Status of CIAE medical cyclotron

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Abstract

A 30 MeV compact cyclotron devoted to medical radioactive isotope production is being built in CIAE. It was originally designed by IBA, Belgium. Some major modifications of the design have been taken. In order to improve the performance of the machine, the magnet redesign and adjustment have to be taken. All equipments in control room are already in position. RF, power supplies, vacuum and water cooling system have been tested. The machine is being in final installation and ready for commissioning.

I. GENERAL DESIGN FEATURES

CIAE medical cyclotron is a fixed–field, fixed–frequency isochronous cyclotron accelerating H^- ions beam up to a maximum energy of 30 MeV and extracted beam intensity of 350 μA and low power consumption less than 100 KW.

Negative hydrogen ions are produced by an external multicusp ion source located above the cyclotron yoke [1].

The beam from ion source is injected axially and inflected in the median plane by an electrostatic helicoid inflector. It is then accelerated by two 30 ° dees electrodes while it is contracted to a fixed magnetic field. The two dees are located in the magnet valleys, allowing the magnet gap to be very small. The H^- ions are continuously accelerated until the beam passes through the carbon foil, the negative ions are stripped off their electrons, become positive. Continuously adjustable energy from 15 to 30 MeV is achieved by varying the radial position of the carbon foil.

Partially intercepting foils permit the extraction of two beams at the same time and will direct them to one of the two extraction beam lines.

The extracted beam passes through a 7 meter transport line to a solid target where a pneumatic carrier will ship the isotope products from the station to an unload hot cell for radioisotope distribution.

This project with most of equipments made in China has been made significant progress. Various systems of the machine are installed in construction site seperately and test results are satisfied.

II. THE MAGNET SYSTEM

The magnetic structure of Cyclone 30 has been specially designed to reduce the electrical power consumption combining the advantages of separated sector cyclotron and compact cyclotron. In order to meet the fabrication enviroment of China and to improve its performance, redesign was taken based on DE 3D programm [2] and some structure modifications are made including:

- In original design, the upper and lower yokes are each seperated into two pieces: base plate and base ring. In order to reduce mechanical work and loose the tolerance, the two seperated pieces are combined together as one. The field stability and vacuum seal both are improved also.
- 54 ° angle four sector poles are rigidly fixed and sealed onto base plate by the grub screws with two polyflon material sealing rings.
- 8 positioner are used for positioning the upper yoke once it has to be lifted.

Now the magnet mapping is finished by means of a Hall probe controlled automatically. The required isochronous field related to R.F. phase shift and first harmonic are adjusted by azimuthal shimming of the pole edges. High quality isochronous field profile is obtained.

The measurement results are shown in Fig. 1, 2 and 3.

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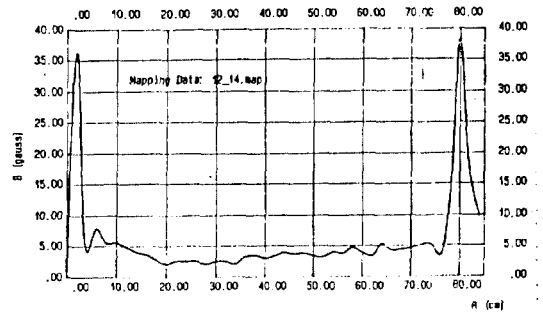

Fig. 1 Amplitude of first harmonic

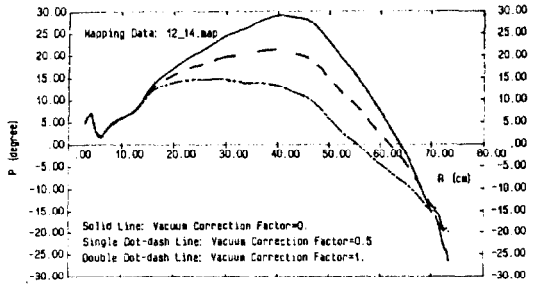

Fig. 2 Total phase shift with different vacuum corrections

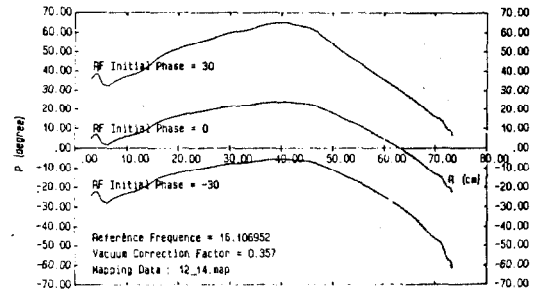

Fig. 3 Total phase shift with different RF initial phases

The isochronous field can can be achieved using electrical power 7 KW only.

