PRESENT STATUS OF THE K=110 MEV AVF CYCLOTRON AT TOHOKU UNIVERSITY

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Abstract

The AVF cyclotron at Cyclotron and radioisotope center (CYRIC) at Tohoku University has been replaced from the K=50 MeV AVF cyclotron to the K=110 MeV one and it has been used for experiments in various fields since 2001. A control system for the new cyclotron and the beam transport system have been developed by use of the programmable logic controllers (PLC) and Labview GUI programs. In addition, several equipments such as a sinusoidal beam chopper, a beam buncher and a beam current monitoring system have been developed and constructed.

THE K=110 MEV AVF CYCLOTRON AND ITS CONTROL SYSTEM

At CYclotron and RadioIsotope Center (CYRIC) in Tohoku university, the K=50 MeV AVF cyclotron was used for more than twenty years for study in various field, for example nuclear physics, neutron physics, material physics and production of short-lived radio isotopes including positron emitters for positron emission tomography (PET). The K=50 MeV AVF cyclotron has been replaced to the K=110 MeV AVF cyclotron in March 2000 [1]. Table 1 shows the specifications of the K=110 MeV AVF cyclotron. The special feature of this cyclotron is that it has another beam-extraction port for the negative ion acceleration. H^- ions accelerated in the cyclotron are converted to H^+ ions by using a foil stripper. In this case, there is no need to use deflector electrodes for the beam extraction, so it is possible to extract a high intensity beam. Details about the development of the H^- ions acceleration will be reported by T. Endo et al. [2] in this volume. The table 2 shows the operation time of the cyclotron during 2000 - 2003. After the development of the ECRIS [3][4], heavy ion beams have been available.

On the occasion of design for the control system of new cyclotron, we have adopted the following guiding principles; 1) totally real-time computer control system, 2) robust networking among rooms and instruments for realize less wiring as possible, 3) only for human safety by hard wirings. The PLCs, which are widely used for factory automation, are one of the best candidates for the purpose [5].

As shown in figure 1, all devices such as vacuum pumps and magnet power supplies are connected to the appropriate PLC modules through the relay terminals in the distribution box in each room. A PLC unit consists of some modules including CPU modules. When many PLC modules are necessary or PLC modules should be located in many places, some base modules can be daisy-chained by the optical fibers. The top base module, which has at least one CPU module, is called the main block and the others are called the sub-blocks. All main-blocks are concentrated to the control room to keep them away from radiation damages, while sub-blocks are located in the distribution box in each room to shorten the length of wirings.

Table 1: Specifications of the cyclotron at CYRIC

weight	200 t
radius	923 mm
sector	4 pair
main coil Bmax	19.6 kG
main coil power	230 kW
trim coils	12 pair
Dee	2
Dee angle	90 º
frequency	11 ~ 22 MHz
max. Dee voltage	50 kV
max RF power	70 kW × 2

Table 2: Operation time of the cyclotron at CYRIC

beam	2000	2001	2002	2003
H^-	0	0	0	48
p	251	1275	1695	1725
d	0	182	169	24
α	65	257	433	375
$^{12}C^{3+}$	0	93	106	92
$^{12}C^{4+}$	0	155	96	22
$^{13}C^{3+}$	0	0	0	64
$^{14}N^{3+}$	0	0	128	172
$^{16}O^{4+}$	0	0	164	72
$^{16}O^{5+}$	0	0	48	171
Total	316 h	1962 h	2839 h	2765 h

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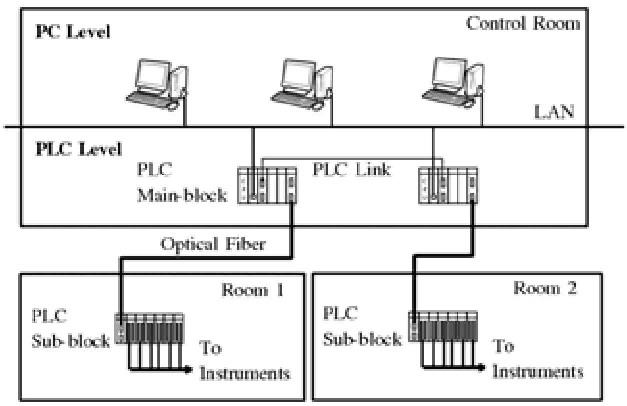

Figure 1: A schematic view of the control system.

