空間光変調器を用いた多点同時レーザープロセス

Parallel laser processing using a spatial light modulator

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Holographic laser processing is one of the promising techniques that increase the throughput of laser processing [1]. In the method, the spatial phase distribution of a laser beam is modulated using a spatial light modulator to generate multiple light spots with arbitrary distribution. We can expect that the method can increase the speed of laser processing by the number of light spots. However, it is not that simple. Is the quality of laser processing by a holographic method equivalent to that by a single beam irradiation? The answer is "NO". We should take care of two matters in holographic laser processing; the first one is deformation of the beam propagation [2] and the other one is the interference between physical phenomena at multiple photoexcited regions [3]. Unfortunately, these matters are never described in the manual of an SLM, because they are not in the scope of the suppliers of SLMs. Here, I will review these issues that should be taken into consideration in holographic laser processing.

(1) Beam propagation

To start holographic laser processing, we need to calculate a phase pattern that generates a desired light spots' distribution. Normally, only the central intensity at the center of each light spot is taken into consideration in the calculation. This means that the calculation does not guarantee how the beam propagates. The example is shown in Figure 1, in which unexpected light focusing appears out of the focus and the propagations of six light beams are not parallel. The deformation of the beam propagation could be critical in bulk laser processing such as waveguide writing inside glass. I will explain what condition generates such deformation and show a method that improves the symmetry of the beam propagation by applying constraints for intensities [2].

(2) Interference of stress or thermal energy [3]

Simultaneous laser irradiation at multiple positions generates complex stress and temperature distributions due to interference of stress and thermal energies, which influence the final structural changes. For example, inside single crystalline lithium fluoride (LiF), cracks of different lengths are generated by simultaneous laser irradiation at multiple spots [Fig. 2(a)]. The modification of the crack length originates from the interference of stress waves [Fig. 2(b)] and dislocation bands [Fig. 2 (c)], which prevents or facilitates crack elongation. In the presentation, I will explain how these stress modulation influence the crack generation and the application of the modulation of stress distribution.

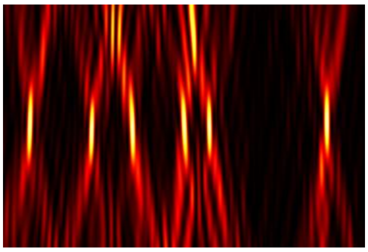

Fig. 1. Intensity distribution of light of laser beams generated by hologramic method in the beam propagation axis.

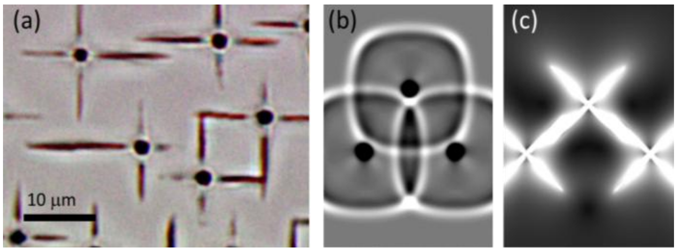

Fig. 2. (a) Cracks generated by focusing fs laser pulses at multiple spots inside single crystalline LiF. (b) Stress distribution of interference of three stress waves. (c) Stress distribution of interference of stress from dislocations.

[1] Hayasaki et al., Applied Physics Letters **87**, 031101 (2005).
[2] Sakakura et al., Optics Letters **36**, 1065 (2011).
[3] Sakakura, OYO BUTSURI **84**, 997 (2015); Sakakura & Namura KOGAKU **49** (2020) To be published.