Large-aperture laser beam alignment system based on far-field sampling technique

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ABSTRACT

Laser beam alignment is very important for high-power laser facility. Long laser path and large-aperture lens for alignment are generally used, while the proposed alignment system with a wedge by far-field sampling technique reduces both space and cost requirements. General alignment system for large-aperture laser beam is long in distance and large in volum because of taking near-field sampling technique. With the development of laser fusion facilities, the space for alignment system is limited. A new alignment system for large-aperture laser beam is designed to save space and reduce operating costs. The new alignment for large-aperture laser beam with a wedge is based on far-field sampling technique. The wedge is placed behind the spatial filter to reflect some laser beam as signal light for alignment. Therefore, laser beam diameter in alignment system is small, which can save space for the laser facility. Comparing to general alignment system for large-aperture laser beam, large-aperture lenses for near-field and far-field sampling, long distance laser path are unnecessary for proposed alignment system, which saves cost and space greatly. This alignment system for large-aperture laser beam has been demonstrated well on the Muliti-PW Facility which uses the 7th beam of the SG-Ⅱ Facility as pump source. The experimental results indicate that the average near-field alignment error is less than 1% of reference, and the average far-filed alignment error is less than 5% of spatial filter pinhole diameter, which meet the alignment system requirements for laser beam of Multi-PW Facility.

Keywords: laser technique, beam alignment, far-field, large-aperture beam, near field, imaging system

1. INTRODUCTION

The inertial confinement fusion (ICF) facility is the largest and most complex of high-power lasers, such as SG-Ⅱ Update System in China [1], National Ignition Facility in the United States [2], and LMJ in France [3]. Large-aperture laser beams in these lasers, propagating from the master oscillator driver to the target, interact with more than 100 near-field optics and pass through several spatial filter pinholes over a distance exceeding 100 m [4]. For purpose of high-power optical performance, alignment system for large-aperture laser beam becomes essential parts of this kind of laser. The alignment system for achieving to adjust the laser beam is not only the key subsystem that guarantees the high power laser facility to run efficiently, safely, reliably, but also is the one of key factors guarantee the qualities of laser beams near-field and far-field. General alignment system is long in distance and large in volum because of taking near-field sampling technique. With the development of laser fusion facilities, beam diameter, paths and components increase greatly. Therefore, the space for alignment is limited especially of Multi-PW Facility which is based on SG-Ⅱ Facility. [5] General alignment system cannot meet the space requirements anymore. A new alignment system for large-aperture laser beam is designed to save space and reduce operating costs.

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High-Power Lasers and Applications VIII, edited by Ruxin Li, Upendra N. Singh, Robert F. Walter, Proc. of SPIE Vol. 10016, 100160I · © 2016 SPIE
CCC code: 0277-786X/16/$18 · doi: 10.1117/12.2245743

2. PRINCIPLES

The position of optical components is fixed to achieve a properly adjusted laser system. However, mechanical frame distortion, temperature changes, output light excursion from the master oscillator, and micro vibration of foundation and supporting frame all can cause the beams to deviate from the original laser path. In order to make sure the laser beam from the oscillator can stably and accurately pass through preamplifier, main amplifier, target chamber, and tiny pellet each run, it is important and absolutely necessary to align the beam lines before a new shot of the laser system. The main mission of the alignment system for large-aperture laser beam is to make laser beamlines pass through the pinhole of the spatial filter accurately by far-field sampling technique.

The alignment for laser beam is based on the principle that two points can determine one light path. Generally, the two points as mentioned above are selected for near-field and far-field references. Figure 1 shows the position of near-field and far-field in the laser beam. As Figure 2 shown, the near-field determines the positon of the laser beam, and the far-field determines the direction of the laser beam. Therefore, the alignment unit includes near-field alignment and far-field alignment. Generally, the near-field is at a certain position in the laser beam, and the far-field is the focal position of laser beam. The mission of the alignment unit is to obtain the centering and pointing errors of the beam lines and to null the beam displacement.

