

Development of a resistive target heating system for laser-acceleration of heavy ions

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The acceleration of ions with ultra-intense lasers is a fast developing research field of the recent years. Especially the generation of intense, high quality beams with energies up to 60 MeV has a wide range of applications due to the unique beam properties, such as radiography and isochoric heating. These protons are generated in a process which is called Target Normal Sheath Acceleration (TNSA) [1]. Hot electrons, which are produced in the relativistic laser plasma interaction, propagate through the target. When the first electrons reach the rear side and escape, the remaining positive charge leads to an electrostatic field, which confines the other electrons. In this electron sheath a high electrostatic field in the order of 10^{12} V/m is created, which immediately ionises the atoms due to field ionisation. Normally, there are impurities on the target surface, such as water or oil, which contain hydrogen and other atoms beside the target material. The ions and protons are accelerated in the electric field, where protons are accelerated the most due to their charge over mass ratio. As the protons are running in front of the other ions species, they are shielding the electric field from these ions. Therefore, independent of the target material, one always gets energetic protons and less energetic ions.

For the acceleration of heavy ions it is necessary to remove the hydrogen containing contaminations on the target surface. In this case it is possible to get energetic ions. This has been proven for light ions, such as flourine and carbon. Thereby energies up to 5 MeV/u have been measured [2]. The acceleration of heavy ions is not only important for practical applications, it gives also information about the strength of the accelerating field, as the appearance or absence of a charge state gives limits for the electric field.

For reproducible acceleration of heavy ions and well defined experimental conditions it is important to remove the hydrogen reliably. One possibility, which reaches this conditions is the resistive heating of the target to more than 1000°C for several minutes. All hydrogen containing materials either evaporate at this temperature or crack up. A critical issue of the heating system and the targets is, that they have to survive these high temperatures for a certain time without evaporating the bulk material into vacuum chamber.

To realize such a target heating system thin tungsten targets, which are coated with thin layers of other material, such as carbon or CaF₂, are used. Of course, this material has to have a melting point, which is high enough to survive the heating.

The tungsten target itself is a strip with a typical thickness of 10µm-50µm and a width of 1 mm. This strip then is clamped with the electrical connectors onto an insulator plate.

To prevent the evaporation of material during the heating of the target, we used only ceramics as insulator, stainless steel and copper. No part of the device is glued. The cables, which deliver the current to the target, have to be without insulation on the last centimeters.

The target is heated typically with around 20 W, which leads to a bright white glowing target. Due to the low resistance of the target a current of 10-20 A is necessary. To remove the hydrogen a heating time of 3 minutes is sufficient. If required by the experimental conditions the heating time can be much longer. Times of two hours without destruction or failures of the system have been demonstrated.

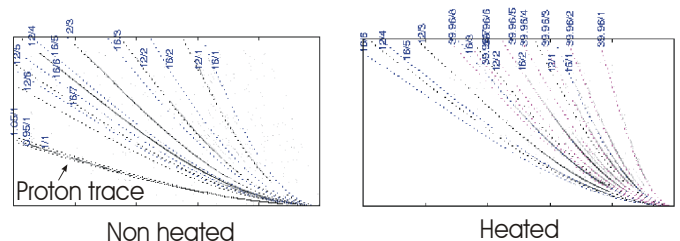


Fig. 1: Results from Thomson parabolas demonstrating the successful removing of the protons

The elimination of the hydrogen by the heating system is very efficient. Fig. 1 shows the traces of different ion species in the Thomson parabola for a heated and an unheated target. With heating no protons can be seen in the figure 1. Instead the intensities and energies of the heavier ions are increased significantly.

On addition to the removal of the hydrogen it is also planned to eliminate other impurities like oxygen and carbon, which can not be evaporated due to their high melting point. In this case a laser of low intensity is used to ablate these materials from the surface directly before (some µs) the experiment.

For applications it will be necessary to run the heating system at a high repetition rate as this lasers will work with a continuous target which is moving at a high speed. Target heating in the described way is not possible for this setup. In this case heating with microwaves is proposed, which could heat the target without electric connectors.

References

- [1] S. C. Wilks et al., *Phys. Plasma* **8**,542 (2001)
- [2] M. Hegelich et al., *Phys. Rev. Lett.*, **89**, 085002 (2002)