# PRESENT STATUS AND REVIEW OF 680 CYCLOTRON AT TOHOKU UNIVERSITY

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## Abstract

The acceptance tests of 680 type cyclotron at the Cyclotron and RI Center of Tohoku University have been completed last December. The fundamental concept of design is based on the Orleans cyclotron at CNRS, France, but the modification to boost proton energy to 40 MeV was carried out on cavities and power amplifiers. During the process of magnetic measurement analysis it was found that the strength of central magnetic field bump was insufficient for the focalization of beam.
After trying computation by the use of two dimensional magnetic map program we made magnetic measurement again on the two test pieces of central plugs. In this measurement a magnetic wheel was devised in order to enable the measurement without disassembly of the vacuum chamber. After all, it was proved that the setting parameters of circular coils by computation fitted very well to the actual values. The beam tests were also carried out on the emittance at 40 MeV proton and the energy resolution measurement at 35 MeV alpha.

## Outline of Cyclotron

680 cyclotron was designed to be versatile variable energy cyclotron having two $60^{\circ}$ angle dees with 4-sectors. The choice of $60^{\circ}$ dees leads to a small dee capacitance and enable the use of high radio-frequency from 20 to 40 MHz. As a consequence the acceleration can be achieved by 2nd,3rd and 4th harmonic mode. Carefull investigation on this central region( 1 ) made possible to use a single fixed puller with a roughly single orbit for all energy and particles. This new design was successifully proved during the beam test , because only one fixed position of ion source was taken for the test of the guaranteed beams.

The main coil power supply was regulated to $10^{-5}$ order of current stability. The magnetic measurement was carried out by a high speed automatic wheel which runs two degree pitch azimuthally. An example of magnetic field fitting to isocronous field by the use of 8 circular coils is shown in Fig. 1.

As shown in Fig. 2, a master oscillator chain system was employed. The regulation loop gives the stability of dee voltage within 0.1 % and also automatic tuning of the cavity.
The cavities are of a kind of moving panel type allowing frequency variation by means of moving a rotary panel along a curved wall without any sliding contacts. The power tube supply was equipped with crow-bar circuits and the volatage was altered by changing taps of transformers.

The cooling of the cyclotron was made through the circulation of deionized water of $30 \pm 1^{\circ}C$. The temperature regulation was adopted to ensure the stability of the power supplies and the radio-frequency system.

## Beam Test

The results of beam test are summarized in Table 1. Also, the fluctuation of beam current was measured and $\pm$ 10 % stability was obtained. The emittance was measured by placing two motor driven gap fixed slits along the external beam line by taking the slit gap as 0.5 mm. These results are shown in Table 2. The energy resolution experiment was carried out by observing scattered alpha particles from a thin foil of iron. The analysis of energy resolution was made by a SSD with the sensitive depth of 2 mm. The energy resolution can be estimated 0.4 % for FHW at 35 MeV alpha of 3.5 $\mu$A after subtraction of such contribution as kinematic effect and others.

## Acknowledgement

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## References

( 1 ) A. Dupuis, J. Kervizic, B. Laune, G. Meyrand, D. T. Tran, D. Tronc and G. Goin, 14 th European Cyclotron Progress Meeting.

| PARTICLE & ENERGY | guaranteed CURRENT | measured CURRENT | measured EFFICIENCY |
|---|---|---|---|
| proton MeV | μA | μA | % |
| 3 | 15 | 15 (1) | 43.5 |
| 15 | 30 | 100 | 65 |
| 25 | 50 | 50 | 63 |
| 39.5 | 40 | 50 (2) | 71.5 |
| deuteron | | | |
| 5 | 15 | 15 | 47 |
| 10 | 35 | 60 | 69 |
| 25 | 50 | 52 | 66 |
| helium 3 | | | |
| 7 | 10 | 11.5 (3) | 30 |
| 20 | 30 | 38 | 50 |
| 50 | 40 | 40 | 66.5 |
| 65 | 30 | 40 | 60 |
| helium 4 | | | |
| 10 | 10 | 32 | 54 |
| 20 | 20 | 50 | 67 |
| 50 | 30 | 30 | 64 |

measured ENERGY (1) $H_2^+$ 5 MeV
(2) 40 MeV
(3) 7.2 MeV

Table 1.

Result of beam test

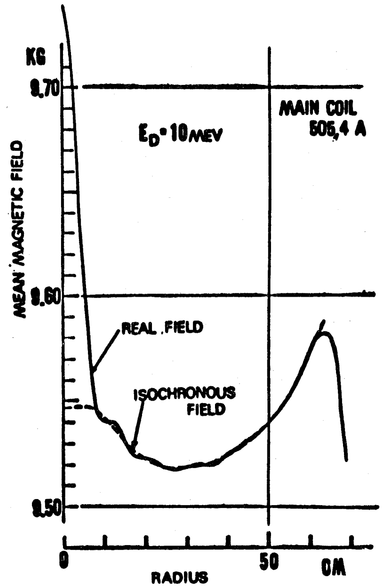


Fig. 1.Fitting of magnetic field to isochronous field

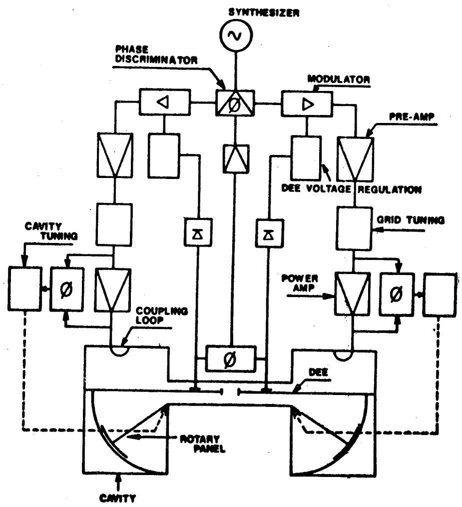


Fig. 2. Block diagram of RF system of 680 cyclotron

Table 2. Result of emittance measurement, where notation S1 means that measurement was made by sweeping S2 slit

EMITTANCE

$E_P$ = 40 MEV

| | 20 μA | | 40 μA | |
|---|---|---|---|---|
| | S 1 | S 2 | S 1 | S 2 |
| X-AXIS | 20.4 | 27.6 | 20.9 | 30.2 |
| Y-AXIS | 21.7 | 23.2 | 30.0 | 29.3 |

MMMRAD

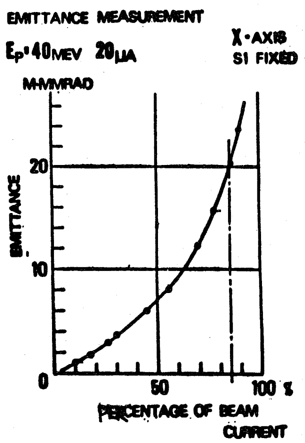


Fig. 3. Relation between emittance and fraction of beam current