RECENT IMPROVEMENTS AND STATUS AT NIRS CYCLOTRON FACILITY

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Abstract

The NIRS-Chiba isochronous cyclotron has been working in routinely, and providing the stable beams for bio-medical studies and various kind of related experiments since 1975. The clinical trail of eye melanoma has been under continued. Recently two new beam lines were constructed in order to carry out the bio-physical study , and to produce the long-lived R.I.s for SPECT. Some progressive improvements, such as updating the magnetic-channel and development of a floating septum system, were performed for stable operation of the cyclotron. Some of the improvements and the current status of the cyclotron are described.

1. INTRODUCTION

In 1975, the NIRS-Chiba isochronous cyclotron [1] (NIRS-930) was constructed for biomedical studies such as the clinical trials of fast neutron therapy, production of the short-lived radio-nuclides and preliminary study for proton therapy. The fast-neutron therapy, which had been the main purpose of the cyclotron and performed for almost twenty years, came to an end in December 1994 because a new facility of heavy ion accelerator complex HIMAC [2] (Heavy Ion Medical Accelerator in Chiba) was started. The utilization of the NIRS-930, therefore, has been expanded into new research fields. In conjunction with the HIMAC operation a new small cyclotron(HM-18) was installed for PET diagnostic, in 1994.

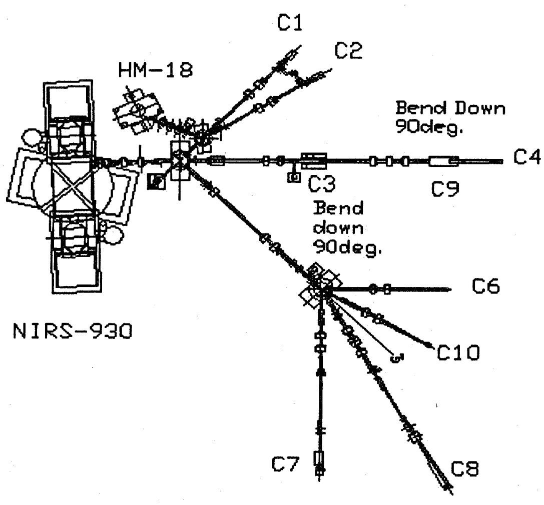

Figure 1 : Floor plane of NIRS cyclotron facility in August, 2001.

The small cyclotron was set up in the same vault of the NIRS-930 so as to good use of the existing R.I.-production ports.

2. STATUS

The NIRS cyclotron facility constitutes of two cyclotrons (NIRS-930 and HM-18) and nine experimental beam lines as can be seen in Fig.1. The NIRS-930 has been used mainly for clinical trials of proton therapy such as eye melanoma, production of the short-lived radio-nuclides, research of bio-physics, development of particle detectors for space application and so on. The small HM-18 has been operating routinely to product short-lived radio-pharmaceuticals, for PET with the target stations of C1 and C2, where the beams are provided from both cyclotrons, but not simultaneously.

Two new beam lines C10 and C4 were constructed during the past two years. The line C10, which was installed in the general-purpose experimental cave, is used for basic study of bio-physics. Recent activity of this experiment is that a precisely measurement [4] of the doubly differential cross section (DDCS) for 5-1000 eV at 30-150° with the impact of 6.0 MeV/n α particles (~ 50 nA on the target) was obtained. The line C4 was designed and constructed for development of long-lived radio-nuclides for SPECT with high current proton beam of 65 MeV. It will be started in this summer. The high flux neutron cave C3, which had been used for fast neutron therapy, was modified in order to study biological effects by an accidental neutron exposure to humans, which was started at Jun of this year.

C1, C2 : Production and development of short-lived R.I.s,
C3 : Biological studies with high flux neutron beam
C4 : Production of R.I.s for SPECT,
C6 : Development of particle detectors and beam monitors,
C7 : Radiobiological experiments with heavy ions,
C8 : Studies of radiation dosimetry,
C9 : Proton therapy for eye melanoma,
C10 : Experiments of biophysics.

The C6 is used in progressive for development of particle detectors [5] for space application.

