High-precision observation and simulation of femtosecond laser ablation

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Laser processing technology using ultrashort pulsed lasers has many advantages over conventional processing technologies, such as the ability to freely fabricate ultrafine shapes on various difficult-to-process materials, including carbon fiber composite materials and glass, without contact and without the effects of thermal damage. Therefore, improving the controllability of laser processing technology is an important issue for industrial applications. Furthermore, in recent years, microstructure fabrication technology using ultrashort pulsed laser processing has also advanced remarkably, and it has become clear that it can be used to fabricate elements for terahertz light wave control [1,2,3]. However, the mechanism of laser-induced material destruction is still not fully understood due to the complex interplay of physical phenomena on various spatial and temporal scales in non-equilibrium open systems.

As a starting point to address these issues, it is important to clarify the reproducibility of femtosecond laser ablation with high accuracy. To this end, it is necessary to precisely determine the correspondence between the beam profile of the femtosecond laser pulse and the shape of the resulting laser-processed crater. We have developed an original method to measure the beam profile at the laser focus point directly and have succeeded in developing a method called fluence mapping, which provides a one-to-one correspondence between the intensity at each location in the laser spot and the depth of the laser trace by directly comparing it with the measured laser trace geometry (Figure 1)[4]. As a result, extremely high reproducibility and localization in dielectric laser processing were revealed. Furthermore, this has made it possible to match the experimental and simulation conditions of laser ablation with high accuracy. Therefore, we have also succeeded in demonstrating that nonlinear simulations of femtosecond laser propagation in air can predict the radius of the laser-processed scar with extreme accuracy over a wide range of laser intensity [5]. This means that our simulation technique can also be used to predict processing results. Thus, it has become clear that femtosecond laser processing can process materials with high accuracy and reproducibility on the submicron order, and the groundwork is being laid for exploring the mechanism.

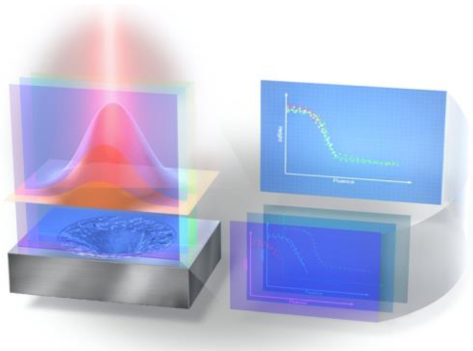

Fig.1 Conceptual diagram of fluence mapping method

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