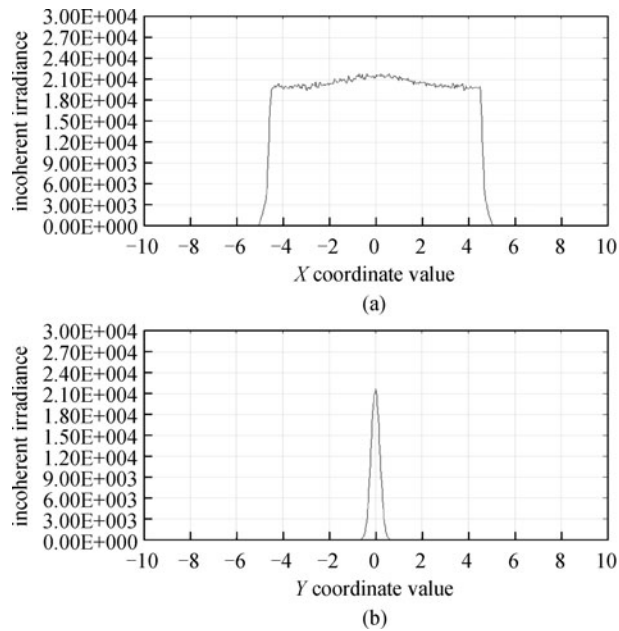


Fig. 4 (a) Intensity distribution of the line focus along the slow axis direction; (b) intensity distribution along fast axis direction

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