

Experimental and numerical study of ultrashort pulse laser-induced stress waves from picoseconds to nanoseconds

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Stress waves induced by ultrashort pulse laser play an important role in laser processing such as laser shock peening, which utilizes laser-induced pressure to induce residual stress and modify the mechanical properties of the material. For the further development of the laser processing utilizing laser-induced pressure, it is crucial to understand the stress distribution of the stress waves. However, few studies have experimentally measured the distribution of the waves. K.T. Gahagan *et al.* measured the two-dimensional profile of laser-induced shock waves in picoseconds [1]. To identify the precise stress distribution from hundreds of picoseconds to a few nanoseconds, we measured the displacement distribution on a picosecond scale and constructed a numerical simulation based on the experimentally obtained displacement.

Figure 1 (a) shows a schematic of the displacement measurement. The pump pulses (wavelength: 1030 nm, pulse width: 290 fs, pulse energy: 100 μ J) are focused onto the surface of the Al layer while the probe pulses pass through the Michelson interferometer. The results are shown in Figure 1 (b). Based on the displacement measurement results, the stress wave propagation is numerically calculated using the FEM simulation software “Abaqus/Explicit”. Figure 1 (c) shows the calculated pressure distribution. The three-dimensional pressure distribution of the waves was captured using a time-resolved Mach-Zehnder interferometer [2]. The result is shown in Figure 1 (d). The overall agreement between the numerical results and the experimental measurements demonstrates the effectiveness of the pressure distribution measurement method and validates the accuracy of the simulation model.

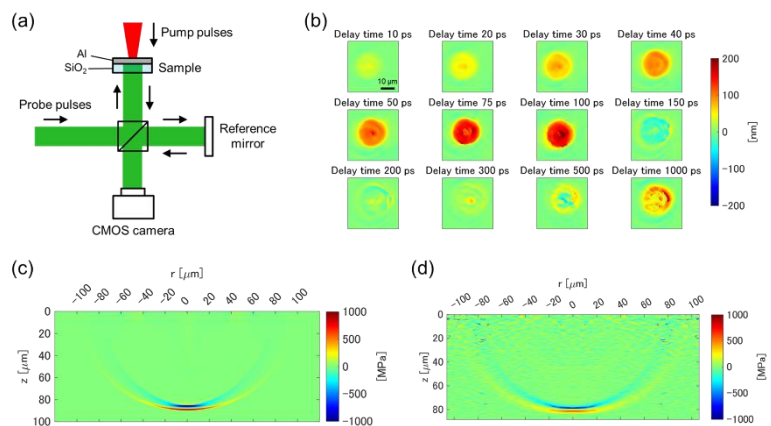


Figure 1: (a) Experimental setup for displacement measurement, (b) displacement distribution of stress waves, (c) numerically calculated pressure distribution ($t = 14.5$ ns), and (d) measured pressure distribution of stress waves ($t = 14.5$ ns).

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References:

- [1] K. T. Gahagan, D. S. Moore, D. J. Funk, J. H. Reho, and R. L. Rabie, *J. Appl. Phys.* 92, 3679–3682 (2002).
- [2] J. Hattori, Y. Ito, D. Veysset, K. Nakagawa, K. Nelson et al., in *Frontiers in Ultrafast Optics: Biomedical, Scientific, and Industrial Applications XXIII* (SPIE, 2023), Vol. 12411, pp. 52–54.