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Development of a Beam Pulse Monitor for the JAERI AVF Cyclotron

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Abstract

A beam pulse monitor has been developed for timing information about pulsed beams produced by the JAERI AVF cyclotron. This monitor provides fast timing signals for beam pulses of proton and heavy ions using a micro-channel plate, which detects secondary electrons and photons yielded by interaction between the beam and a target. In addition to using a wire target, we adopted a thin aluminum foil target for increasing the amount of electrons and photons. The monitor has been tested in 45 MeV proton and 260 MeV neon beams.

1. Introduction

The JAERI AVF cyclotron (K=110) accelerates various ion beams from proton to xenon in a wide range of energies mainly for materials science experiments. The extracted beams from the cyclotron are pulsed at the same frequency as the RF of the cyclotron and thinned out at an interval (1μs~1ms) by a beam chopping system for time-of-flight experiments and time-resolving analyses.

The timing information on the beam pulse is needed for tuning parameters of the chopping system to a required condition of the beam pulse. Use of a trigger signal produced by detection of the beam pulse allows higher time-resolution experiments than that of a signal originated from the RF because of fluctuation of phase difference between the beam pulse and the RF. We have a plan in which the cyclotron beam energy will be measured by a time-of-flight method with fast timing counters to calibrate an analyzing magnet.

For these purposes, a beam pulse monitor, detecting the beam pulse with high time resolution and high sensitivity, has been constructed and tested using 45 MeV proton and 260 MeV neon beams.

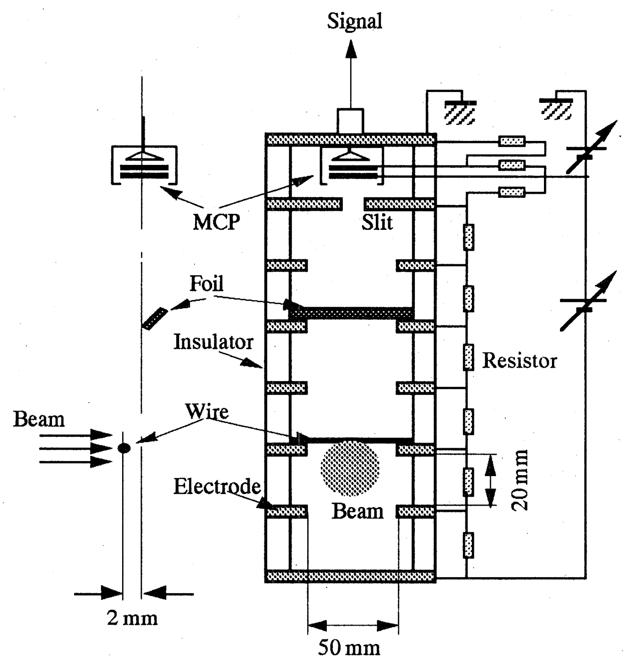

Fig. 1 A beam pulse monitor with a hollow structure, constructed from insulator rods and electrodes, has two targets and a MCP. The targets consists of a foil and a wire, stretched between a set of electrode away from each other for independent use. The left figure indicates that the targets are arranged not to disturb a flow of electrons from the wire target.

2. Beam Pulse Monitor

The beam pulse monitor provides a fast timing signal of the beam pulse by detecting secondary electrons and photons emitted from a target inserted into the beam[1]. A structure of the monitor is shown in Fig. 1.

The monitor allows installation to a small port 98 mm in diameter and permits transmission of a beam 40 mm in diameter through the inside of the monitor. The monitor is driven by a stepping motor to adjust the relative positions between the targets and the beam.

Wire targets is widely used in beam diagnoses for their convenience, but it is difficult to provide enough secondary electrons and photons produced by interaction between a wire target and high-energy light ion beams. Therefore, a foil target, having a large interaction area with the beams, has been adopted for detection of high-energy light ion beams. A wire target was also mounted for detection of low-energy heavy ion beams so as to minimize the degradation of the beam.

The foil target is a 3 mm thick aluminum-foil strip with 5 mm width, and the wire target is a tungsten wire 0.3 mm in diameter. The foil and the wire targets are placed in front of the MCP at a distance of 50 mm and 94 mm, respectively. The foil and the wire targets are stretched in parallel with the MCP and at a right angle to the beam direction. They are positioned away from each other in the beam direction so as not to disturb a flow of the secondary electrons from the wire target. The foil target is tilted at an angle of 45 degrees to the beam axis for efficient detection of secondary electrons and photons emitted from the surface of the foil.

Secondary electrons are collected into a micro-channel plate (MCP, F4655-10, Hamamatsu photonics Ltd.) through a slit using an electrostatic field. The operational voltage of the MCP is -2.4 kV, a recommended maximum voltage.

The collection field for secondary electrons, biased up to -6 kV relative to the entrance of the MCP, is produced with seven sets of electrodes. The electrodes are spaced at 20 mm by insulator rods of Al_2O_3. Each electrode is connected with neighbor ones by dividing resistors to form a uniform electrostatic field. A floating high-voltage power supply with two outputs is used for adjustment of the collection field independently from the MCP voltage. One of the outputs serves a potential of the MCP and the other serves a potential of the top of the electrode relative to the MCP.

The entrance face of the MCP, and the surfaces of the wire and the foil targets were evaporated with CsI for optimizing the emission of secondary electrons[2)].

