MULTI-STRIP CURRENT MONITOR FOR PULSED LASER PLASMA DIAGNOSTICS

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Abstract

A compact position-sensitive beam instrumentation devise is under development. The beam detection area of this devise is composed of multi-strip electrodes. Their signals are scanned by multiplexers, which reduces the number of read-out lines and feed-through connectors. Combined with an electrostatic deflector and the multi-strip electrodes, this monitor can be identify charge to mass ratios of particles. A prototype of this monitor is fabricated for measurement of ion distribution and charge states in laser induced plasma. This model has fifteen strip electrodes and the multiplexed signal and the clock signal are read out through two coaxial cables. Thus, only three cables are needed including a +5 V power supply line. The first test result is described in this paper.

INTRODUCTION

Highly charged high current ion beam production and acceleration with laser are studied for several years [1]. Direct plasma injection scheme [2,3] is most promising scheme for capturing and accelerating intense heavy ion beams.

High power (more than 10^{12} W/cm^{-2} power density) laser irradiation on the solid target induces laser ablation plasma. The plasma contains a stream of high brightness highly charged ion flux. By extracting the ions from the plasma, intense ion beam can be easily provided. In the conventional laser ion source, however, once high intensity ion beam is extracted, the beam quality is deteriorated by its own space charge. Due to severe non-linear force of the space charge, the emittance of the extracted beam grows immediately. The DPIS was developed to mitigate the problem of the strong space charge effect. The ablation plasma is created in a high voltage region and is transferred to an RFQ with its initial expanding velocity. At the entrance of the RFQ, the ions contained in the plasma are extracted from a nozzle, which is connected to the high voltage region. Then the beam is captured by the RFQ electric field, and is accelerated efficiently. The ion beam is not exposed by the strong space charge effect in the LEBT (low energy beam transport) line (see also Fig. 1).

The acceleration of relatively light ion nucleus (such as carbon, aluminum, iron) with DPIS already demonstrated. In the next step, to accelerate heavier species like silver, gold, bismuth and uranium is under consideration. That requires newly designed vane for DPIS heavy ion acceleration. For designing of new vane, measurement of ion condition in laser plasma is a critical issue.

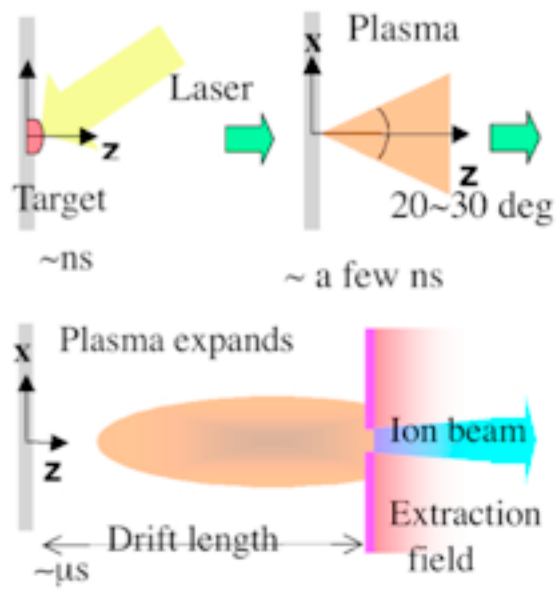

Figure 1: Image of DPIS (Direct Plasma Injection Scheme)

LASER PLASMA ANALYSER

The information of plasma mainly required for designing of RFQ vane is spatial and charge state distribution of ions. To measure them, faraday cup and electrostatic charge to mass ratio analyzer are needed. Usually, such analyzers are not handy for trial experiment to search optimum laser irradiation conditions.

