TEMPERATURE MEASUREMENTS OF CARBON STRIPPER FOIL BY PULESD 650KEV H- ION BEAM*.

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Abstract

Thick carbon foils (>300 mg/cm^2)has been used for stripping of H$^-$ ion beam into protons at the injection stage of the 3GeV Rapid Cycling Synchrotron (3GeV-RCS) in J-PARC. The carbon stripper foils with high durability at high temperature >1800 ºK are strongly required. A new irradiation system for foils is in progress using the KEK 650keV Cockcroft-Walton accelerator which can simulate the high-energy deposition upon foils in the RCS. The most important factor that affects the foil lifetime is the foil temperature. We are developing the measuring method of the temperature using a photo-transistor when a foil is irradiated by the short pulses with several tens ~ several hundreds microsecond durations. Preliminary results are described in this report.

INTRODUCTION

The Japan-Proton Accelerator Research Complexes (J-PARC)requires thick carbon stripper foils (250-500 μ g/cm^2) to strip electrons from the H$_-$ beam supplied by the linac before injection into the RCS (Rapid Cycling Synchrotron). The 200 MeV H$^-$ beam from the linac has a pulse length of 0.5 ms with a repetition rate of 25 Hz and an average beam current of 335 μ A. For this high energy and high-intensity beam, conventional carbon stripper foils will break in a very short time and even a diamond foil will be ruptured at around 1800 ºK by the MW class accelerator.

We have been developing carbon stripper foils of 350 μ g/cm^2 by means of both the controlled DC and AC/DC arc-discharge method. Recently, we have successfully developed hybrid type thick boron doped carbon stripper foils, which showed a drastic improvement with respect to not only the lifetime, but also the thickness reduction and shrinkage at high temperature during long beam irradiation[1],[2]. For this purpose, an irradiation system has been developed for the lifetime test with 650 keV negative hydrogen beams (H$^-$) of dc and pulsed operation[3],[4].

Although several calculated results have been reported on the foil temperature[5][6][7], no experimental result of time structure of temperature is reported. The new photo-detector is installed in this irradiation system to observe the time structure of beam spot.

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H$^-$ ION SOURCE

There are two set of 750keV H- pre-injectors in the KEK-12GeV proton synchrotron. After shutdown of12GeV-PS in 2006, an irradiation system was installed in the low energy beam line of the second 750keV pre-injector. The 750keVpre-injector consists of a high voltage generator, a high voltage terminal and an accelerating column. The parameters of the 750keV Cockcroft-Walton accelerator are shown in Table1. The high voltage generator is one of the Cockcroft-Walton type which can generate dc voltage of 800kV(max.) The nominal maximum output voltage of the high voltage generator is -800kV, but the actual maximum voltage of the accelerating column is -720kV. A beam energy of 650 keV is selected during the irradiation experiment to keep a stable dc beam.

A high current multi-cusp negative hydrogen ion source is installed in the accelerating column of the KEK 650keV pre-injector. This ion source is based on the surface-production mechanism. A converter electrode isinserted in the central part of plasma chamber of ionsource. The high current of negative ions are produced at the surface of the converter electrode, which is coated with some metal vapor of cesium, and are extracted from an anode hole of the ion source.

Table 1: Parameters of the 650keV pre-injector

HVT voltage (Acc. Voltage)	-640~-650kV
Beam energy at beam irradiation	640~650keV
Accelerated particle	H$^-$ ions
Type of ion source	Multi-cusp surface H-
Beam current (pulsed mode)	30mA/peak (20-25Hz, 0.2-0.3msec)
Beam current (dc mode)	0.1~0.3mA/dc

EXPERIMENTAL SETUP

Figure 1 shows a target chamber which is placed in the 650keV energy beam line. A movable multiple target folder is installed in this target chamber, and four target flames are mountable on the target folder.

The H$^-$ ion beam irradiation for several carbon foils were performed by dc and pulsed beam. The temperature of beam spot on the carbon foil was measured by an optical pyrometer (with red color filter: λ=0.65μm). In dc beam mode, the irradiated beam currents were 40~280 μA. The maximum temperature at the beam spot of 2-3 mm diameter is 2300 ºK at most.

By the pulsed mode, the maximum irradiated beam has a peak current of about 7 mA (witdh:0.3msec, Repetition rate:25Hz). The average temperature of about 1400 ºK was measured by optical pyrometer during the pulsed mode irradiation. A photo-detector with a photo transistor circuit is installed in target chamber to observe the time structure of light from the beam spot.