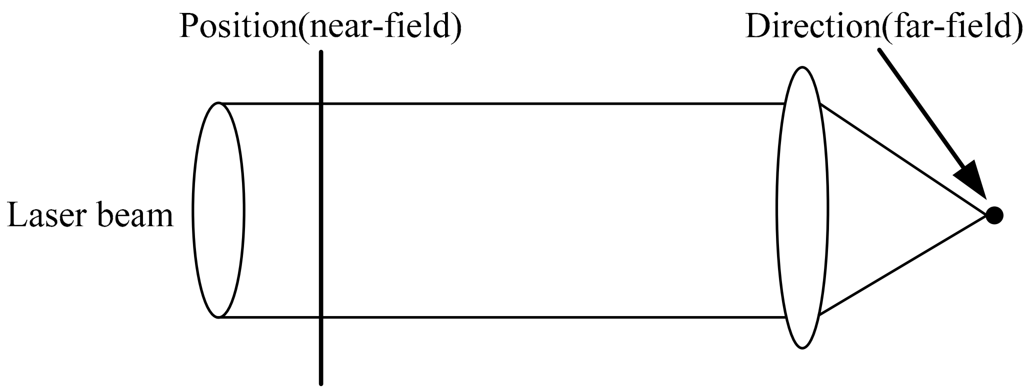


Figure 1 The position of near-field and far-field in the laser beam.

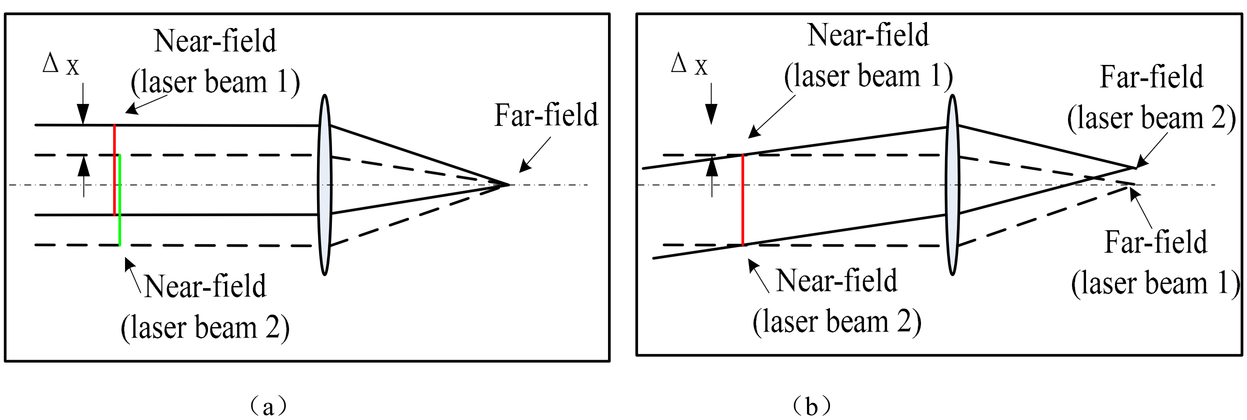


Figure 2 Near-field and far-field in two laser beam. (a) two laser beam with different position; (b) two laser beam with different direction

3. TECHNIQUES

General alignment system

General alignment system is usually coaxial with the main laser beam based on near-field sampling technique. In order not to affect the main laser beam, the general alignment system is often placed behind a mirror to take sample by light leakage as Figure 3 shows. The charge-coupled device (CCD) is used for imaging the laser signals. Near-field CCD (NFCCD) and far-field CCD (FFCCD) detect near-field and far-field laser signals using a large-aperture lens behind a baffle, respectively. Each baffle is installed with a stepper motor to protect the CCD by moving the baffle in or out the laser beam path. Under the small energy laser circumstances, the baffles are shifted out the laser beam path to detect the laser signals by driving the stepper motor. Once the energy is up to CCD's damage threshold, the baffles are shifted in the laser beam path to protect the CCD. The mirrors IM1 and IM2 are installed with stepper motors to adjust the main laser beam by changing the movement of these two mirrors.