Therefore, a compact laser plasma analyzer is under development. The image of our laser plasma analyzer is shown in Fig. 2 (a). In our analyzer, slit electrostatic deflector electrodes and detection area is aligned from upstream. Detection area is position-sensitive and composed of multi-strip electrodes. The signals of those electrodes are scanned by multiplexers driven by 32 MHz clock (see Fig. 2 (b)), which reduces the number of read-out lines and feed-through connectors on vacuum chamber. Such multiplexed signals can easily be recorded by digital oscilloscopes. The multiplexing read-out circuit diagram is shown in Fig. 2 (c). Combining deflected angle and ToF information, this monitor can identify charge to mass ratios of particles.

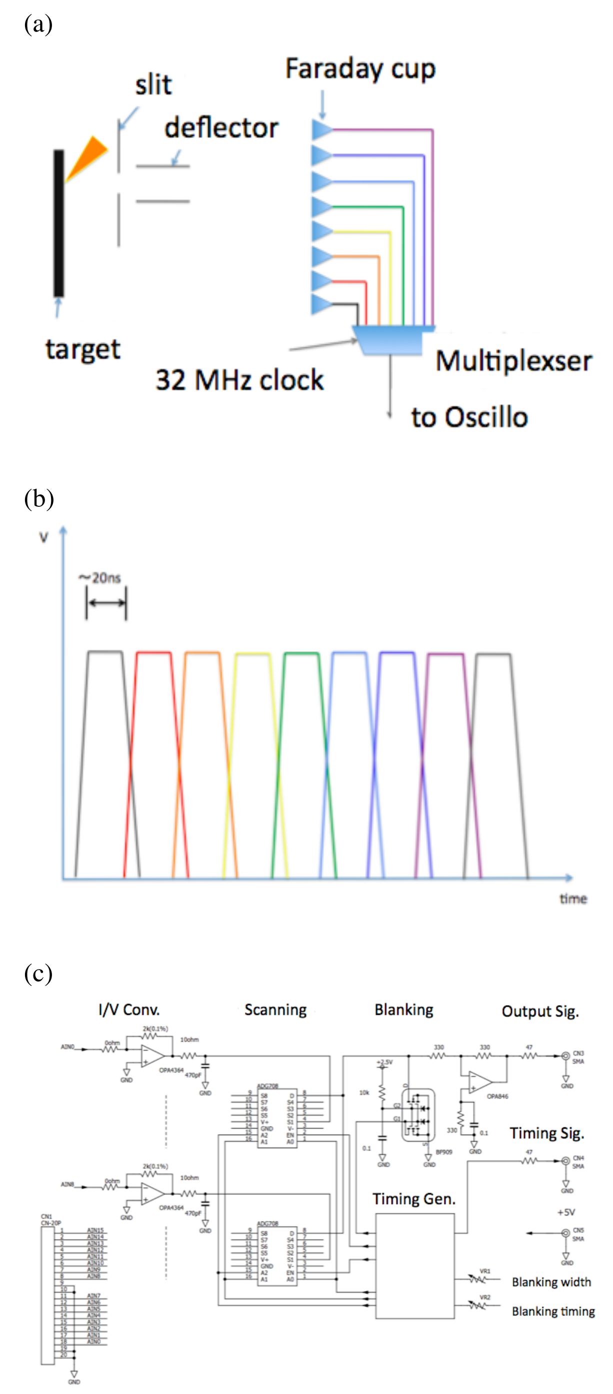

Figure 2: (a) a concept of our detector. (b) an image of multiplexing (the colors correspond to the line colors in (a)). (c) the diagram of multiplexing readout circuit.

TEST MODEL

For evaluation of our detector concept, a test model is fabricated. This model has fifteen strip electrodes. Each strip has 2mm width and 30 mm length. The electrodes are arranged at 1 mm interval (see Fig. 3 (a)). The picture of test model is shown in Fig. 3 (b). The multiplexed signal and the clock signal are read out through two coaxial cables. Thus only three cables are needed including a +5 V power supply line. The configuration of the deflecting electrodes is designed with Poisson. The applied deflecting electrodes shape and equipotential lines are shown in Fig. 3 (c). The calculated trajectory of carbon ion (200 eV kinetic energy and +1 charge state) is also shown in this Figure.