In addition, switching magnets, quadrupoles, steering magnets and corresponding power supplies are fabricated based on our own design. Their quality is same or better than the requested theoretically.

Ⅲ. R.F. ACCELERATING SYSTEM

The R.F. accelerating system is made in chinese manufacturer. The accelerating electrodes, the "dees" are supported by stems inserted in the valleys. When the yoke lifted, the dees split into a lower and an upper parts. This configuration gives the acceleration system exceptional mechanical stability and does not require fragile insulators.

The dees are made of solid copper and are conduction cooled. This considerably reduces the risk of water–leakage inside the machine and thus the contamination risks.

The two 30° dees operate on the 4th harmonic mode with respect to the particle revolution frequency. To prevent any phase mismatch and to simplify the R.F. system, they are connected at the center below the median plane to leave room for the inflector.

The R.F. cavities are entirely located in the valleys. The R.F. power needed to obtain 50 KV of dee voltage is approximately 5.5KW per cavity. In addition, up to 15 KW of R.F. power are used for beam acceleration.

A single R.F. amplifier delivering 25 KW of power at 65.5 MHz is installed in the median plane and is capacitively coupled to the cavity. The variable load due to the beam behaves as a variable load resistor on the final tube. so the amplifier always operates at peak efficiency.

Zero–bias, grounded–grid triodes are used for the final 25 KW amplifier and 3 KW driver amplifier. This design give the system absolute stability and eliminates the grid and screengrid power consumption. The R.F. system has been tested and the working frequency was measured. The result shows that Dee circuit coincides well with the results of magnetic mapping.

Ⅳ. VACUUM AND WATER COOLING SYSTEM

The vacuum chamber of cyclone 30 cyclotron is a cylinder made of aluminium alloy, sealed onto the magnet yoke by "O" rings. Some openings on the vessel for beam exit, stripper entry, R.F. feed etc. are isolated from ambient atmosphere by air–lock system and "O" rings.

Three types of pumps are used in the cyclotron. Roughing is performed by forepumps from 1000 mbar down to 10^{-2}mbar. High vacuum is maintained by two oil diffusion pumps (3000l / s) from 10^{-2}mbar down to 10^{-6}mbar and by two cryogenic pumps (1500l / s) to improve vacuum around 10^{-7}mbar adequate for extracting

beam above 350 μA. Cryopumps could also increase the pump–down speed in the cyclotron.

Demineralized water is used for machine cooling through manifold with stainless steel ball valves, flow controllers, distributing the water to all cooling circuits.

Temperature, resistivity and flow amount of water are used as control interlocks to guarantee the safety of the equipments.

All the vacuum and cooling system have been installed and tested for the machine operating properly.

V. CONTROL SYSTEM

The cyclotron and related equipments are controlled by a SIMATIC S5–135U programmable controller because of its reliability and its versatility. It also offers the possibility to expand and interconnect with other programmable devices. Normal operation of the cyclotron is entirely automatic, from cyclotron start–up to targetry and chemistry, requiring no operator during routine production. Color monitor displays graphically the operations.

A spillproof keyboard and two "virtual" knobs that can be used for preset the cyclotron parameters. To meet the control rquiremeuts of PLC, special interfaces are added in relevant devices. For examples, power distrubution and power supplies, water and vacuum control and interlocks, beam measurement and displays··· ··· . Now the whole control system are installed in control room, part of main functions has been tested, some with real devices and some with simulations. Overall hardware and software test will be done in final general testing.

VI. REFERENCES

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[2] Tianjue Zhang, Mingwu Fan: " Automatic mesh generation and graphic display for 3D finite element codes" , Proc. of China–Japan Accelerator Symposium, 1990.