An electric circuit of photo-detector with a photo transistor is shown in figure 2. A large non-linear signal output is expected from the relationship between the temperature and the intensity of thermal radiation.

EXPERIMENTAL RESULTS

During pulsed beam irradiation, It was observed that brightness changed by time to time. Figure 3(a) corresponds a video image scan with a beam pulse, and figure 3(b) corresponds off-phase of beam pulses.

No image of un-brilliant beam spot was observed with pulsed beam of 25Hz.

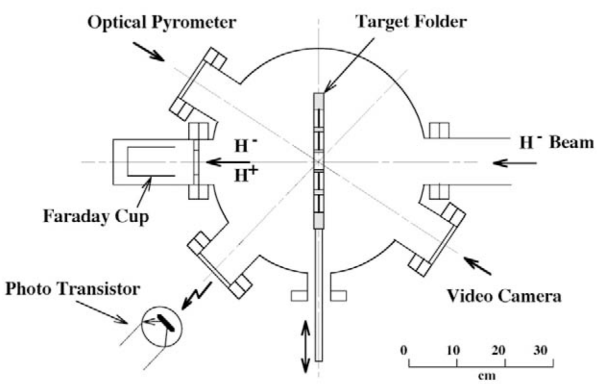


Figure 1: Experimental Setup of a target chamber.

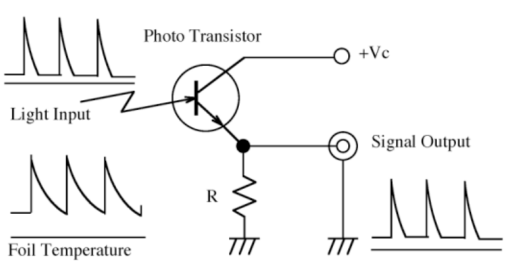
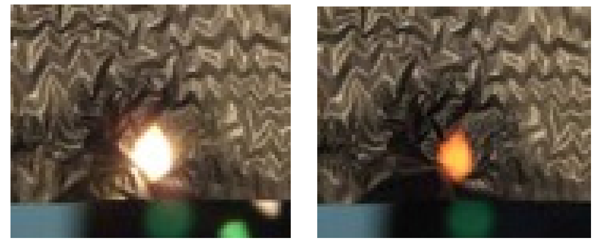


Figure 2: Electric circuit of photo detector

In same condition, A photo-intensity from beam spot was observed. It was observed that a output signal of photo transistor has a time structure show as in figure 4.



(a) (b)

Figure 3: Brightness of beam spot.
(a) includes a beam pulse
(b) between beam pulses

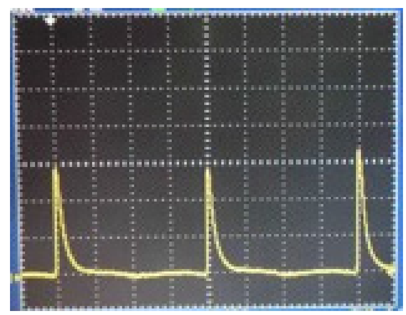
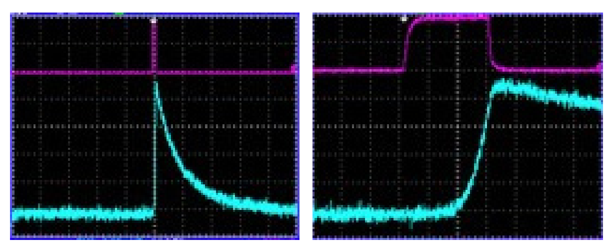


Figure 4: Waveform of photo-transistor output signal
Hor.: 49msec/div, Ver.: 0.1V/div



(a) (b)

Figure 5: Time structures of photo-transistor output.
U: Beam pulse signal: 1mA/div.
L: Photo transistor output signal: 2mV/div.
(a) Hor.: 5 msec/div. (b) Hor: 0.1 msec/div.

During duration of beam pulse, a large non-linear photo-signal was observed as expected from several numerical simulations [5][6][7].

These photo signals had a lower limited value and some offset one. There are many difficulties to identify the relationship between an average temperature and a peak temperature at the beam end.

Furthermore experiments with comparison between dc and pulsed beam irradiation, are needed to get the calibrated value of fast temperature measurement.

SUMMARY

We are developing the measuring method of the temperature using a photo transistor when a foil is irradiated by the short pulses with several tens ~ several hundreds microsecond durations. Preliminary results are presented. During duration of beam pulse, a large non-linear photo signal was observed as expected from several numerical simulations.

Furthermore experiments are needed to get the precise calibrated value of fast temperature measurement.

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