SECONDARY EMITTION MONITOR WITH ELECTRON MULTIPLIER

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Abstract

To monitor the spill shape, secondary electron monitor was developed, where electrons are multiplied with an electron multiplier. The output is further amplified with a current amplifier. Regarding experiences in the previous R&D of the monitor, improved monitor in several points was installed in the beam line. In this report the installed monitor and its tested performances are presented.

1 INTRODUCTION

In the operation of the synchrotron, many type of beam monitors are important to tune the machine. In the beam tuning of slow extraction, a beam spill monitor is important to know the time structure of the extracted beam. Monitoring this beam signal, we can see that the extracted beam is good or not in its time-shape for an irradiation of cancer treatment. When we have started the operation of the HIMAC synchrotron, a thin plastic scintillator was using. Though the monitor could be used in the daily operation, there are several points that are better to be improved. These are followings:

a. Effect of multiple scattering is large in the case of proton or low energy heavy ion beam.
b. The plastic scintillator has damage quickly with beam hitting, which coloured brown. This damage makes position dependence of the beam, which produce smaller pulse at the damaged place. To suppress this effect under a certain value, we must replace the plastic scintillator frequently.

To improve these situations, we have made an R&D of a secondary emission monitor. In this test monitor, secondary electrons emitted from an aluminium foil are amplified with an electron multiplier (selatron, EME-2061c)[1]. After several beam tests, we found that the monitor of this type was possible to use for a machine tuning in the daily operation, and a refined monitor was installed in the beam line for daily use. In the machine operation this monitor is used for the flowing different usage:

a. Monitor the beam spill shape on an oscilloscope.
b. Use for the feedback of the extracted beam to obtain flat beam spill.
c. Monitoring the beam intensity for machine operation and for an experiment.

In the design of this beam monitor system, above requirements were considered to fulfil.

2 MONITOR

As a source of secondary electron, a polypropylene film of 3μm thickness courted with 15μg/cm^2 aluminium is used. In the prototype monitor for a beam test, aluminium foil with a thickness of 2μm and a surface area of 10×10cm^2 was used. Though we could use this thin aluminium foil without any broken, it required special attention to attach on a monitor flame. In the case of polypropylene, its handling is easy. Concerning the effect of the multiple scattering, the polypropylene film of 3μm thickness has less effect of multiple scattering. In figure 1, the mean square angles of the multiple scattering are shown, which are calculated with the following formula;

$$\theta^2 = Z^2(Es/pc\beta)^2\, t/X_0 \quad , \qquad (1)$$

where Es = 15MeV and t is the thickness of the scatterer, X_0 is one radiation length of the scatterer in g/cm^2 , and Z is the charge, p(MeV/c) and cβ are the momentum and velocity of the beam. In the case of the polypropylene the effect of the multiple scattering is smaller than the aluminium foil by factor of two. With this thin film, effect of emittance growth is acceptable even in the case of low energy of 100MeV/u. Considering these two advantages of easy handling and small multiple scattering, we have chosen to use the polypropylene film.

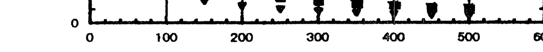

Figure 1: Comparison of multiple scattering angles of heavy ion with e/m=0.5 between three cases of 0.2mm scintillator, 2μm aluminium, and 3μm polypropylene.

Yields of secondary electron were measured [2], and the ratio of the electron emission ranges from 0.4 to 1 with carbon beam. The energy range between 100 and 400 MeV/u. The beam intensity of carbon is 3×10^8 pps for treatment in HIMAC, corresponding current of the secondary electron is less than 48pA. This current value is too small to directly observe the spill shape in the oscilloscope even if a current amplifier with a high input impedance is used. To observe the beam spill with the emitted secondary electron in an oscilloscope, the electrons are amplified with an electron multiplier of a HAMAMATSU R5150-10. (After several experiences, we have decided to use this electron multiplier instead of the selatron) An input aperture of the electron multiplier is narrow, the emitted secondary electrons are focussed on the input aperture. For this purpose the polypropylene declined 45 degree to the beam line, and the electrodes are arranged to make desired electric field for focussing as shown in Figure 2.

The output current is further amplified with a current amplifier. In this amplifier, there are four gain settings that can be selected with remote control. There are three outputs, that are isolated each other.

