Holographic optical engine (HolOE)

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Holographic beam shaping achieved by exploiting the rewritable capability of a spatial light modulator (SLM) displaying a computer-generated hologram (CGH) is very useful in a variety of applications, especially material laser processing [1]. Although it provides high-processing throughput and high light-use efficiency, the accuracy of the beam shaping is degraded according to static and dynamic imperfections in the optical system. In order to compensate the static imperfections, a method that performs the optimization of the CGH in the optical system, called as an in-system optimization, was developed [2, 3]. A further method that allowing it to dynamically compensate for unknown and sudden disturbances for continuously optimizing a CGH during laser processing was developed [4]. Recently, it was extended to three-dimensionally focused beams [5].

Figure 1 shows the architecture of the holographic optical engine (HolOE) composed of a beam forming module (BFM), beam observation module (BOM), and a CGH optimization software installed in a computer. The BFM is composed of a target optics, a liquid-crystal-on-silicon SLM (LCOS-SLM) and relay optics. The BOM is composed of an image sensor (IS) and a Fourier lens. Firstly, a CGH data is given from a computer to LCOS-SLM. The CGH displayed on the LCOS-SLM spatially modulates the illumination beam and the modulated beam is given to a sample. It is also given to the IS located on the conjugated plane with the sample plane. The obtained image is transferred to the computer. The computer recalculates the CGH. This process is continued until the satisfied reconstruction is obtained.

Figure 2 shows the experimental setup of a holographic femtosecond laser processing machine. A femtosecond laser pulse was generated by a laser diode-pumped Yb:KGW femtosecond laser (Light Conversion, Pharos) with a maximum power of 10 W, a center wavelength of 1030 nm, a repetition frequency of 10 kHz, and a minimum pulse duration of ~150 fs. Half of the maximum laser power was input to a harmonic generator (Light Conversion, HIRO). The second harmonic generation wave, with a center wavelength of 515 nm, was used for this experiment. The maximum laser power was 1.87 W on the LCOS-SLM (X10468-04, Hamamatsu). The pulse energy was adjusted with a half-wave plate (HWP) and a polarized beam splitter (PBS), and the light pulse was collimated to a diameter of 8 mm by a 2× beam expander (Thorlabs, GBE02-A). The pulse was diffracted by a CGH displayed on the LCOS-SLM. The resulting spatially shaped optical pattern through a 50× microscope objective (Sigma, EPLE-50) with a numerical aperture (NA) of 0.55 mounted on an axially-moved piezo stage (Sigma, SFS-OBL-1) was made incident on a sample fixed on a linear stage (PI, V-738). A cooled CCD image sensor (IS1) (Bitran, CS-61M) was used in the BOM. A CMOS image sensor (IS2) (Thorlabs, DCC3240M), a white LED, a lens, a dichroic mirror (DM) and a green-cut filter (GCF) were used to monitor the laser processing.

Figure 3 shows an example of the holographic laser processing. The 120 parallel beams were optimized with the installed HolOE upto the uniformity of 98%. The sample was a thin glass. The through hole was fabricated with a single shot. The pulse repetition was 10kHz. The total pulse energy was 5.57μJ. The stage speed was 94mm/s. The throughput of the drilling reached to 1.2M/s, which was beyond the maximum laser repetition of 1MHz. This performance overcame laser processing with the beam scanning.

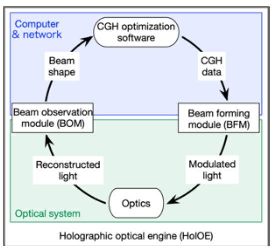

Fig. 1 Architecture of HolOE.

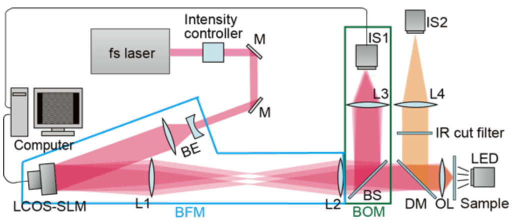

Fig. 2 Holographic laser processing machine.

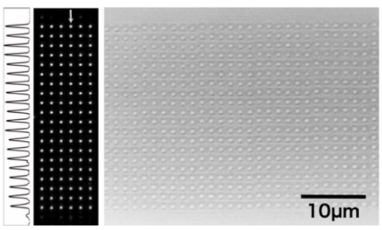

Fig. 3 120 parallel drilling of thin glass.

References

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