Transactions of the Korean Nuclear Society Spring Meeting
Chuncheon, Korea, May 25-26 2006

Improved Spatial Filter and Serrated Aperture for High-Energy Pulsed Lasers

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1. Introduction

Spatial filters are essential components of high-energy pulsed laser systems where they are used to remove high spatial-frequency components from a high-energy pulsed laser-beam to control instabilities in the laser-beam amplification process [1]. The spatial filter is a focusing lens-collimating lens pair with a pinhole placed at their common focus. Figure 1 shows a conventional washer-type pinhole structure and conical-type pinhole structure. It was demonstrated that a conical-type pinhole structure in a spatial filter was suitable for high-energy laser system because of the better reduction of plasma generation as shown in Fig .1) [2]. Diffraction ripples of relay planes in high-energy pulsed laser system are amplified by self-focusing in optical components such as amplifier materials [3]. This result can cause damages of optical components. A serrated aperture with a spatial filter provides a solution to the damage problem by perform its apodization functions [4]. Therefore, we have investigated the spatial beam profile in combination with a serrated aperture and conical-type pinhole structure for high-energy pulsed laser system.

2. Conical pinhole and serrated aperture design

2.1 Conical pinhole

Conical pinholes as shown in Fig.1 (b) were designed (considered in Ref. [2]). Usually, for a pinhole to be small enough to clip unwanted light, the intensity of the laser pulse on the rim of the hole is sufficient to ablate the plasma (expanding plasma) which eventually expands into the beam waist (focus) during the pulse as illustrated in Fig. 1(a). Therefore, a conical-type pinhole structure has the tapered internal surface which causes off-axis rays to be refracted in a low density plasma layer. Table 1 shows detailed parameters of designed conical pinholes.

Table 1. Parameters of designed conical pinholes.

Name	Outlet Φ[mm]	Inlet Φ[mm]	Length L [mm]
P03	0.32	0.58	5.12
P04	0.43	0.75	6.88
P05	0.53	0.95	8.48
P06	0.64	1.15	10.24

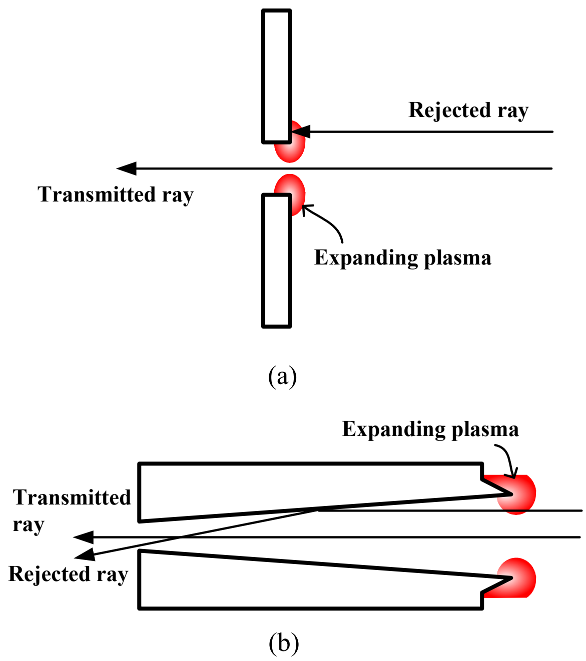

Figure 1. Side cross-section view of a (a) conventional washer-type pinhole structure and (b) conical pinhole structure [2].

2.2 Serrated aperture design

Serrated aperture was designed from Eq. (1) as following [5,6]:

$$\alpha \leq \frac{3.83f}{k\tau 2\pi} \tag{1}$$

α is the pinhole radius, *k* is wave number of the propagating light and *f* is the input focal length of the spatial filter. τ is the serration period. The equation (1) is valid only if the height-to-period ratio (*H:L*) of the serration is large enough. According to Ref. [6], this aspect ratio has to be larger than 6.

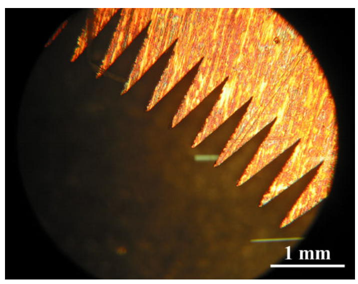

Figure 2. Photograph of V-shaped edge of the serrated aperture. (Tip is approximately 25um round and pitch is 1.2mm)

Based on the equation (1), we made a serrated aperture for high-energy pulsed laser beam as shown in Fig. 2.

