A xy microstrip device, as 'focal' plane detector of a Thomson spectrometer, for plasma-laser characterization.

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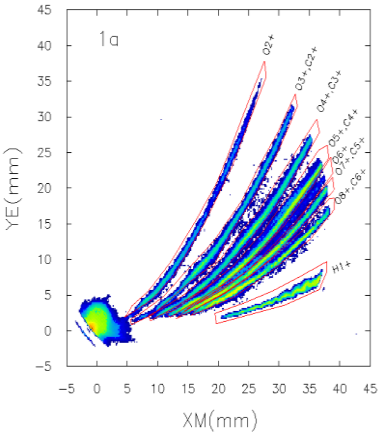
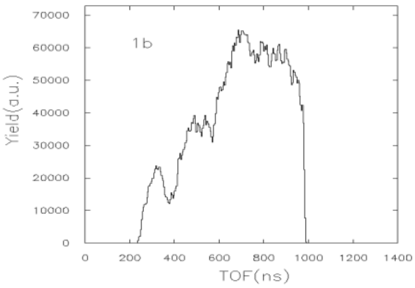
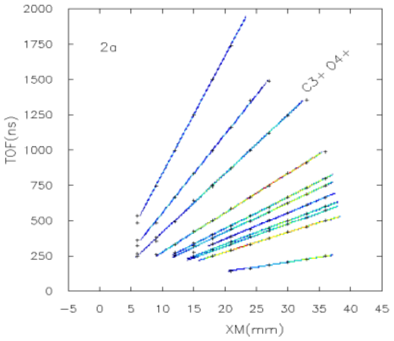
Abstract.

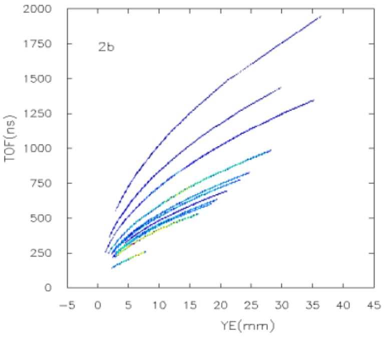
Fast ions emission from a laser ablated target is today object of great interests in non-equilibrium plasma physics, because of many possible applications (Radiography, Hadron-Therapy, Fast Ignition, Ion Implantation, Lithography…). To determine the energy spectra of identified charge/mass ion streams, magnetic spectrometers, as Thomson parabola, are generally employed, followed by MCP + phosphor screen + CCD setup, or solid track detectors and digital microscopy analysis, for detection and readout processes. In this contribution we plan to substitute the above-cited devices with a 2D-array micro strip ion collector system, which is positioned in xy detection plane. For a given strip couple, the x and/or y values, joint with the time of flight measurements, will determine the mass/charge identification and portions of energy spectra. Each ion collector is about 1100 times more sensitive than a conventional one[1]. Results are presented and discussed.

Fast ions emission from a laser ablated target is today object of great interests in non-equilibrium plasma physics, because of the fundamental aspects involved in, and of many possible groundbreaking applications, i.e. Radiography, Hadron-Therapy, Fast Ignition, Ion Implantation, Lithography.. To determine the energy spectra of identified mass/charge (m/q) ion streams, magnetic spectrometers, as Thomson parabola, are generally employed, followed by MCP + phosphor screen + CCD setup [2], for detection and readout processes. These systems are generally very sensitive, but rather complex to manage and in getting spectrum characteristics (ion identification, energy and yield). In addition, the time of flight parameter is not employed to get physics information. Alternatively, off-line techniques based on solid track detectors, as CR39 and digital microscopy analysis are often employed. The lastly cited, although allowing accurate identification of (m/q) species and characterization of ion spectra, does not permit on-line control of experimental results and needs of a laborious microscopic analysis. Fujifilm imaging plates are worthy of mention, because of their high sensitivity and the possible re-use [2]. In this contribution an alternative device, which uses a double array (x, y) of micro-strips, with function of ion collectors (IC), located at detection plane of a Thomson parabola spectrometer (TPS), is sampling the time of flight spectra (TOF) at the given positions x (and/or y) of micro-strips. Because of beam limitation introduced by pinhole at entrance of TPS, a very high sensitivity to each ion collector strip is needed. Such sensitivity can be obtained by means of a specific, amplifier based, IC device with Gain $\cong 10^3$ [1], or by a MCP setup. Due to magnetic and electrical ion displacements inside the spectrometer, the ‘ensemble’ of sampled TOF spectra will determine the energies and the (m/q) identification parameter of ions related to magnetic e/o electric deflection as defined by the xy micro-strip positions. Although the present approach is substantially different from that of reference [3], we notice that in last paper the TOF parameter is also employed. To show the feasibility of the project we refer to the specific plasma-laser conditions of experiment performed by our research group, May 2011, in Prague PALS Laboratory. The iodine laser, operating at 1315 nm fundamental harmonics and 300 ps FWHM pulse length, has been employed to irradiate thin hydrogenated target targets placed in vacuum at intensities on the order of 10^{16} W/cm^2.To investigate proton and ion emission in the forward and backward directions, ion collectors and semiconductor detectors in TOF technique have been used. A TPS [2], put in forward direction 1.2m far from the target, was employed to obtain (m/q) ion identification and energy distributions. Deflecting voltage potential up to 3kV and magnetic fields up to 0.2 T have been used. Two pin holes,1mm and 100 μm in diameter ,respectively, were put to the entrance of TPS to collimate the incident ions. At a distance of 0.165cm from the spectrometer exit, at 90° to beam direction a MCP system, followed by a phosphor screen and CCD camera, was axially positioned to read-out and record the parabolic traces produced by ion trajectories. Figure 1a shows the image of parabolas obtained by irradiating with laser at 290J, 438nm third harmonics, a mylar target, 1.9 μm thick. In this run the TPS has been operated with 0.1 T magnetic field and 3kV voltage potential. The CCD file has been read by ImageJ [4] and converted in intensity by RGB conversion code; then the PAW [5] code has

