Uniform Shock Generation and Flyer Acceleration by High Power KrF Laser

I. Matsushima, E. Takahashi, Y. Owadano, T. Kadono, M. Yoshida
National Institute of Advanced Industrial Science and Technology, 1-1-4 Umezono, Tsukuba, Ibaragi 3058568, Japan

Abstract
High power lasers are interest tools to investigate the equation of state (EOS) of condensed matters at high pressures. Laser-driven shock can be generated by intense laser irradiation on a solid target. In conventional impact experiments, flyers have been accelerated by explosives or two-stage light-gas guns. High power lasers have possibility to accelerate flyers faster than those methods. A KrF laser is useful for ultra-high pressure research. The short wavelength of the KrF laser (249nm) generates high ablation pressure efficiently. The electron-beam pumped KrF laser amplifiers can supply high output laser energy with long pulse duration. The broad bandwidth of KrF laser takes an important role to improve the target irradiation uniformity of focused laser beam. In laser-driven shock experiments, plane shock waves are desired. In impact experiments, the flyers should be flat to investigate EOS.

We have developed a broadband random phase (BRP) irradiation technique[1,2] as a beam smoothing method for KrF laser. The combination of a broadband laser oscillator with wide beam divergence and a random phase plate (RPP) is effective to make a smoothed irradiation profile in the target. To obtain a flat-top style profile, a Fresnel phase zone plate (PZP) can be used in stead of RPP. With using the PZP, the peak-to-valley nonuniformity of 15% has been achieved with the focal spot diameter of 600µm. For more flexible focused beam profile control, another technique employing image relay is under development.

Plane shockwave generation and uniform target acceleration have been demonstrated with the broadband PZP irradiation of KrF laser system ASHURA[3]. An aluminum plane target with the thickness of 100µm has been irradiated by the laser beam with the energy of 60J and the pulse duration of 12ns (FWHM). The rear surface of the target was observed by a line-imaging optically recording velocity interferometer system (Line-ORVIS) including a streak camera.[4] The shockwave caused by the laser irradiation has reached the rear surface after 16ns from the laser pulse start. The shockwave has reached the rear surface at the same time within the temporal resolution of 2.2ns over the observed spatial area of 450µm. This means the shock created by the laser has been spatially uniform. After the shock arriving, the target has been accelerated uniformly referring to the observed fringe shift. From the measured shock and free surface velocity, the pressure and the density behind the shock front are derived as 12.7GPa and 3.08g/cc respectively. These values correspond to the Hugoniot point calculated from SESAME EOS table.

The uniformly accelerated target will be useful as a flyer in the impact experiments. The flyer should keep its state in a condensed phase for the duration of flight. If the intense short laser pulse is used, there will be a strong shock generated in the flyer. As a result, entropy may increase extremely to the extent of that the flyer will be vaporized. Hence in order to reduce the entropy and temperature increase in the flyer, the longer pulse beam of KrF laser is expected to be suitable.[5]

To extend the EOS study with KrF lasers, faster and massive flyers will be needed. For this purpose, five beams bundle irradiation experiments are under planning. Adequate temporal overlapping of the beams can generate a suitable waveform to accelerate the target effectively. The bundle irradiation increases the total laser energy on targets. A quasi-tailored laser pulse with the energy of 1kJ is expected by the five beams bundle irradiation in Super-ASHURA system.

References

Keyword: KrF laser, shockwave, EOS, uniformity