BEAM HANDLING DEVICES

A sinusoidal beam chopper

The sinusoidal beam chopper for neutron TOF experiments at CYRIC has been improved by developing both the new RF system and the PLC based control system [6]. The maximum peak-to-peak amplitude of 50 kV between the electrodes has been obtained with good voltage and phase stability. The beam chopper driven by the new RF system has successfully been used for a more energetic beam from the cyclotron.

Fig. 2 shows the measured TOF spectrum for gamma flash from the target with or without the beam chopper driven at 1/8 chopping rate. It is found that the beam chopper has clearly deflected beam bursts from the cyclotron. In the course of regular experiments at CYRIC, the performance test was successfully carried out with increasing proton beam energy up to 90 MeV.

A beam buncher

A beam buncher system has been developed to increase beam intensity of the cyclotron. Figure 3 shows the picture of the electrodes of the beam buncher. It has two electrodes with 4mm gap and their apertures are 60 mm. The input impedance of RF frequency between 10 MHz and 21 MHz is 450 Ω and the maximum peak-to-peak amplitude between electrodes is 1.2 kV. According to the acceleration frequency of the cyclotron, the signal of each frequency (1f, 2f, and 3f) is summed up to form a saw-tooth like wave and is applied to the electrode. The phase and the amplitude stability in each frequency are within ±1° and within ±1%, respectively. Table 3 shows the bunching factor in several acceleration conditions.

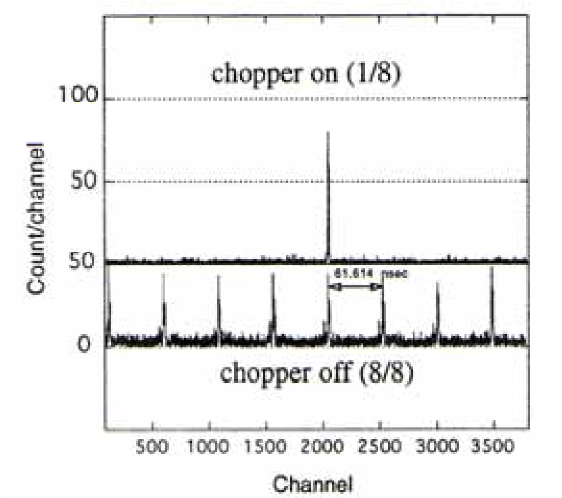

Figure 2: Result of performance test for the sinusoidal beam chopper, by which unwanted micro-bursts of the beam are removed from the beam-line.

Table 3: The bunching factor in several acceleration conditions

Beam	Energy (MeV)	harmonic number	the bunching factor
p	16	2	3.8
	35	1	5.9
	50	1	7.6
	65	1	4.4
	70	1	6.1
d	40	2	5.2
α	45	2	3.7
	50	2	3.9
C	70	2	5.5

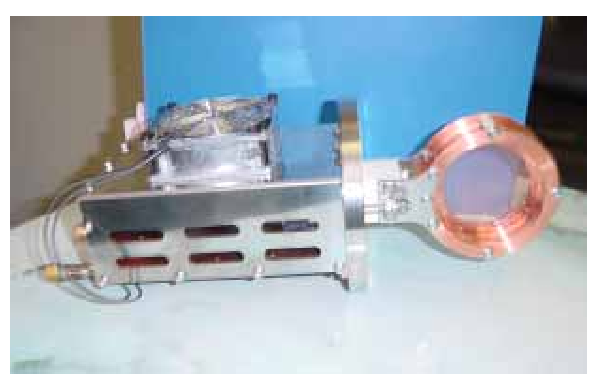

Figure 3: A picture of the electrodes of the beam buncher.