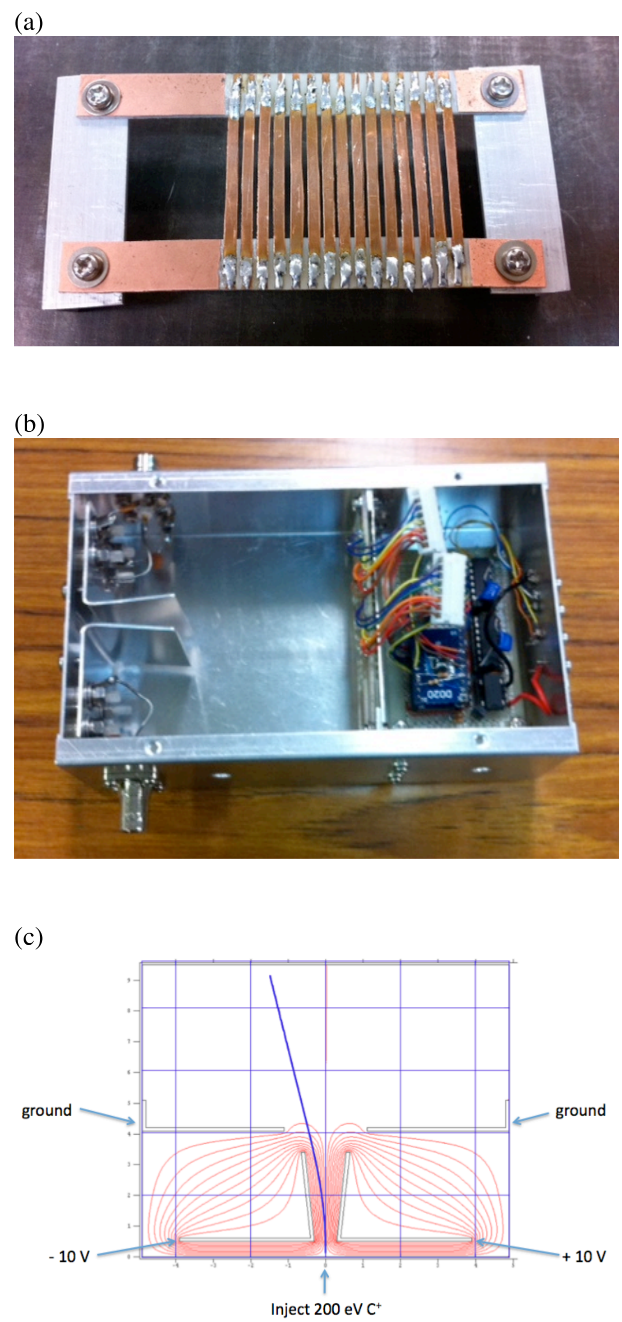

Figure 3: (a) multi-strip electrodes. (b) a picture of test model. (c) a deflector shape and the calculated orbit of 200 eV carbon (1+) ion deflected by electric field (deflecting electrode voltage is +- 10 V).

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TEST EXPERIMENT

As test study, we measure laser plasma induced from carbon target. Figure 4 is the picture of the test experiment. Before the test experiment, the ToF spectrum of ions is measured by a conventional Faraday cup as a reference. The measured spectrum is shown in Fig. 5. In this figure, a prominent peak is rising from ~2 μs. The measured ToF spectrum of our detector is shown in Fig. 6. Figure 6 (a) is the acquired spectrum when the deflectors are off. Figure 6 (b) is the one when the deflectors are on (deflecting voltage are +-10 V). Comparing these cases, some difference is seen. However, the acquired peaks start rising from about 10 μs. This is not consistent with the result from the conventional Faraday cup. This difference is supposed to be due to that deflecting electric field is not sufficient against dense laser plasma for particle separation.

To improve this condition, electron suppressor is planned to be installed. Because electron energy is very low in plasma, a permanent dipole magnet will be applied as the suppressor.