3. Experimental set-up

Figure 1 shows the experimental set-up for the analysis of spatial beam profile in combination with a serrated aperture and conical-type pinhole structure. A solid-state Nd:YAG laser(model Quanta-Ray Pro-230) was used as a source beam. A serrated aperture is located in between mirror 3 and 4. The aperture has a 10.06 mm diameter outer boundary. The serrations have a height of 1.2 mm, a period of 200 μm, and a V-shaped taper. The beam transmitted through the serrated aperture propagates through a 1.4 x magnifying vacuum spatial filter. The input lens has a focal length of 50 cm. The four conical pinholes were inserted in a rotary aperture holder which can be rotated to select the desired size.

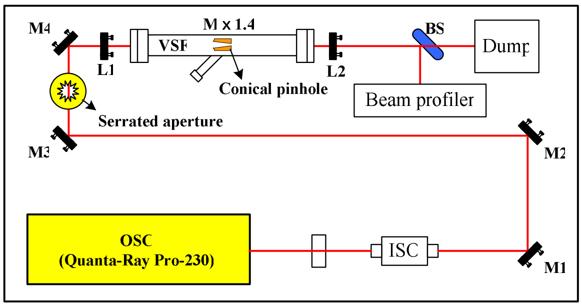

Figure 3. Experimental set-up for the analysis of spatial beam profile in combination with a serrated aperture and conical-type pinhole structure.

3. Results and discussions

Figure 4 shows experimental results of the spatial beam profile before the serrated aperture and after the vacuum spatial filter. The spatial beam profile of source beam clearly shows the ring patterns which can cause optical damage as shown in Fig. 4(a). However, after passing through the vacuum spatial filter (in Fig. 4(b)), the spatial beam profile shows the flat-top profile which is required at front-end part for high-energy laser systems (before parabolic beam shaping in order to extract the maximum possible energy). The result is considered the effect of combination of a serrated aperture and conical pinhole.

4. Conclusions

We have investigated the spatial beam profile in combination with a serrated aperture and conical pinhole structure for high-energy pulsed laser system. The results presented in this study indicate that it is possible to shape the spatial beam with flat-top profile by the effect of combination of a serrated aperture and conical pinhole. Consequently, this study also can be optimized for future high energy laser systems.

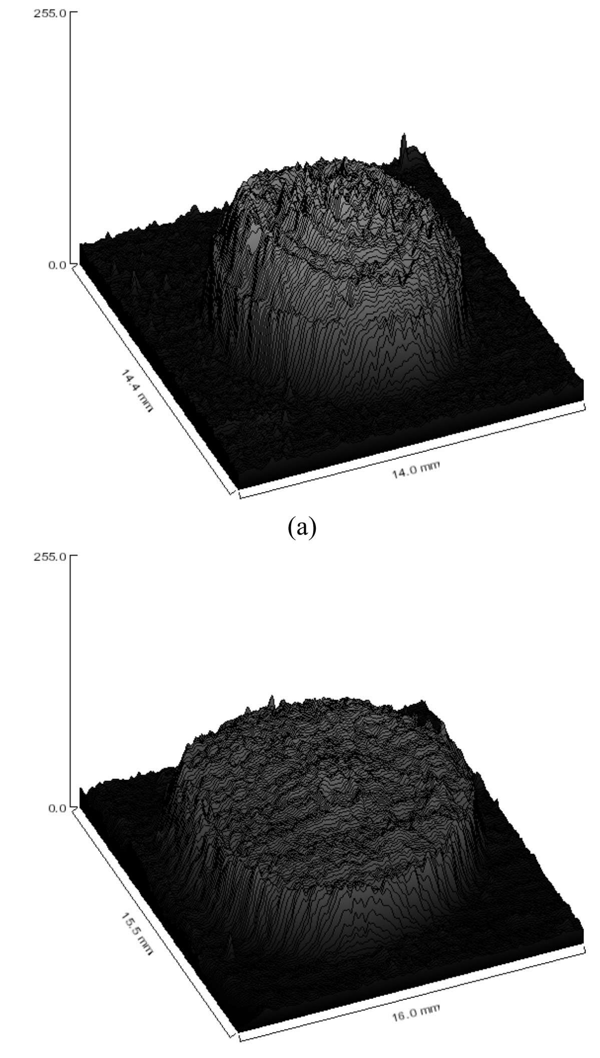

Figure 4. Spatial beam profile (a) before a serrated aperture and (b) After the vacuum spatial filter.

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