The 20 MeV compact cyclotron

F. Dupont and B. Gremont
Thomson, C.S.F., Orsay, France

Presented by R. M. Jean

ABSTRACT

The isochronous compact cyclotron built by Thomson, C.S.F. is a multi-particle, variable energy accelerator. The energy range is 6 to 19 MeV for protons and α-particles, 5 to 9 MeV for deuterons, and 8 to 25 MeV for Helium 3.

The main features of this machine are as follows.

Very compact magnet (11 tons) with a rather small power consumption (30 kW).

Rf system operating on the second and fourth harmonic modes within the 25 to 50 Mc/s frequency range.

Extraction system including an electrostatic deflector, a gradient correcting channel, and a quadrupole

Zucker type source.

The choice of the energy range is a compromise between the increasing price and the field of possible experiments. The 19 MeV maximum energy gives a wide access to:

Activation analysis: the reaction threshold for deuterons is 8 to 10 MeV.

Nuclear medicine: the cyclotron is the only way to obtain short-lived isotopes which are more and more used in medical research. A deuteron energy of 9 MeV allows one to obtain a great number of short-lived isotopes.

Neutron production: with 19 MeV protons and several tens of microamperes of beam, we can have up to 3 or 4×10^{10} fast neutrons/cm^2/s by choosing the best production reaction.

1. INTRODUCTION

In the last two years, there has appeared a growing need for small, compact isochronous cyclotrons in the range of 10 to 20 MeV for protons, mainly for biomedical research. After the completion of several isochronous cyclotrons throughout the world during the last few years, it appeared more and more possible to build very simple isochronous cyclotrons at low prices and with minimum maintenance.

Our experience with big isochronous cyclotrons and with medical linear accelerators has helped us considerably in building a compact isochronous cyclotron which can be operated by anybody without special training. The first machine has been put into operation recently in the Thomson, C.S.F. Laboratories.

2. DESCRIPTION

2.1. *Magnet*

For a small cyclotron the critical dimensions are the overall size of the magnet which limits its ability to be put in a small vault to reduce the cost of installation. Our magnet is 2 m long, 1 m high, and 0·9 m wide.

The focusing magnetic field is achieved by four straight sectors slightly tapered from the centre to the maximum radius. The magnetic gap is 25 mm between the hills. A central plug, machined to locate the ion source, completes the magnetic field. The trim coils are located under the hills and are in the vacuum.

The total power consumed by the magnet is 30 kW.

2.2. *Vacuum*

In this compact cyclotron, because there is no large degassing surface, a single vacuum circuit is sufficient. A roughing pump of 25 m^3/h and a diffusion pump of 2000 1/s give a pressure of 2×10^{-6} mm Hg without source operation.

2.3. *Rf system*

The rf system is, as in larger machines, composed of a master oscillator, a preamplifier, and a final power amplifier directly coupled to the rf cavity. The coupling is of a capacitive type. The maximum power needed for 30 kV on the dee at 50 Mc/s is 15 kW.

The azimuthal length of the dees is 40° and they are located between the hills. The return rf currents are carried out by a sheet of copper between the hills and the trim coils.

Variation of the radio frequency is obtained by changing the length of two short-circuited coaxial lines. This is done by remote control from the console. The frequency stability is better than 10^{-5}, and the amplitude regulation is in the order of 10^{-3}.

2.4. *Source*

The cold cathode Zucker type source gave some trouble initially due to its small size but modifications, particularly to the shape and cooling of the cathodes, have resulted in a satisfactory source. The gas flow necessary for operation with hydrogen is 2 to 3 cm^3/min.

2.5. *Extraction system*

The extraction system consists of an electrostatic deflector, 40° long, with 30 kV high voltage supply. Computation showed no difficulties in extracting the beam with this deflector and we have checked this on the cyclotron. We are now building a gradient magnetic channel to keep a well-focused beam during and after extraction.

2.6. *Controls and supplies*

Controls and metering are all contained in a small console. Extensive interlocks prevent the operator from causing damage to the machine. The power supplies for the rf system, main coils, and trim coils are located in one cabinet in the cyclotron vault.

3. PERFORMANCE

3.1. *Beam current*

The present aim is to obtain 100 μA of internal beam current of protons, deuterons, and alphas. We hope in the future to increase these currents to 500 μA.

The external beam current will be of the order of 70 μA of deuterons, protons, and alphas. The future goal is 150 μA.

3.2. *Energy*

For protons and alphas, the energy is continuously variable from 6 to 19 MeV; for deuterons, the energy range goes from 5 to 9 MeV. For $^3He^{2+}$ the energy range will be 7 to 28 MeV.

3.3. *Operation*

Since the completion of the machine in May 1969 we have operated the cyclotron with good results with 9 MeV deuterons at 1 or 2 μA of internal beam current to avoid activation. We have extracted this beam without difficulty.

4. CONCLUSION

Just 18 months after the beginning of the project we have had good results from this compact cyclotron and with the experience from the first machine we are now able to build for chemists and medical people a variable energy cyclotron reliable and easy to operate, for a moderate investment cost.