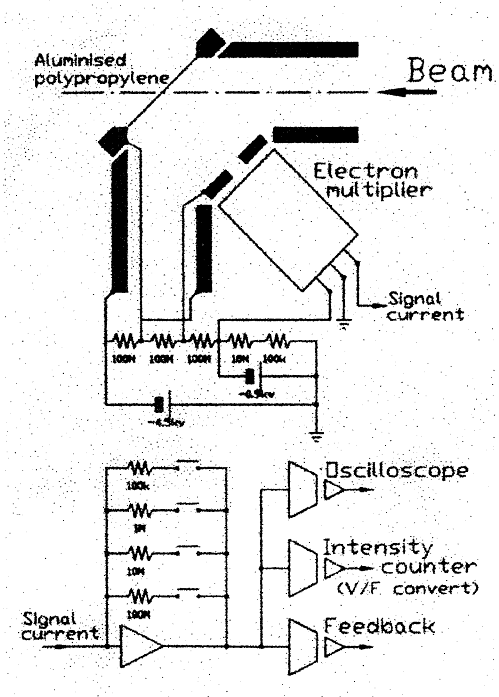

Figure 2: Monitor system.

3 BEAM EXPERIMENTS

The monitor was installed at the downstream of the first quadrupole magnet in the beam transport line from the synchrotron. The profile monitor is just in front of this monitor, which is used to know the beam position.

As a spill shape monitor, we can use with as low beam intensity as 10^6 pps. In the observed spill signal, we can clearly see the ripple of 777Hz due to frequency modulation in RF-KO extraction.

To use as an intensity monitor, we have used a VFC (Voltage Frequency Converter). The output counts of this converter are proportional to the integrated output voltage of the current amplifier. Changing the beam intensity widely from 10^5 to 10^9 pps, output counts of the VFC are measured. In each measurement the beam intensities were calibrated with parallel plate ionzation chamber that was at downstream of the beam line. As seen in figure 5, measured data show linear dependence on the beam intensity in the wide intensity range with some offset value. This linear dependence is convenient to use as an intensity monitor. In the case of the selatron as the electron multiplier, the dependence was not linear[3]. This is one reason why we use the R5150-10 as the electron multiplier though we have started the test with the selatron.

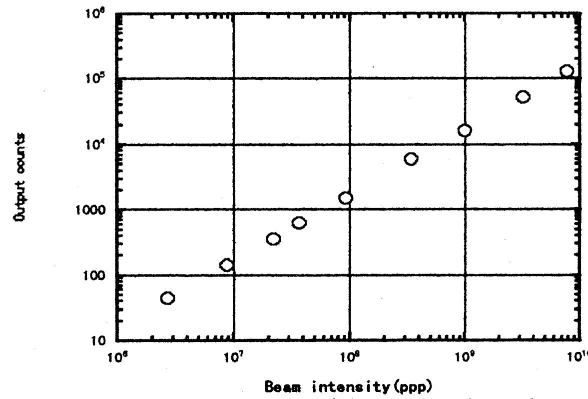

Figure 3: Output counts of the VFC vs beam intensity.

To use this monitor as an intensity monitor, dependence on the beam position should be small. In figure 9, output counts are shown as a function of the beam position. If we use the selatron, the variation of the output was small enough. In the case of the R5150-10, the variation of output was large. This is the left problem that should be improved to use as an intensity monitor.

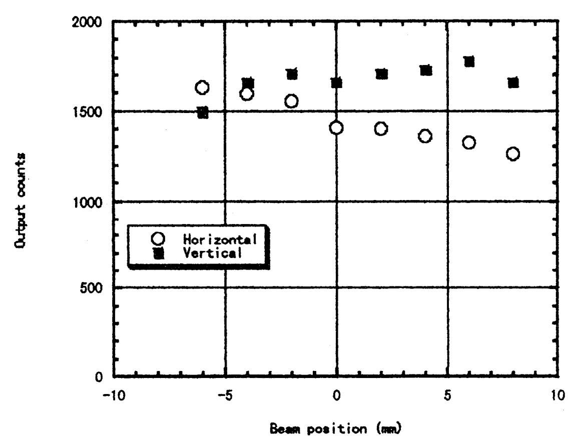

Figure 4-1: Position dependence of the monitor output with the selatron.

