§41. Materials Ablation Effects on the Wall Lifetime and Pellet Implosion Frequency in IFE Power Reactors

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It is widely recognized that along with DT-pellet implosions, IFE reactor chamber wall components will be exposed to short-pulses of 14 MeV neutrons, intense X-rays, high-energy unburned fuel particles and pellet debris such as CD complex ions. As a result, wall materials will be subjected to ablation. This may lead to the formation of aerosol and/or the redeposition (i.e. condensation) of ablation-ejected particles. These processes will directly affect the implosion pulse frequency, i.e. reactor power output, and also the wall lifetime as well for the reason to be mentioned next.

Whether the wall surface material is a solid or liquid, one predicts that, in the chamber periphery region, ablation-ejected particle flows cross over each other, leading to local density maxima, which can then result in the formation of aerosol[1]. In addition, aerosol formation can also take place at the center or on the axis of symmetry of a reactor chamber in the form of sphere or cylinder.

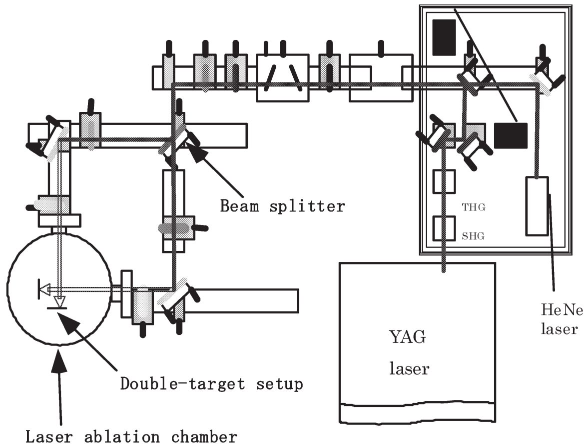
Depending up on the collision condition of ablation-ejected particles, including atoms, ions and clusters, aerosol particles to be formed may grow by coalescence, but can also shrink by disintegration. As such, ablation-ejected particles will interact with one another in a yet-to-be explored manner.

Importantly, the airborne time of these aerosol particles could be orders of magnitude longer, compared with that for direct redeposition. These airborne aerosol particles are likely to absorb or reflect the subsequent laser beams intended for implosion, affecting directly the reactor power output. It follows from these arguments that the pellet implosion frequency must be controlled to avoid the aerosol effects. Despite its critical importance, this technical issue has not yet been clearly addressed in the IFE research community.

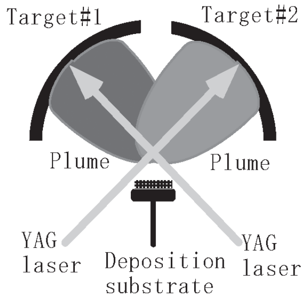
The present work is intended to investigate the materials ablation behavior, including redeposition and aerosol formation. A new experimental setup has been put together for this purpose and is named LEAF-CAP for the Laboratory Experiments on Aerosol Formation by Colliding Ablation Plumes. A schematic diagram of the LEAF-CAP facility is shown in Fig. 1-(a). A ~1J YAG laser (~50ns, 10Hz) is employed as the energy source and is converted into the third harmonic so that the wave length is 355nm at which the energy absorption by materials is more than 80%. This laser beam is optically split into two equal-power beams for the ablation of two arc-shaped targets, i.e. double target setup shown in Fig. 1-(b), with the cross section shaped into a rectangle of about 1mm x 10mm. The power density under these conditions is of the order of $1J/cm^2$, well above the threshold for plume formation via ablation.

Actual plumes generated from Cu targets are shown in Fig. 1-(c). As can be seen, both these plumes are focused due to the target arc shape, and apparently colliding each other at around the focal point. Interestingly, when one of these targets is shielded from laser exposure, the plume has been found to show a much longer tail. The spectroscopic data taken from one such single plume are shown in Fig 3. These are suggestive of some collision effect although the details are unclear at this point.

Future plans include visible spectroscopy of the colliding spot with a new optical setup, and film deposition rate measurements, using a quartz crystal monitor.



(a)



(b)

(c)

Fig. 1 A schematic diagram of the LEAF-CAP facility: (a), the double-target setup: (b), and a photo of colliding plumes from Cu-targets.

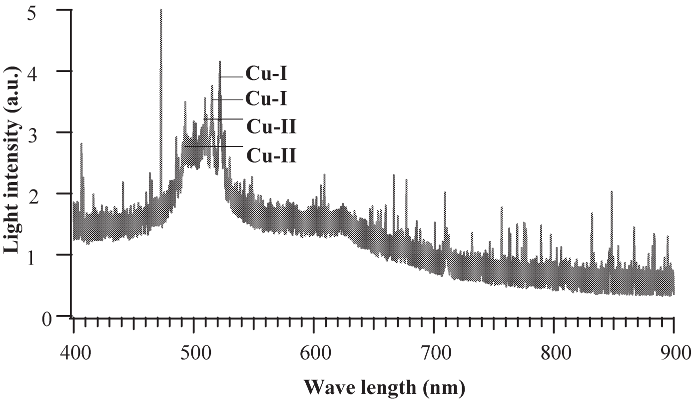


Fig. 2 Visible spectroscopy data of a Cu-plume, indicative of a “green” light consistently with the appearance shown in Fig. 1-(c).