Operation of those two cyclotrons is scheduled in the daytime from Monday afternoon to Friday except the regular maintenance time during two weeks of March and August annually. Table 1 shows the statistics of beam time distributions among the research fields in 2000.

Table 1 : The distribution of beam time among research field.

1.	Clinical trial of eye melanoma	:	88.8 h	(6.8 %)
2.	Production and development of: short-lived radio-nuclides	:	215.8 h	(16.6 %)
3.	Studies of particle detectors and radiation dosimetry	:	450.2 h	(34.6 %)
4.	Basic research of radiological experiments	:	7.5 h	(0.6 %)
5.	Related Experiments	:	207.3 h	(15.9 %)
6.	Preparing beam	:	331.9 h	(25.5 %)
	Total	:	1301.5 h	

2. IMPROVEMENTS

The NIRS-930 cyclotron having K=110 consists of four sectors and two Dees(86 deg.) connected to moving panel type of rf-cavities. The frequency range of 10.7-21 MHz covers 1st and 2nd harmonic in the acceleration modes. The stable beams of proton with energy up to 70 MeV, and deuteron, ^{3}He, alpha and few kind of heavy ions are sufficiently delivered with the extraction efficiencies of 50 ~ 70 %. Following, some progressive improvements in the NIRS-930 are presented.

2.1 Floating Septum

It has been required high energy and high intensity beam extraction from the NIRS-930 cyclotron. For examples, proton beams of 40MeV x 15 μ A for ^{38}K and 65MeV x 10 μ A for SPECT are needed in the field of R.I. production, and the deuteron beam of 25MeV x 25 μ A is minimum requirements to produce high flux neutron beam for biomedical studies, respectively. In order to preserve the pre-septum electrode by the thermal damage owing to the irregular beam hitting in such the operation, we developed a "floating septum system" for the deflector. The system is composed of a new pre-septum electrode insulated from the earth potential, a beam current read-out electronics and interlock-circuit to control the ion source. Fig. 2 shows a schematic drawing of the beam current read-out circuit of the floating septum system. The system works under the condition that, when the electric beam power on the pre-septum exceeds more than 600 W then the arc voltage of the ion source should be turn-off in an instant.

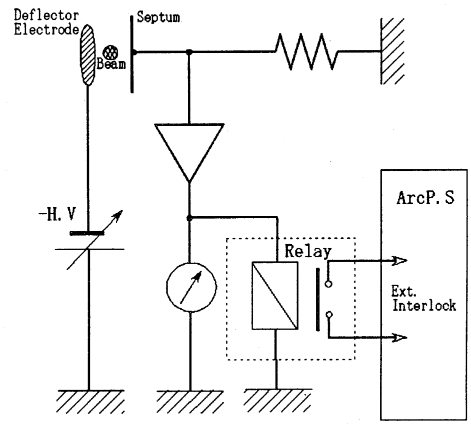

Figure.2 : Block diagram of floating septum system.

2.2 Magnetic Channel

The magnetic-channel, which had been used almost twenty-six years since the cyclotron construction, was replaced by a new one due to troubles of the small air leak and going down the flow rate of the cooling water. The new magnetic-channel was designed and manufactured by Sumitomo Heavy Industry in Japan. On the occasion of the replacement we have checked up on the magnetic field characteristics such as field strength and field polarity for the both of the old and new one. Of course we verified the field distribution with a computer simulation by MAXWELL-2D[3] as shown in Fig.2. In resulting, those three cases were accepted as almost same stance. The temperature rise between inlet and outlet of the cooling water for an one of the longest coil (A1) as shown in Fig.3 become 65 degrees at the excitation current of 1100A in the flow-rate of 2.8 l/min.

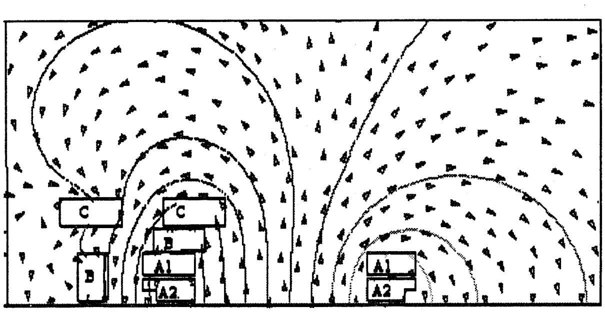

Figure.3: Mid-plane symmetry of magnetic field distribution of the magnetic-channel.

