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Production and acceleration of protons by Titanium Hydride solid disks via excimer laser ablation

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ABSTRACT

In this work we present the preliminary investigations about the production of proton beams by pulsed laser ablation of solid disks produced by compressed Titanium Hydride (TiH) powder. The laser we used was an excimer KrF, operating at low intensity and *ns* pulse duration. The ion emission was analyzed by the time-of-flight technique using a Faraday cup as ion collector. We performed initial studies on the produced plasma for different laser fluence values. In free expansion mode we obtained protons and titanium ions having kinetic energy of some hundred of eV; by applying a post-accelerating voltage we analyzed the beams up to 15 keV.

1. Introduction

In the last years, new techniques to produce proton beams made use of the interaction between high power femtosecond laser pulses and thin metallic foils [1]. In contrast with other techniques, these give the advantage of obtaining highly collimated and energetic protons beams *from the rear* of the target surface, but require laser systems that, at the time of writing, are not easy to setup. Depending on the laser parameters, two mechanisms seems to be responsible of this behaviour: Target Normal Sheath Acceleration (TNSA) [2] and Radiation Pressure Acceleration (RPA) [3]. Despite of the high quality beams obtained through TNSA and RPA systems, well known techniques, such as pulsed laser ablation (PLA), still play a fundamental role for applications, since the former have extremely high total costs of ownership.

It is widely known that the use of the PLA technique allows to easily obtain ions from thick solid targets, whose energy can be easily increased by post acceleration [4,5]. Today it is possible to rapidly arrange laser beams at intensities of the order of 10^8 W/cm^2 and ns pulse duration that, interacting with solid matter in vacuum, produces hot plasmas [6] at high temperatures and densities, of the order of tens of eV and 10^{17} electrons/cm^3 [7]. Thermal interactions, adiabatic expansion in vacuum and Coulomb interactions are responsible for the primary ions acceleration in plasma. By applying post acceleration, it is possible to extract specific charged particles. This idea can be applied to plasmas of moderate density owing to their low electric conductivity. The percentage of ionized material obtained in Laser Ion Sources (LIS) is not very high, with respect to the total ablated material, but sufficient to get ion beams of high intensity.

Nowadays, ion beams of moderate energy have a wide range of applications, from scientific to industrial ones. In this work, we present the preliminary results of a LIS performed for ions acceleration. The resulting protons beams could be utilized in various fields, for example as injector for hadrontherapy applications [8].

Bearing in mind these considerations, we developed a simple but powerful ion accelerator. In our homemade device we used an excimer laser to get PLA by compressed disks of TiH powder and a vacuum chamber that we used to generate and study the relative plasma production. By using a suitable Faraday cup, mounted in front of the target, we characterized the collected beams.

2. Materials and methods

We used a Compex 205 KrF excimer laser operating at $\lambda = 248$ nm, $\tau = 23$ ns and maximum energy of 600 mJ. By applying a 15 cm focal distance lens, a power irradiance of the order of 10^8 W/cm^2 was obtained on a solid target mounted in a vacuum device at a pressure of 10^{-6} mbar.

The vacuum device consists of a plasma generation chamber (GC) and a removable expansion chamber (EC), which allows an initial free expansion of the plasma before the ion extraction gap, as shown in Fig. 1. The target support (*T*) was mounted on the GC by an insulating flange (IF) and kept at an high positive voltage, up to +15 kV in DC mode. Four 1 nF capacitors were connected between the IF and the GC to stabilize the accelerating voltage during the fast ions extraction phase. The EC is an almost hermetic cylinder of a length (21.1 cm) sufficient to decrease plasma density. The EC

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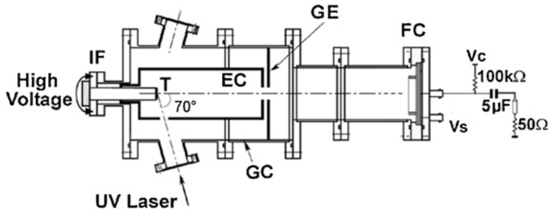

Fig. 1. Sketch of the experimental setup.

was indispensable to avoid arcs versus ground. Moreover, the EC has an extremity (the one opposite to the target holder) drilled with a 1.5 cm diameter hole, necessary for ion extraction from the plasma plume.

A grounded electrode (GE), placed in front of the EC, allows to generate an intense electric field. At the right end of the apparatus, there is a Faraday cup (FC, with a diameter of 7.7 cm) in order to collect and record the ion beams signals by a fast LeCroy WaveSurfer 422 200 MHz oscilloscope, connected to the FC through a 50 Ω characteristic impedance cable. The total fly length available for ions, from the target surface to the FC, is 28.0 cm.