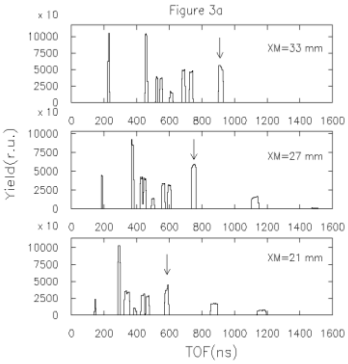




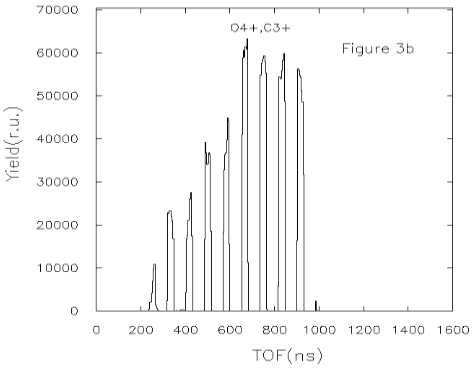




been used to display results. Labels indicate the ion species assigned by means of simulations. The groups of events have been selected by graphical ‘cuts’. In Figure 1b the yield distribution, assigned to the C^{3+} and O^{4+} contributions, is shown. Simulations of parabolic traces left by ions on detection plane of the TPS have been performed following, step by step, the time evolution of ion trajectories. Constant magnetic and electric fields have been assumed, both in the same direction and normally to incident beam direction (defined by central position of target and pin hole). Ions of C^{1+} to C^{6+}, O^{1+} to $C^{8+}$and H^{1+} have been considered for calculations, for energies ranging from few tens of keV to several MeV. Let us to assume an orthogonal reference system with the origin in target center position and Z-axis along the incident ion direction; the magnetic field, B, and the electric field, E, both taken along the X axis. As shown in Figure 2a, the TOF (total flight distance 153cm from target to detection plane) in function of magnetic displacement YM, has linear behavior with slope which depends on ion parameter (m/q). Similarly in Figure 2b, the TOF v/s the electric displacement, YE, shows a parabolic shaping with a coefficient which also is depending on same parameter. Because of these properties (which are expected from the basic equations of non-relativistic ion motion in the magnetic and electric fields), it is possible to get ion identification by means of TOF-XM, and/or TOF-YE measurements. The TOF measurements can be performed by assuming the laser shot laser signal as start and ion collection micro-strip signal as stop; the XM, or the YE displacements are given directly by the given micro-strip XM or YE positions. Each micro-strip array is consisted by 16 micro-strips, with dimensions of 1mmx50mm and 2mm spacing. Association of physical event parameters (xM, yE, Yield) extracted from primary CCD data by ‘cuts’ selection, and computed parameters (XM,YE,TOF, Energy, etc.) can be performed by standard procedures of PAW; so a new nt-ple of events characterized by xM, yE, Yield and XM or YE,TOF, m, q, Energy, etc., can be processed. Considering measurements based on magnetic XM displacements, each micro-strip will sample events (shown in Figure 1a) for TOF values which depend on the given micro-strip position. Figure 3a reports TOF



calculations for some XM positioning. As it can see, each ion distribution is sampled with TOF values which are varying with the XM location. When we consider the expected ‘results’ by the 16 strips TOF measurements, we obtain points, reported in Figure 2a with cross symbol, which follow the corresponding lines of (m/q) parameter. Then, on each TOF spectrum it is possible to recognize the contribution due to various ion species. By regrouping contributions produced by the same species from the 16 strips, the TOF spectrum sampled to some specific portion is obtained for the identified ion species. Figure 3b shows the expected ‘sampled ‘spectrum for ions O^{4+} and C^{3+} which is in agreement with spectrum reported in figure 1b.



As a conclusion, in this contribution a new method to obtain identification of ion species and TOF spectra related to the sampled portions, is outlined. The simulations have been performed by simple analytical procedure, by assuming constant and sharp cut-off magnetic and electric field contributions. We did not take into account the effect of time resolution in TOF calculations, neither the opening distribution nor source dimensions on incident ion paths. However, to show the feasibility of the method, an actual experimental case has been taken as starting point in our speculations. So, we believe, the outlined method is leading to rather realistic predictions. Further investigations both by simulations, including the above cited contributions and setup TOF-resolution, and by experimental measurements, are needed to show in a more complete way the sensitivity of the method.

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[4] ImageJ-Open Source:Java source code.

[5] PAW-Physics Analysis Workstation.CERN-program library-2002; http://paw.web.cern.ch/paw/.