The monitor was installed in a chamber at the end of the beam line, where the pressure is around 10^{-4} Pa.

The output signal from the MCP was amplified by a fast preamplifier (Ortec VT120) and fed into a constant fraction discriminator (Ortec 935) to produce fast timing signals. A time to amplitude converter (TAC) was started by the MCP signal and stopped by the RF signal with a divided rate. The output of the TAC was fed into a CAMAC analog to digital converter (ADC) and analyzed on a personal computer with a data taking system, "K-max".

3. Results and discussion

Time spectra for 45 MeV H^+ and 260 MeV $^{20}Ne^{7+}$ beams at a collection voltage of - 4 kV are shown in Fig. 2 and 3. Each spectrum shows the time structure of the beam having one or two peaks in this case. Difference between the peak widths measured with each target indicates that the time resolution using the foil target is superior to the one using the wire target.

The expansion of the peak width for the wire target suggests interference with the secondary electrons emitted from the wire target. A flow of secondary electrons from the wire target may be disturbed and widen in time when passing through the field near the foil target.

At a collection voltage of 0 V, the peaks of the spectra appear at faster positions on time axis than the peaks of the spectra at collection voltages of more than a few kV. An example of the peak shift is shown in Fig. 4.

The results of the test suggest that the main particles collected into the MCP are photons at 0 V and electrons at -4 kV. Adjustment of the collection voltage allows the selection of the particles detected with the MCP.

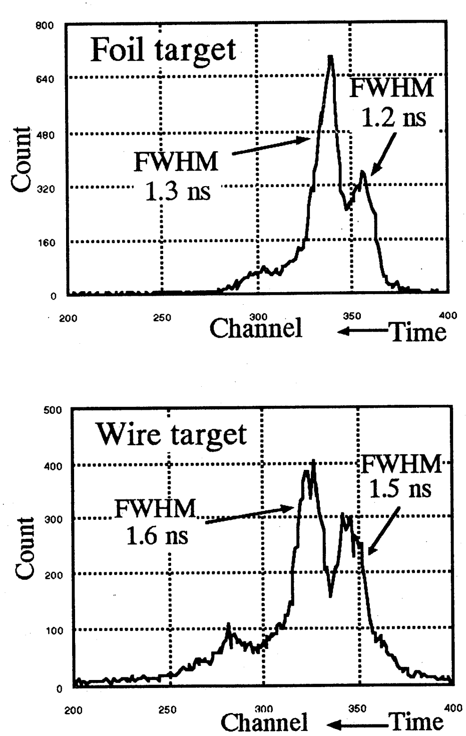

Fig. 2 Time spectra measured with the foil target and the wire target at the collection voltage of - 4 kV for 45 MeV H^+ beam. The values of FWHM were evaluated on the assumption of the Gaussian distribution.

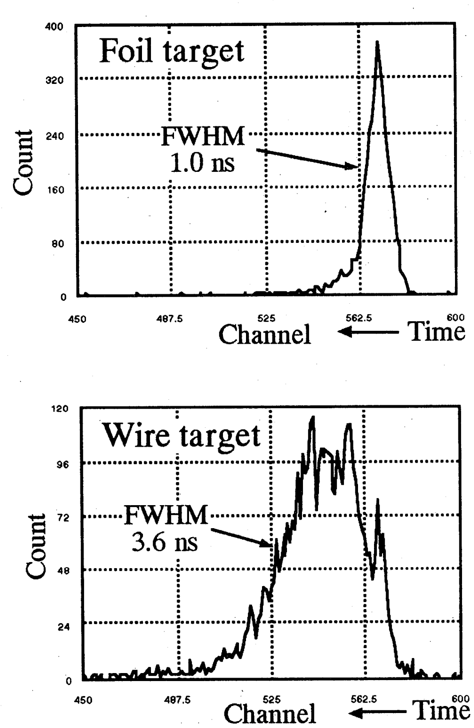

Fig. 3 Time spectra measured with the foil target and the wire target at the collection voltage of - 4 kV for 260 MeV $^{20}Ne^{7+}$ beam. The values of FWHM were evaluated on the assumption of the Gaussian distribution.

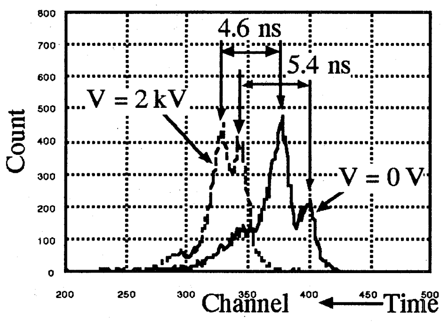

Fig. 4 Time spectra measured with the foil target at collection voltages of 0 and - 4 kV for 45 MeV H^+ beam. An average of the time differences between the corresponding peaks of them is 5.0 ns, which is in agreement with a calculated value of 5.6 ns, the difference between the traveling times of electrons and photons.

4. Conclusion

We have developed a beam pulse monitor which provides a fast timing signal for light and heavy ion pulsed beams produced by the JAERI AVF cyclotron using a MCP. An aluminum foil and a tungsten wire can be used for producing electrons and photons originated from the beam pulse. In this arrangement of the targets, the foil target is superior to the wire one in time resolution.

References

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