2.3 RF-system

The NIRS-930 cyclotron has two Dee system operation by MOPA. The RF-system is consists of Low-Level, pre-amplifier and main amplifier, connecting for each RF-resonator as can be seen in Fig.4. In the pre-amplifier, two 500W transistor-amplifier in parallel operation had been used, however, it was complicate to operate those two amplifiers in the same condition. The mainly troubles of the system are heating up of the oil-combiner due to it gain unbalance, and troublesome to maintenance of the amplifier when it was damaged. Recently so that new system has been constructed with a single 1kW amplifier. Resulting, simplification of the gain adjustment and making the gain balance for each channel has been realized in operating the RF system.

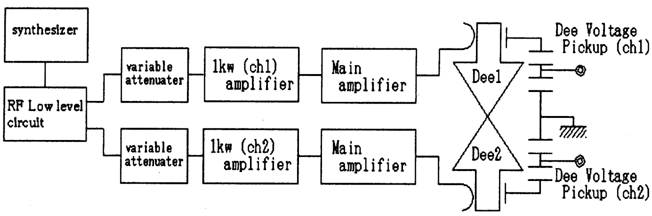

Figure.4 : RF system of NIRS-930

2.4 *Magnetic Interaction*

Weak magnetic interactions have been existing between two switching magnets (SWR and SW1) in the beam line under the parallel operation. For example, the beam from the NIRS-930 is transport to one of the experimental course such as C4, C6, C9 and so on with a suitable field strength, a small deflection on the target is occurred when the SWR is changed its magnetic field strength for deliver to the C1 and C2 and viceversa. The beam deflection is caused by a leakage flux from the SWR due to its magnetic saturation in the return yoke, where C1 course need more high magnetic field strength rather than C2 in the SWR. Of course we measured the leakage field strength inside of the SW1 and related beam lines near around produced by the SWR.

The best resolution to minimize the field interaction is that the return yoke of the SWR was supplemented with pure iron having more highly permeability and to increase the cross-sectional area of the return yoke. In result, the field interaction is reduced by a factor of about ten. Fig.5 shows the measurement result of the field differences inside of the SW1 at variable field exciting with change the field strength of SWR for C1 and C2 in the before and after of the modification.

In the work of this modification, the field simulation was carried out by POISSON [6].

4. OUTLOOK

The axial injection system has been proposed to provide various kinds of heavy-ions for the related studies, and it has planed to equip an external ECR type of ion source. The source tuning and the system operation are under testing.

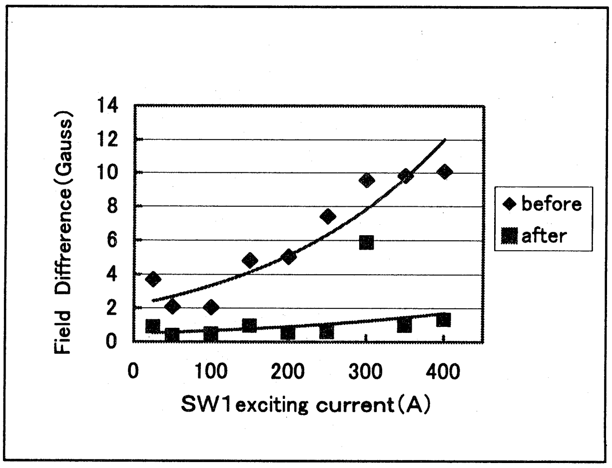

Figure.5 : The field differences inside of the SW1.

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REFERENCES

[1] H.Ogawa,et al, IEEE Trans. Nucle. Sci. NS-26,No2, (1978) 1988.
[2] S.Yamada, et al., Proc. 1995 PAC, Dallas,(1995)
[3] "MAXWELL 2D" Field simulator, Ansoft corporation.
[4] Y.Sato et al, Rev. Sci. Instrum. 67 (1996) 2000.
[5] M.Takada, et al., Nucl. Instr. and Meth. A465 (2001) 498-542.
[6]Reference Manual for the POISSON/SUPERFISH Group of Cords,LA-UR-87126