A beam current monitoring system

There are more than one hundred current monitoring such locations as probes, Faraday-cups and beam-stoppers, where we must measure beam current to operate the cyclotron and following beam transport lines. So far, extremely long cables connected directly from local spots to the control room were used to measure the beam current, because measurement spots are distributed extending over seven rooms (Cyclotron vault and 6 target rooms). The basic policy of our control system is to increase the flexibility against the modification, therefore we would like to remove all cables connected across the rooms except for the emergency lines. Moreover, if measured data could be included into computers, the analysis of beam current becomes much easier.

For example, a plotting of beam current versus probe position and a trend graph of total beam charges of the irradiated target should be available.

To realize them, a new beam current measurement system, based on WE7000 from YOKOGAWA Electric Company, is constructed. Fig. 4 shows the picture of WE7000 station configured as beam-current monitor.

The WE7000 is the computer based measuring device, which has many useful performances as an oscilloscope module and a wave generator module and so on. In addition, a special ammeter module is available. It has 4 CH inputs and has a wide input range from 1 nA to 10 mA full scale. The specification of this module is listed in table 4. The WE7000 stations and a PC with the special interface board are connected in series through the optical fibers. All functions can be controlled from the PC using appropriate Windows APIs.

Since these APIs can be also called from LabVIEW, we can construct GUI programs in the same way as in the case of PLC and LabVIEW.

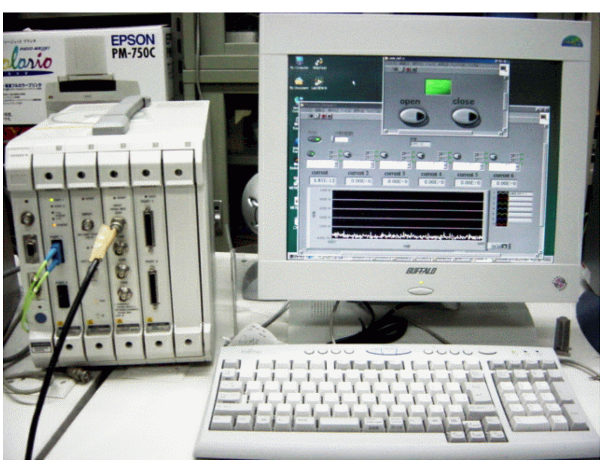

Figure 4: A picture of the WE7000 station and the Labview programs for beam current measurements.

Table 4: Specification sheet of the DC current amplifier module of WE7000.

inputs	4 CH	
connector	BNC	(isolation type)
range (accuracy)	1 nA	(± 1% of rdg + 20 pA)
	10 nA	(± 1% of rdg + 50 pA)
	100 nA	(± 1% of rdg + 500 pA)
	1 μA	(± 1% of rdg + 5 nA)
	10 μ A	(± 1% of rdg + 50 nA)
	100 μA	(± 1% of rdg + 500 nA)
	1 mA	(± 1% of rdg + 5 mA)
	10 mA	(± 1% of rdg + 50 mA)
A/D resolution	16 bit	(including a sign)
conversion precision	1 %	
input capacity	< 0.01 μF	
sampling ratio	100 kS/s	
band	10 kHz	(–3 dB)
dimensions	33 (W)× 243 (H) ×232 (D) mm	

SUMMARY

The K=50 MeV AVF cyclotron has been replaced to the K=110 MeV AVF cyclotron successfully. The control system of the cyclotron has also been developed. In addition, several beam handling devices such as a beam chopper, a beam buncher and a beam current monitoring system have been developed and constructed.

One of the authors (T.S.) expresses of our condolences to the passed away of the emeritus Professor Manabu Fujioka.

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