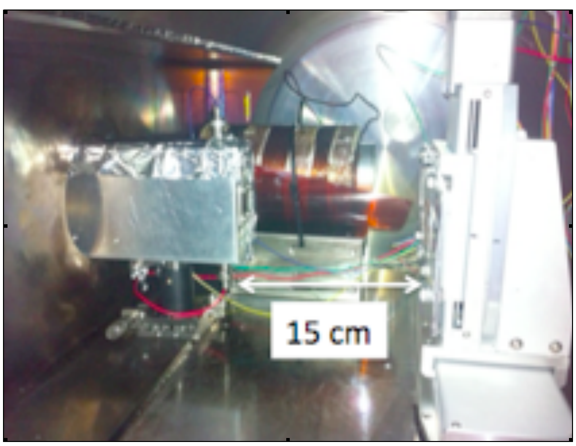

Figure 4: the detector and target layout in test experiment. The Left metal box is the test model of our detector, and right one is a target holder.

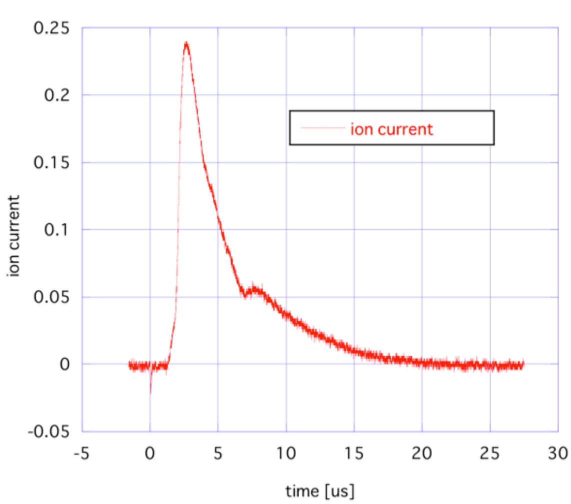

Figure 5: The ToF spectrum at detector position measured by a conventional Faraday cup in advance.

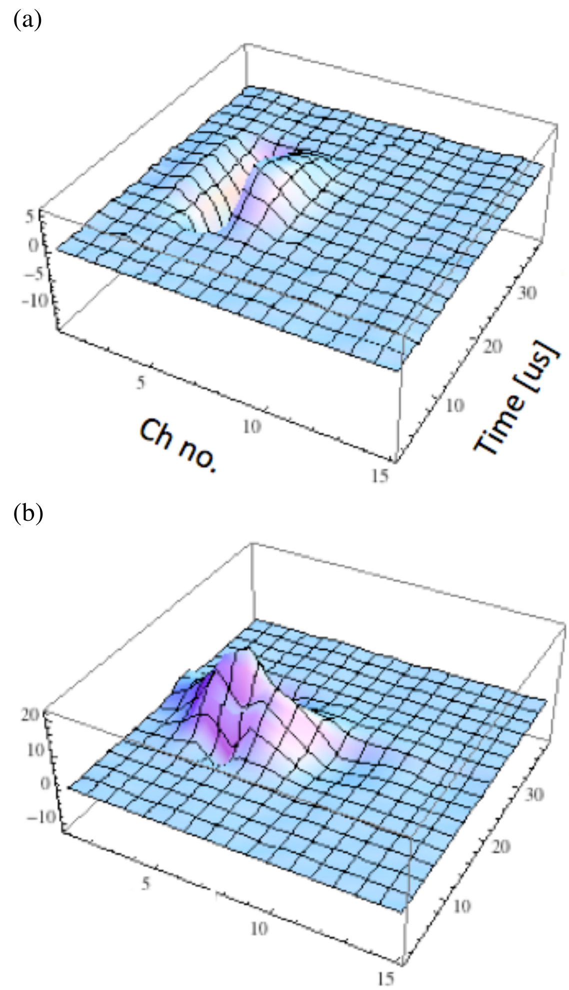

Figure 6: Measured date by our test model. (a): deflectors are off. (b): deflectors are on (+- 10 V)

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