The target used in this work were solid disks obtained by compression of TiH powder. The compression was made at a pressure of 5 atm. The choice of this particular type of target is justified from the fact that hydrogenated materials are generally good sources of protons and heavy ions; moreover, TiH powder is relatively cheap and widely available on the international market. Additionally, it could also have an high level of purity, that in our case is reported to be of 99%.

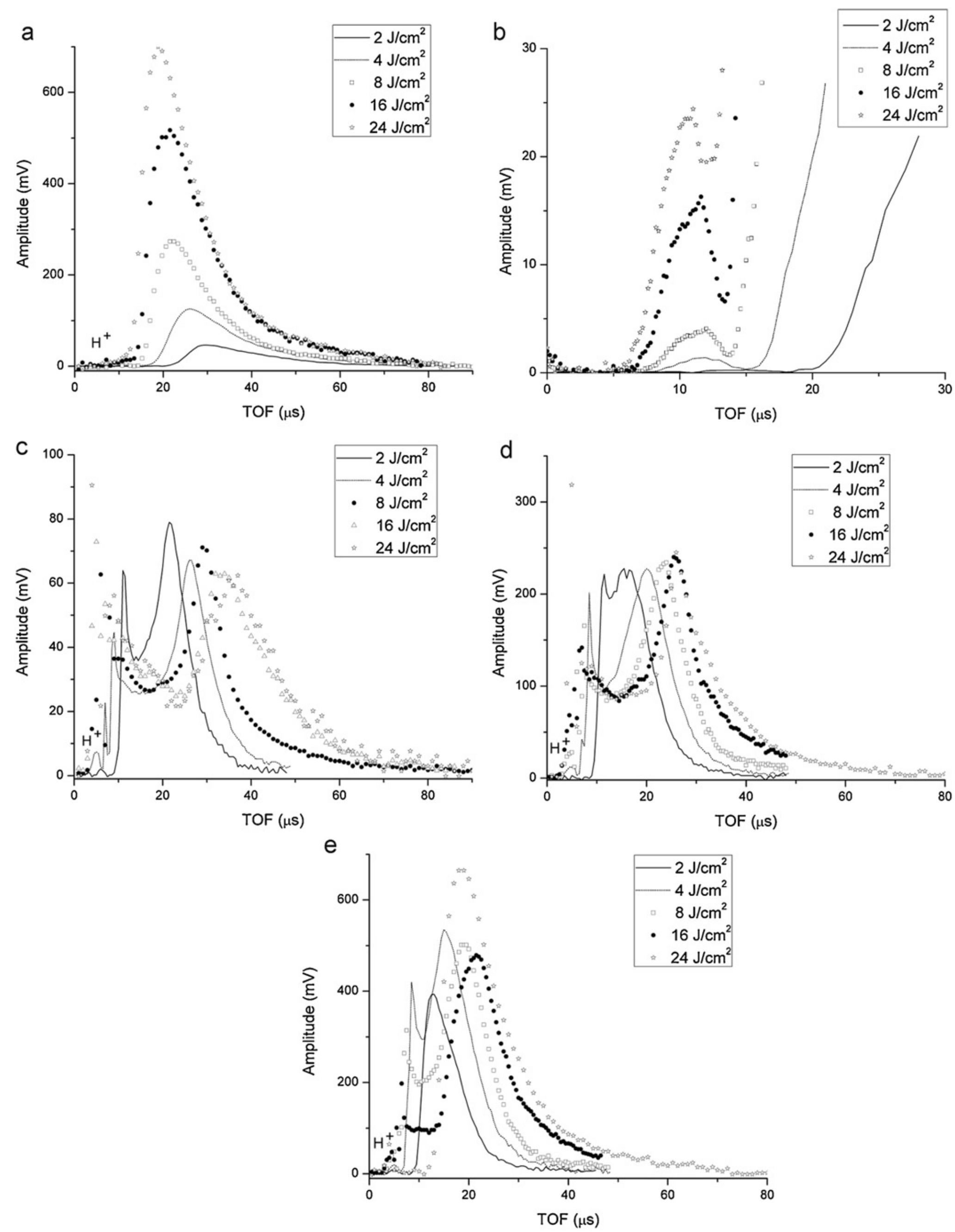

Fig. 2. Typical ions signal obtained by FC in free expansion (a,b) and under an accelerating voltage of 5 kV (c), 10 kV (d) and 15 kV (e).