§58. Laboratory Experiments on the Formation and Recoil Jet Transport of Aerosol by Laser Ablation

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Along with repeated pellet implosions, the interior surface structures of the target chamber of a high-repetition rate inertial fusion reactor are exposed to short pulses of high-energy x-ray, unburned DT-fuel particles, He-ash and pellet debris. As a result, surface materials are subjected to ablation, emitting particles in the plasma state. Ablated plasma particles will either be re-deposited elsewhere on the wall or collide with each other, perhaps in the center-of-symmetry region of the chamber volume. Colliding ablation plasma particles can lead to the formation of molecular clusters to grow into aerosol, possibly floating thereafter, which can then deteriorate the subsequent implosion performance via laser scattering, etc. Clearly, this points to a need for the in-situ removal or displacement of aerosol from the position of ignition. Proposed in the present work is a method of directed transport of aerosol particles by the use of laser ablation-induced jet recoil momenta.

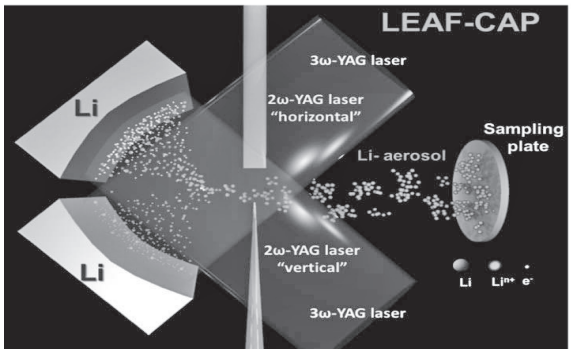

Fig. 1 An artist rendering of the lithium aerosol formation process in the LEAF-CAP setup [1].

Employed in our recent work is a laboratory-scale laser ablation experiment setup, referred to as LEAF-CAP for the Laboratory Experiments for Aerosol Formation by Colliding Ablation Plumes [1]. Used for the primary ablation process in the LEAF-CAP setup is a 1 Joule YAG laser beam (3rd harmonic), which is first split into two equal power beams, both line-focused down to 1cm x 0.01cm, irradiating two arc-shaped targets at 10Hz, each 6ns long, so that the energy density ranges from 3 to 10 J/cm^2/pulse. These two targets are set in vacuum, positioned in such a way that ablation plasma plumes will collide with each other in the center-of-arc (CoA) region, as shown in Fig. 1.

In our recent work, colliding ablation plumes from graphite have been found to generate aerosol in the form of carbon allotropes such as carbon nano-tubes [2], whereas those from metals tend to form aerosol in the form of droplets [3]. In both of these cases, aerosol particles have been observed to flow in the compound velocity direction of the colliding plumes, apparently cancelling the momenta in the counter directions and to be deposited eventually on the sampling plate.

In the present work, the LEAF-CAP setup has been modified with an additional 250m Joule YAG laser beam (2nd harmonic), line-focused in the two directions, i.e. horizontal and vertical, to intersect the flow of aerosol at around 5mm away from the CoA-region at 10Hz, each 8ns long, as illustrated in figure 1. The energy density in this laser beam is set typically at 3.3J/cm^2/pulse. Also, a quartz crystal film thickness monitor is employed, set at the position of the sampling plate, so that the arrival rate of aerosol can be monitored in real-time during the double-action laser ablation process. One can then expect to see a decrease in molecular arrival rate when the redirection of aerosol occurs as a result of the ablation by 2ω-YAG laser irradiation. In parallel with aerosol arrival rate monitoring, visible spectroscopic measurements are conducted, viewing the region where the aerosol flow is intersected by the 2ω-YAG laser beam. In a separate experimental setup, where the film thickness monitor is removed, ion charge collector measurements have also been conducted although results are not presented here.

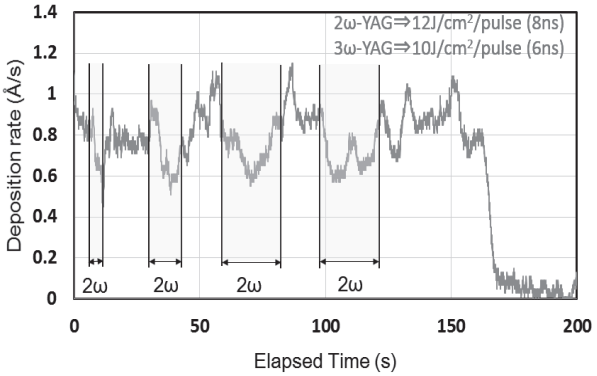

Fig. 2 Lithium aerosol arrival rate data, measured by a quartz crystal film thickness monitor, with and without 2ω-YAG laser beam irradiation, indicated by the yellow-highlighted zones.

In the case of lithium, as shown in Fig. 2, noticeable changes in molecular arrival rate have reproducibly been seen with the irradiation of 2ω-YAG laser beam, even as there is intrinsic fluctuation and/or noise in the arrival rate monitoring signal. In the case of vertically line-focused irradiation, the energy density of 2ω-YAG laser is particularly raised to 12J/cm^2/pulse so as to enhance the effect of ablation-induced jet. In the case of carbon, however, no clear sign of ablation-induced jet effects has been identified in the aerosol arrival rate monitoring data. This may be due to the decomposition of carbon aerosol being rather isotropic or due to the insufficient energy density of 2ω-YAG laser irradiation.

[1] Hirooka, Y. et al., J. Phys. Conf. Ser. **244** (2010) 032033(4pp).
[2] Hirooka, Y. et al., Nucl. Fusion **54**(2014)022003(6pp)
[3] Hirooka, Yoshi et al., Fusion Eng. Des. **87** (2012) 760.