

The dynamical processes of laser-induced shock wave plasma generation at various surround gas pressures

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Deskripsi Lengkap: <https://lib.ui.ac.id/detail?id=20277883&lokasi=lokal>

Abstrak

ABSTRACT

A comprehensive study has been made on the dynamical process taking place in the laser-plasma generation induced by a TEA CO₂ laser bombardment on metal target and non-metal target from low to high pressures surrounding gas. In the case of metal target, pure zinc plate was used as a target and bombarded with 400 mJ laser pulse energy. Dynamical characterization of plasma expansion and excitation were examined in detail both for target atomic emission (Zn I 481.0 nm) and gas atomic emission (He I 587.6 nm) by using a unique time-resolved spatial distribution measurement and conventional emission spectroscopic detection method. The results

showed that the plasma expands and develops with time. The mechanism of plasma generation can be classified into three cases depending on the surrounding gas pressures; target shock wave plasma in the pressure range between 2 Torr and 20 Torr, coupling shock wave plasma in the pressure range between 50 Torr and 200 Torr and gas breakdown shock wave plasma in the pressure range between 200 Torr and 1 atm. In all cases in the laser-plasma generation under TEA CO₂ laser bombardment on metal target, shock wave process always plays an important role for exciting the target atoms and gas molecules.

In the case of non-metal target, a museum glass was used as a target and bombarded with a 400 mJ laser pulse energy. By using the conventional emission spectroscopic detection method, namely temporally and spatially integrated and time-resolved spatially integrated of plasma emission, it was shown that the plasma mainly consists of target atomic emission. Only weak gas atomic emission intensity could be observed even at 1 atm of surrounding gas pressure. These results indicate that the gas breakdown is not a major process responsible to the plasma formation even at high pressure surrounding gas. Shock wave process was considered as an

important role in this plasma formation. By the use of shadowgraph technique to detect the density jump signal due to the shock wave front involving a He-Ne laser as a probe light, simultaneous detection of the shock wave front and the emission front was successfully implemented. The result showed that at the initial stages of plasma expansion shock wave front and emission front coincide and move together with time. At the later stages of plasma expansion the two fronts become separate with the emission front left behind the shock wave front. These results are completely coinciding with the shock wave plasma model.

Unfortunately, in this experiment we succeeded to detect the density jump signal only for high pressure surrounding gas, above 100 Torr. At the pressures lower than 100 Torr the density jump signal was very weak and it is difficult to distinguish with the noise including in the signal.

The other important experimental results that support the shock wave plasma model were also obtained in this experiment, namely the coincidence of emission lines regardless of their atomic weight and sub-target effect. By using lead glass as a sample, which contains Pb, Si, and Ca, it was confirmed that the emission front of the Pb 1450.8 nm, Si I 288.2 nm and Ca I 422.6 nm almost coincide regardless of their atomic weight. This result also supports the shock wave plasma model because, by the stagnation of the propelling atoms, the front position of the all atoms coincides regardless of its mass. In the case of sub-target effect, we confirmed that plasma

could be produced even for such target if sub-target is set behind the sample. In this case we use a sample as a sub-target and a vinyl tape was attached to the quartz sample as a target. The TEA CO₂ laser bombardment was used at 150 mJ and at 1 atm of air. The main role of the sub-target is to produce a repulsion force for atom gushing with high speed. For shock wave, high speed is necessary condition to compress the gas.

Coincidence of the movement of the shock wave front and the emission front in the initial stages of plasma expansion is a direct proof of the shock wave plasma model. By improving the detection technique of the density jump associated with the shock wave, the correlation between the shock wave front and the emission front was examined in detail. For this purpose rainbow interferometer system, which has higher sensitivity compared with the shadowgraph technique, was used to detect the density jump signal. We succeeded to realize simultaneous detection of shock wave front and emission front from 3 Torr until 1 atm of air when a quartz sample is bombarded with a 600 mJ TEA CO₂ laser. In all pressure that were examined, the shock wave front and the emission front always coincide and move together with time in the initial stages and separate at the later stages with emission front left behind the shock wave front. The coincidence of the shock wave front and emission front and move together with time at the initial stages of plasma expansion was also obtained by using ruby as a sample at 10 Torr and 100 Torr of air as well as with museum glass at the same laser pulse energy.