The 20 MeV compact cyclotron

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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 $4 \times 10^{10}$ fast neutrons/cm²/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 m³/h and a diffusion pump of 2000 l/s give a pressure of $2 \times 10^{-6}$ 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 cm³/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 pA of internal beam current of protons, deuterons, and alphas. We hope in the future to increase these currents to 500 pA.

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

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 $^3$He$^2+$ 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 pA 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.