As Figure 3 shows, the main laser beam passes through IM1 and IM2. The transmitted laser light is captured by NFCCD behind the large aperture lens for near-field sampling. The reflected main laser beam passes through the spatial filter, mirror, and be detected by FFCCD behind the large aperture lens for far-field sampling. It's obvious that near-field sampling technique gets large-aperture laser beam before the lens, so large lenses for near-field as well as far-field sampling are needed in this laser system. Therefore, the general alignment system occupies large space and spends expensive cost for large aperture lenses. Moreover, coaxial alignment system occupies long distance in main laser path, which means it directly affects the distance of main laser path.

In conclusion, the general alignment system for large aperture laser beam can't meet the space and cost requirements of high power laser facility anymore. It's so urgent to design a new alignment system for large aperture laser beam, which can satisfy the engineering requirements in high power laser facility.

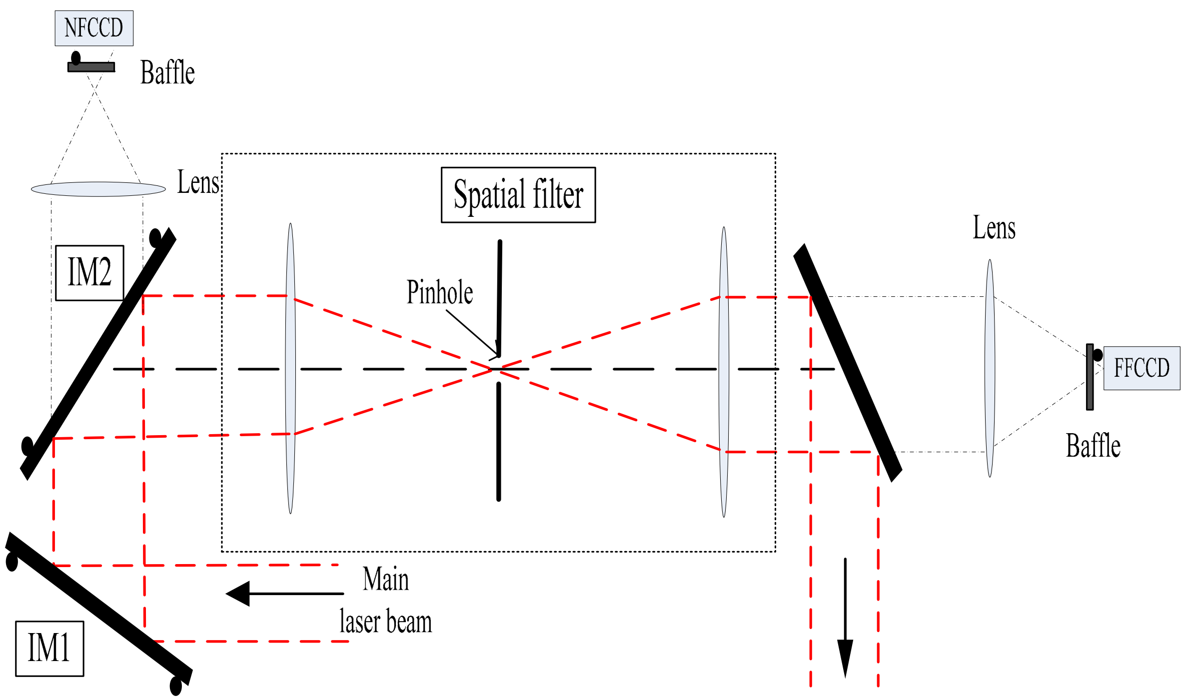


Figure 3 General alignment system.

