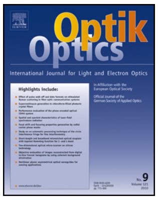
Optik 157 (2018) 148–155

Contents lists available at ScienceDirect

Optik

journal homepage: www.elsevier.de/ijleo



Original research article

# Study of evaluating nearfield beam quality of the high power laser beams

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ARTICLE INFO

*Article history:*
Received 23 September 2017
Accepted 13 November 2017

*Keywords:*
High power laser
Beam quality
Laser nearfield
Spatial beam shaping

ABSTRACT

The nearfield beam quality of the high power laser system is of great importance in order to achieve a very good effect in the specific position. We review various aspects of evaluating this nearfield beam quality, present results obtained in a high power laser system, and discuss the valuable reference of beam quality improvement in the spatial shaping system for high power lasers.

## 1. Introduction

High-power laser plays an important role in many fields, such as inertial confinement fusion [1–3], industrial processing [4], directed energy weapon [5], optoelectronic contermeasures [6], and scientific research [7–10]. The uniform nearfield is the important part of the beam quality for high power lasers. The importance of controlling the laser-beam amplitude in high-power lasers cannot be overemphasized. There are important applications such as gain precompensation [11] and hot-spot suppression. Moreover, the laser nearfield is related to the far-field distribution in propagation which will influence the focusing intensity of the output laser and the alignment of the beam path of the high power laser system [12]. Therefore, it is necessary to control the spatial intensity of laser beam [13–15]. The premise condition is accurate measuring the laser nearfield and selecting the appropriate evaluation method for spatial beam shaping.

The traditional $M^2$ factor is mainly used to evaluate the beam quality of the Gaussian beam, which mainly refers to the laser beams waist size and divergence angle [16,17]. However, the output laser nearfield intensity distribution is usually super-Gaussian type or flat-topped in high power laser systems, such as the National Ignition Facility in the USA [18–20], the laser OMEGA-EP facility in the University of Rochester [21–23], the SG-III laser facility in China [24–26] and the LMJ facility in France [27–29]. The $M^2$ factor is not suitable for analyzing such nearfield beam quality. Therefore, it is necessary to study the evaluation method of beam quality for high power laser systems.

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https://doi.org/10.1016/j.ijleo.2017.11.079

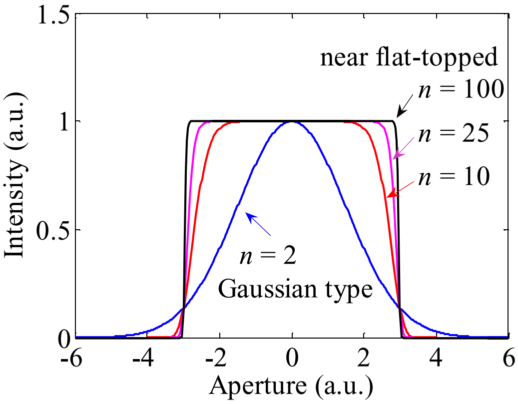

**Fig. 1.** Spatial super-Gaussian distribution against the different orders.

In this work, the scientific-grade CCD with high resolution is used to measure the output nearfield in the high power laser. Several evaluation methods of the nearfield beam quality are analyzed, including the nearfield modulation, the fluence contrast and the edge-softening factor. In the application of spatial beam shaping for high power lasers, the nearfield modulation and fluence contrast are appropriate for evaluating the output nearfield beam quality, which can be used as the reference standard for the optimization of spatial beam shaping.

## 2. The measurement of the nearfield

The laser beam is assumed as to be a round size with super-Gaussian distribution. The laser beam is considered to be with spatial symmetry. Using the slowly varying amplitude approximation and ignoring the temporal and the phase influence, the Intensity of the laser can be expressed as [30]

$$I(r) = I_0 \exp\left[-2\left(\frac{r}{r_0}\right)^n\right] \tag{1}$$

where $I_0$ is the maximum value of the intensity; $r_0$ is the beam radius; $n$ is the order of spatial super-Gaussian distribution. As shown in Fig. 1, different super-Gaussian orders represent different distribution of the laser nearfield. When the order number $n = 2$, the nearfield is Gaussian type, and when $n > 10$, it is near flat-topped.

In the high power laser system, the intensity distribution of the flat-topped area and edge area in the nearfield are mainly concerned. The laser nearfield intensity can be measured by using scientific-grade CCD [31–33], the industrial-grade CCD, the oscillograph recording paper, the film and the knife-edge measuring method [34–36]. The scientific-grade CCD is widely used with high resolution for measuring the laser spatial fluence distribution in high power lasers. Compared with the scientific-grade CCD, the resolution of the industrial-grade CCD is low, which is usually used for rough judgment and analysis. Nevertheless, the nearfield measured by the oscillograph recording paper is mainly related to the laser power. Compared with the CCD the resolution of the oscillograph recording paper is low, but it is easy to use and usually used for auxiliary reference during debugging the beam alignment in the beampath of the laser system. The film belongs to the material of record image in the early age with long storage time but low resolution. The knife-edge measuring method is usually used to measure the beam quality of the Gaussian beam, and it needs to cooperate with the power meter and to process the measuring data. To date, the scientific-grade CCD is widely used to measure the laser nearfield in the high power laser system. The laser nearfield measured by the CCD can be used as the input data of the spatial beam shaping.

## 3. Evaluation of the nearfield and discussion

In the spatial beam shaping system of the high power laser, the typical process of the beam shaping is shown in Fig. 2. The initial nearfield distribution is close to be Gaussian type with high fluence in the center and low fluence at the edge [see Fig. 2(a)]. After spatial beam shaping, the output nearfield is nearly to be flat-topped [see Fig. 2(b) and 2(c)], which is close to the aimed nearfield [see Fig. 2(d)].

There are several methods to evaluating the nearfield beam such as the nearfield modulation, the fluence contrast, the beam edge-softening factor and energy in bucket etc.

### *3.1. Intensity modulation and flux modulation*

In the high-power laser system, the laser peak intensity should be limited and the output laser nearfied uniformity should be improved; otherwise, many unwanted nonlinear optical effects such as self-focusing and stimulated light scattering will