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Three-dimensional analysis of femtosecond laser ablation in fused silica using dual-view interferometric imaging

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Femtosecond laser processing has been widely used for high-precision micromachining, yet its underlying physical mechanisms are often hard to track and control due to a myriad of coupled electronic, mechanical, and thermal processes that evolve in both space and time. To investigate these processes, interferometric pump-probe imaging [1,2] has proved to be a powerful technique due to its sensitivity to transient refractive-index changes induced by these processes. In our previous work, we had established a quantitative side-view Nomarski interferometer and demonstrated that electron density distributions in laser-induced air plasma were quantitatively reconstructed by using Abel inversion [3]. However, when this approach is applied to laser ablation, side-view imaging can lose information from the near-surface regions because of surface diffraction, although this depth can be comparable to the typical depth of the ablation crater.

In this study, we used a time-resolved dual-view interferometric imaging system to compare the experimentally observed top-view phase images with the top-view images numerically reconstructed from side-view images. Figure 1(a) and (b) respectively show the experimentally measured top-view and side-view phase images. The side-view phase image was analyzed using Abel inversion to reconstruct a cylindrical refractive-index-change distribution. Figure 1(c) shows the three-dimensional distribution reconstructed from the side-view image. The corresponding top-view image, shown in fig. 1(d), was then calculated by numerically propagating a probe wave through the reconstructed distribution using the angular spectrum method. By comparing this predicted image with the experimentally measured top-view image acquired simultaneously, we believe it is possible to evaluate whether the side-view reconstruction can explain the top-view observation and to examine near-surface contributions that may not be fully captured by the side-view analysis.

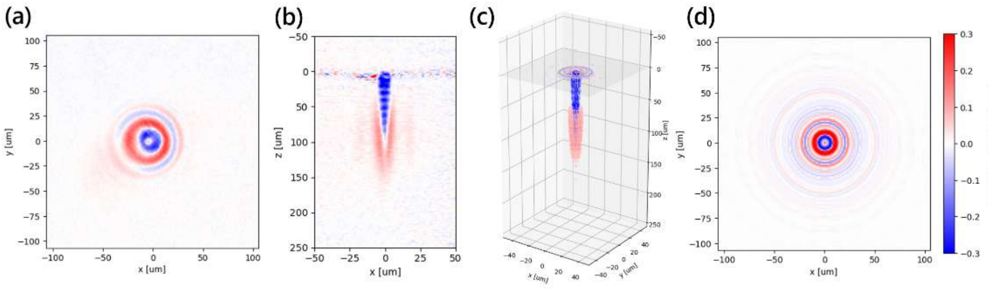

Fig. 1. (a)(b) Measured (a) top-view (b) side-view phase images. (c) 3D phase delay distribution reconstructed from (b) by Abel inversion. (d) A top-view image numerically reconstructed from side-view experimental image.

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