New alignment system

Owing to the space limitation, a new alignment system for large-aperture laser beam in as Figure 4 shows is proposed. The new alignment system with a wedge is based on far-field sampling technique. The wedge is placed behind the spatial filter to reflect some laser beam as signal light for alignment. Compared with the general alignment system shown in

Figure 3, the new alignment system needn't the large-aperture lenses before NFCCD and FFCCD for near-field and far-field sampling, respectively. And it can save space and cost for the high power laser facility greatly.

As Figure 4 shows, the main laser beam passes through IM1, IM2, spatial filter and wedge. A small part of laser light is reflected by wedge to pass into the alignment system. This laser light goes back to the spatial filter and converges below the pinhole. Then it becomes small-aperture laser beam, goes through total reflective mirror, lens, rectangular prism. Finally, the reflected laser light is detected by NFCCD and the transmitted laser light is imaging on FFCCD. Baffles with stepper motor are the same as Figure 3 shows, there is no need to repeat them.

Comparing to general alignment system, the new alignment system use the large aperture lens in the spatial filter as alignment sampling lens, so the large-aperture lenses for near-field and far-field alignment are unnecessary by taking far-field sampling, which save cost and space greatly. Moreover, non-coaxial alignment system does not affect main laser path anymore.

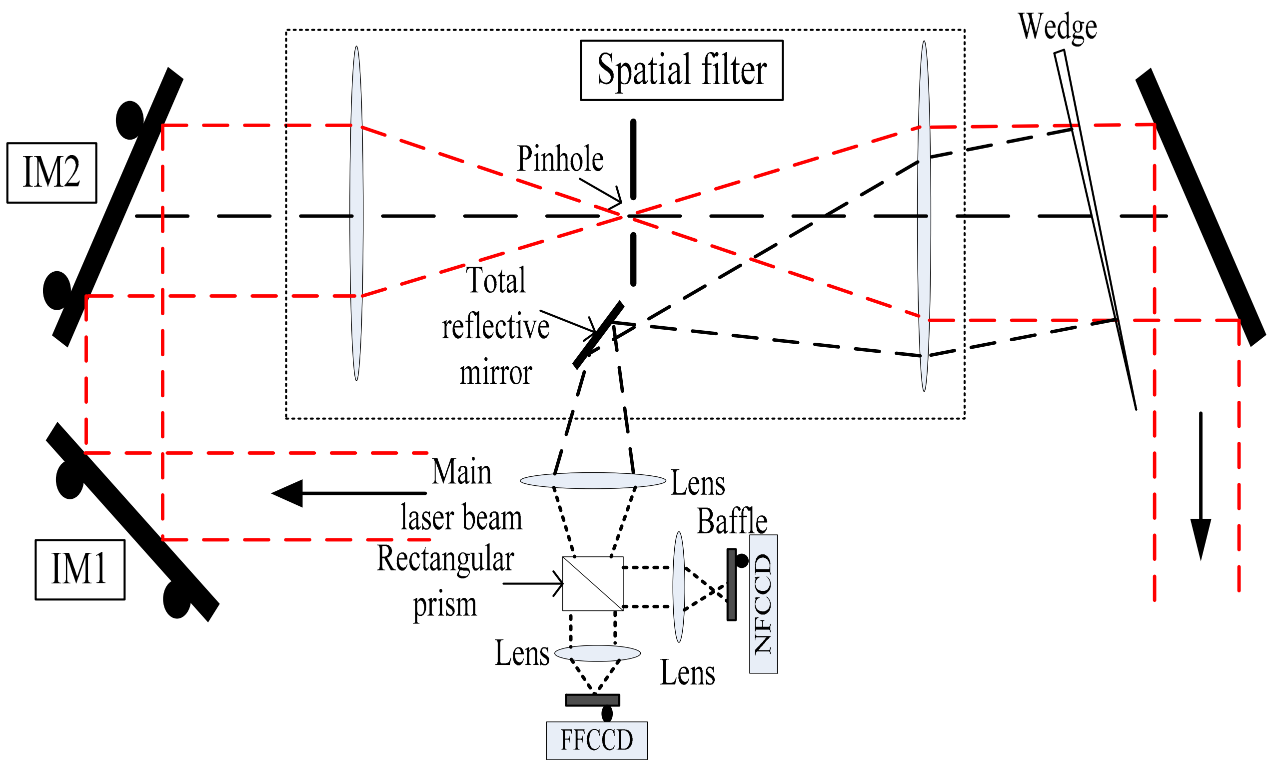


Figure 4 New alignment system.

