Laser Ablation Characterization in Laboratori Nazionali di Legnaro

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Abstract. Using high power laser focalized into a target material generates plasma and it has the consequence to immediately extract and ionize atoms from the target itself. This process is the starting point to have a simple and compact ion source, usually named Laser Ion Source (LIS). This kind of sources are arising in the scenario of ion sources especially in refractory elements ions production, where the atomization of the material to ionize is the main issue because of its high evaporating temperature. These considerations and the fact that ion sources are becoming nowadays more and more important to several fields of science and technology, open an interesting line of research that our group at Laboratori Nazionali di Legnaro wants to investigate. Experiment involves characterization of produced ions by measuring charge state and amount of ions created. Measurements will be performed with several power densities and varying ions collector distance and potential respect to the target. These simple experiments are the necessary preliminary steps to characterize the system and to start a solid future development onto possible different and effective ways to perform ions sources using laser.

1. Introduction
To fully understand a Laser Ion Source (LIS) \cite{1} \cite{2} behavior it is mandatory to familiarize and to deeply analyze laser ablation processes onto target materials. This is the aim of the new laser setup implemented at Laboratori Nazionali di Legnaro, where we start to study laser ablation processes. A Q-switched Nd:YAG is used to ablate target placed in front of an ions collector inside an high vacuum chamber. Thanks to this simple configuration, inspired by \cite{3}, it will be possible to test the system configuration, the signal and data collecting procedure in order to move a secure first step into this new line of research for our group. This work will synthesize the firsts experiments and results with this simple configuration and it will show possible future steps for the experimental setup and measurements.
2. Experimental setup
The experiment involves several systems and can be resembled in figure 1. A laser beam is focalized onto a target inside a vacuum chamber and a collector, placed in front of the target, collects the ion signal from the expanding plasma plume.

![Figure 1. Simplified experimental setup](image1)

![Figure 2. View of vacuum chamber](image2)

2.1. Laser and focalization system
The used laser is a Quantel YG980 Q-switched Nd:YAG laser system, operating at its fundamental wavelength (1064 nm), capable to deliver up to 2 J energy 10 ns pulses at maximum repetition rate of 10 Hz. Laser beam, entering in the vacuum chamber with an angle between 20 and 45 degrees, is focalized onto the target by a 20 cm focal length lens.

2.2. Vacuum Target Chamber
The vacuum chamber (figure 2) was entirely designed and assembled at LNL. The high vacuum is ensured by a diffusive oil pump (Edwards DIFFSTAK 63/150) capable of 135 liter/sec. The final vacuum value measured after 2 hours pumping is $2.5 \times 10^{-5}$ mbar.

Inside the chamber is placed the target-collector system. Target is made of a Copper plate, electrically isolated by a plastic support. It can be rotated to expose different area to each shot of the laser beam and it can be electrically polarized positive or negative respect to the collector and the chamber by an external high voltage power supply. Distance between plates can be varied from 2 to 5 cm. Signals are collected by electrical connection of the plates directly to the oscilloscope (Tektronix TDS 3034C) channels with 50 Ohm terminations. A 3D section of the chamber is showed in figure 3.

2.3. Data collection
In order to collect data from the system an automatic procedure was implemented using MATLAB® as command interpreter between the PC and the oscilloscope. Data of interest, such as laser pulse duration and plates voltages, are automatically recorded and plotted in the PC monitor for immediate evaluation.

3. Results
We measured several parameters to evaluate laser ablation processes and ions generation. Distance between target and collector plate was fixed to 4.5 cm, polarization voltage between plates and laser pulse energy were variable parameters. Figure 4 shows an example of data
Figure 3. Section view of the chamber and target.

Figure 4. Collector plate signals at different polarization voltages (blue - 40V; red 0V; ocher 80V).

collected representing signals generated by extracted charges at different polarization voltages of the collector plate respect to the target plate. Signals are positive or negative due to the type of particle (ions or electrons) attracted by the plate polarization, peaks analysis are under development. Results are consistent with the existing literature confirming that the apparatus is ready to a more intense measurement campaign. Furthermore these processes could be used for a first evaluation of the produced charge state for ions extracted from the plasma.

The high speed of the material, ions and neutral, expelled by the laser ablation process combined to the reduced distance between the target and the collector, does not allow an easy analysis of the charges expelled. Furthermore the absence of some kind of suppressor system on the collector side, allows generation of secondary emission electron even from the neutrals atoms impinging on the plate.

4. Future Developments
As described in the previous section, the distance between the plates is the main illness of this kind of experimental setup. Since the obvious solution is to increase the plates distance, we decided to develop a new setup, including a 1.5 m home made Time of Flight mass spectrometer. In this solution the increased distance between the plates is used to perform a powerful analysis instrument capable to obtain information on the ions charge state production and distribution. Works are in progress using PROE® to design the mechanical setup (figure 5) and SIMION® to study ions trajectories (figure 6) and to define plates voltages.

5. Conclusions
Experiments of ions generation by laser plasma were performed in LNL. An easy setup composed by a target-collector system was assembled to start studies on plasma characterization and observed results are consistent with the existing literature. Future developments, involving the assembly of an home made Time of Flight mass spectrometer, are planned to better characterize these processes of ions formation in term of charge state distributions and efficiency of the generation process.
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