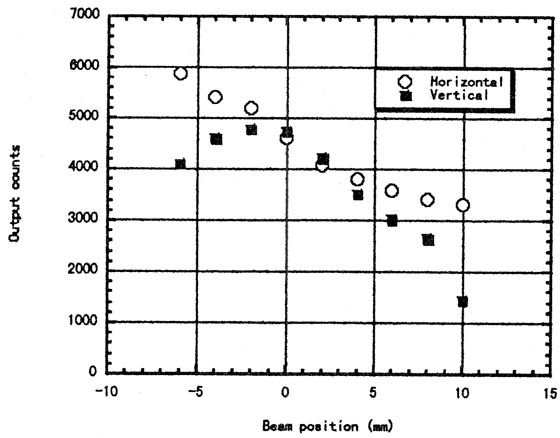

Figure 4-2: Position dependence of the monitor output with the electron multiplier of R5150-10.

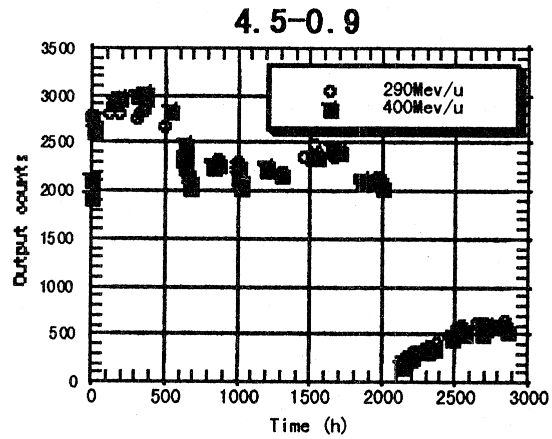

Figure 5-2:Trend of monitor output with low gain of the electron multiplier (R5150-10).

To check the long-term stability, we have measured the output counts with same beam intensity. The monitor system is used with same condition. In the first case where the output currents of the electron multiplier were around 0.5μA with the beam intensity for therapy. The output counts were decreased to half value after one month (see Figure 5-1), which were similar between the selatron and the R5150-10 electron multiplier. In general the gain of the electron multiplier will decrease if we increase the integrated output charge of it. Considering this tendency, we have same measurement with lower gain setting of the electron multiplier with order of 2. In this case the gain of the current amplifier is increased with order of two to have same output voltage of the current amplifier. The obtained result is shown in figure 5-2. Though there were sudden drop of the output, the gain was not decreased rapidly like the high gain experiment.

Though there are several problems in this monitor, we have started to use in the experiment to measured the beam intensity. During the experiment of short period, beam position at the monitor will be same. In this condition, the monitor can be used as an intensity monitor with good accuracy.

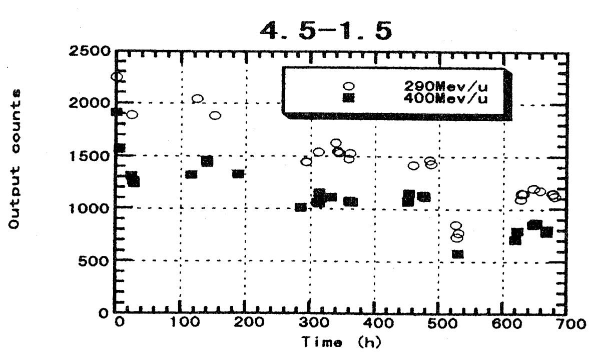

Figure 5-1:Trend of monitor output with high gain of the electron multiplier (R5150-10).

4 DISSCUSSION

The secondary electron monitor with the electron multiplier can be used one year without serious problem. Though there are gain drops at several times, we can use the monitor with increments of the high voltage of the electron multiplier. In our experiences, the gain drop was occurred when we broke the vacuum or peak beam intensity was high. There is beam position dependence of the output current with the R5150-10, whose effect was not strong with the selatron of Murata. One possible reason is a ground electrode in front of the first dynode of the R5150-10. Removing this ground plate or its effect, we will test the position dependence of the output current. Though there are several problems that should be improved, we could use this monitor about one year. From this fact, it will be possible to use this monitor with the electron monitor of the R5150-10 in daily operation and in the experiment where the beam intensity must be monitored.

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