4. EXPERIMENTS AND RESULTS

The new alignment system with a wedge, a total reflective mirror, a rectangular prism, and a set of optical imaging components was demonstrated on the Muliti-PW Facility. The experimental results show that the new alignment system can align the position of high power laser facility beams as well as the direction of laser beam. The experimental results indicate that the average near-field alignment error is less than 1% of reference, and the average far-filed alignment error is less than 5% of spatial filter pinhole diameter, which meet the alignment system requirements on the near-field position and far-field direction of high power laser beam.

The figures bellows show the results of the alignment for the near-field position and far-field direction. The alignment schematic has been testified all right on the Multi-PW Facility. The experiment result was satisfied. The beam adjustment of the Multi-PW Facility can be finished in 15 minutes. To verify the repeatability of the beam alignment, the beam adjustment was repeated every half an hour. Figure 5 shows the experimental setup. All the results are obtained based on the experiments conducted on this setup. Figure 6 is shown as the results of ten continuous experiments. The triangle points are the position of far field beam before alignment. The rhombus points are the position of far field reference. The rectangle points are the position of far field beam after aligning. The experimental results indicate that the position of far field beam fits well with the reference.

Figure 5 The experimental setup.

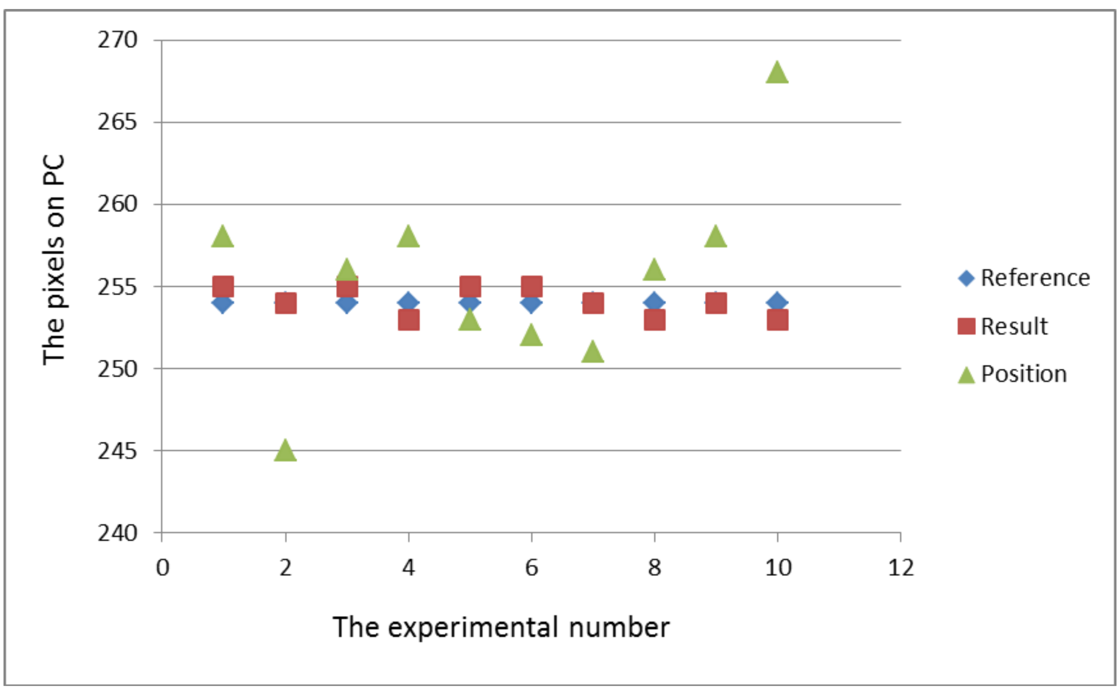
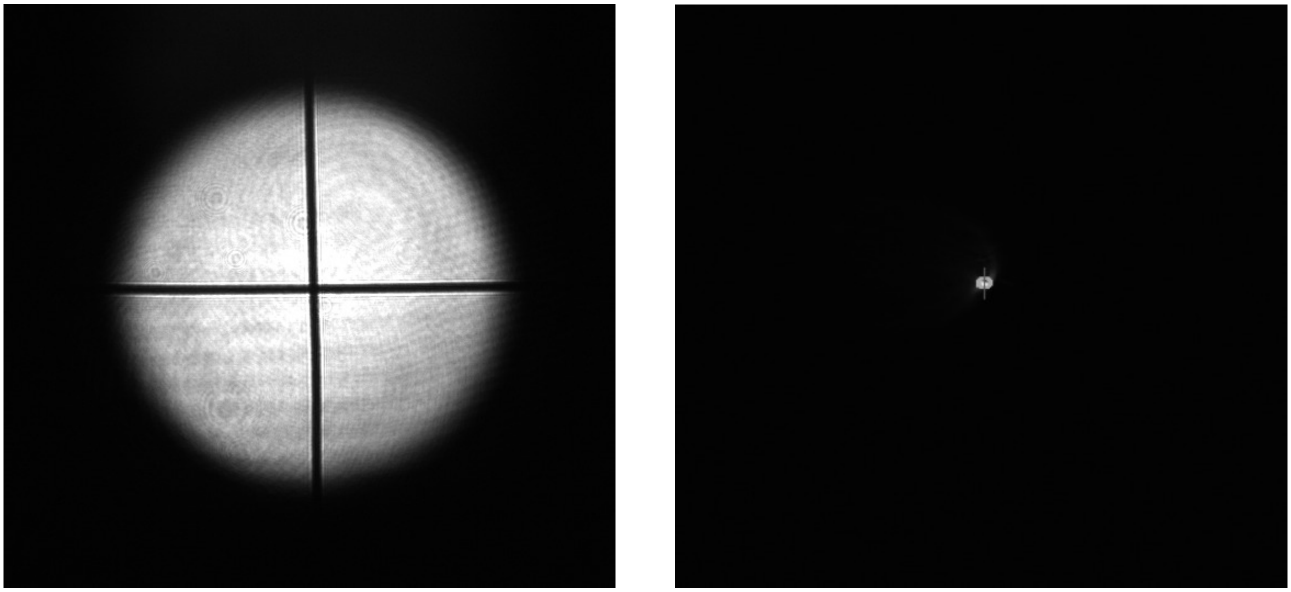


Figure 6 The alignment result of the far field beam.

Figure 6(a) and Figure 6(b) show the near-field image and the far-field image after alignment, respectively. It's clearly shown that the near-field laser beam locates in reference well and the focal spot of the main laser beam is overlapped with the spatial filter pinhole well after alignment.



（a）　　　　　　　　　　　　（b）

Figure 7 Near-field and far-field images after alignment. (a) near-field image; (b) far-field.

5. CONCLUSION

Considering the general alignment system for large aperture laser beam by near-field sampling technique occupying large space, the paper proposes a new alignment system based on far-field sampling technique. The new alignment has been demonstrated well on the Muliti-PW Facility for near-field position and far-field direction alignments. In conclusion, near-field sampling technique is frequently used in alignment system, whereas the proposed arrangement based on far-field sampling technique saving cost and space greatly.

This work was performed under the auspices of the National Natural Science Foundation of China (61205137). The authors would like to express thanks to team staffs in the Muliti-PW Facility for providing the experimental support.

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