10⁸ amplification of diode-pumped Nd:YLF regenerative amplifier with MRF wavefront correction


INTRODUCTION

Recently, high energy (10-100 J), high repetition rate (10-1 kHz), diode-pumped solid-state lasers (DPSSLs) have been developed at several research institutes for high-energy applications such as inertial fusion energy [1]. In these high energy DPSSLs, correction of distorted wavefront is one of key issues. In generally, deformable mirror (DM) is used for such high-energy lasers. However wavefront distortion of sub-millimeter at these large aperture lasers has not been corrected because a spatial resolution of DM has been limited by practical size and number of actuators. A Phase Conjugated Plate (PCP) has a potential to substitute for the DM because of its higher spatial resolution and lower cost than the DM. The PCP is a fused silica plate whose surface is phase conjugated to the distorted wavefront. We have processed the PCP by magnetorheological finishing (MRF) technology which is specialized a spatial resolution of about sub-millimeter and in a surface figure of \( \lambda/100 \) processing [2]. This paper reports that evaluation of fabricated PCP and experimental results about applying the PCP to one Joule-class preamplifier for the 20J x 10Hz output zig-zag Nd:Glass slab laser system.

PHASE CONJUGATE PLATE

With recent technology of manufacturing laser crystal, 1-cm aperture Nd:YLF rod usually has some residual distortions inside it. We numerically designed the PCP for a Nd:YLF rod of 1-cm diameter to correct its residual wavefront distortion of sub-lambda order. In the calculation, it was indicated that the distorted wavefront of 0.117\( \lambda \) is corrected to 0.031\( \lambda \) in RMS (\( \lambda=1053\text{nm} \)) by the surface figure of the designed PCP in Fig. 1 (a) expressed by Zernike polynomial of degree three (n=3, \( R_3^n(\rho) \)) [3]. In order to fabricate the PCP, we have used a wheel head of a few centimeter for the MRF machining (collaborated with Okamoto Optics Work, Inc.). A measured surface figure of a fabricated PCP is shown in Fig.1 (b). We evaluated the difference between Fig. 1 (a) and Fig. 1 (b) as the fidelity of the PCP as shown in Fig. 1 (c). The surface figure of the PCP recreated the designed surface figure in accuracy of 0.06 mm (RMS). There were two local peaks encircled by white dash lines of about 0.3 mm (P-V) in the calculated surface. But it has not become a critical issue for focusing and energy amplification characteristics. However, the fidelity of the PCP can be improved by better using a smaller wheel head of MRF. Thereby, it is possible for a PCP to correct a wavefront distortion up to Zernike polynomial of degree 9th at 10-cm aperture laser. Because a spatial resolution of a PCP of sub-millimeter meets to a spatial resolution of a Zernike polynomial of degree 9th at 10-cm aperture.

EXPERIMENTS

Two PCPs have been applied in the diode-pumped Nd:YLF regenerative ring amplifier system. In the laser system, two spatial filters (SFs) have set between two Nd:YLF amplifiers in order to suppress the parasitic oscillation and image-relay. A laser pulse keeps passing in the ring system until its polarization turned by Pockels cell and output by polarizer. The PCPs have been set at 10 cm behind each Nd:YLF rod. A 1-J output energy amplified from input energy of 10-nJ output of a fiber laser is achieved at the system with the rounds number of over 8. However the laser pulse can’t propagate over 5 rounds without the wavefront correction because almost

![Fig. 1. Evaluation of reproducibility of PCP. Designed surface figure by Zernike polynomial of degree three (a), surface figure of fabricated PCP (b), surface figure calculated difference between (a) and (b).](image-url)
of the pulse energy was blocked by a pinhole of the SF due to its poor focus pattern. Figure 2 shows the output energy as a function of pump energy after 8 rounds. Then $10^8$ amplification of 380 mJ output energy from input energy of 13 nJ was achieved with good agreement with our calculation. A filling factor of a near field pattern (NFP), as a uniformity, shown in Fig. 3 (a) is 60%. A far field pattern (FFP) in Fig. 3 (b) is focused to its near diffraction limit. Encircled energy in its 5 times diffraction limit was 82%. Near future, over 1-J output energy with a near-diffraction limited beam quality will be achieved by increasing pumping energy to 8 J and using a PCP fabricated with higher spatial resolution.

CONCLUSION

We demonstrated wavefront correction by the PCP fabricated up to Zernike polynomial of degree three in accuracy of 0.06 mm. In this result, $10^8$ amplification of 380 mJ has been achieved with a near-diffraction-limited beam quality. These results indicate a PCP is promising to substitute for a DM with its higher spatial resolution and lower cost.

REFERENCES


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