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A VARIABLE ENERGY RACETRACK MICROTRON

H. R. Froelich, A. S. Thompson,
D. S. Edmonds, J. J. Manca

University of Western Ontario,
London, Canada

Summary

A racetrack microtron whose energy may be varied continuously from 4.5 to 18 MeV has been built at the University of Western Ontario, and has been operated to full energy. Electrons from an external electron gun are injected with an electrostatic inflector, and accelerated in a short sidecoupled linac section. The RF power delivered to the linac section can be varied by means of a power splitter, thus allowing the energy gain in the section to be adjusted continuously from 1.5 to 3 MeV. The accelerator can be operated in three different modes: single traversal of the linac section with a final beam energy of 1.5 to 3 MeV, n = 2 with three traversals of the linac covering the final energy range from 4.5 to 9 MeV and n = 1 with six traversals of the linac and a corresponding energy range of 9 to 18 MeV. The magnetic guide field consists of two 180° magnets with alternating high and low field regions. To satisfy the resonance conditions the average induction can be varied up to 0.6 T and the lengths of the drift space between the magnets can be adjusted by moving the pole pieces of the magnets.

Introduction

Microtrons built so far are limited to relatively low magnetic fields by the energy gains that can be achieved in a single cavity. This limitation can be circumvented by using multiple cavity accelerating structures and racetrack configurations of the magnetic guide field.[1] This paper deals with a six orbit microtron that utilizes these two basic design features.

Design Considerations

The final purpose of the microtron described in this paper is to serve in various research applications as a source of electrons with an energy of up to 18 MeV. Since, however, racetrack microtrons with multiple cavity accelerating structures are a relatively untried accelerator type, a modular design was chosen which allows both during the building stage and at any later date, the testing of any promising guide field configuration, accelerating structure, injection or extraction scheme. The accelerator proper consists basically of four modules: a central module, two magnetic guide field modules and an electron gun module. The central module contains the accelerating structure, injector and beam monitoring devices. Each of the last three modules can be detached easily from the central module, thus allowing access to any internal part. Major modifications can be accomplished by replacing only one or two of the modules.

Description of the Accelerator

Electrons from an external 80 kV electron gun are injected into the accelerating structure by means of a 90° electrostatic deflector. The latter consists of two flat electrodes, one of which is connected to ground and the other to the high voltage terminal of the electron gun. Both electrodes are slotted to allow the passage of both the beam from the gun and the beam in the microtron orbits. The slots in the electrodes are of different widths in order to produce a field profile that compensates for the inevitable vertical defocusing of the beam upon passage through the grounded electrode.

The accelerating structure consists at the present time of a short sidecoupled linear accelerator with three accelerating cavities and two coupling cavities. In the $\pi/2$ mode it has a resonant frequency of 2.812 GHz a shunt resistance of 5 MΩ and a Q of 9000. The shape of the main cavities was chosen to obtain a comparatively small outer diameter of the cavity (6.8 cm), so that the return portion of the first orbit could be placed at a distance of 3.8 to 4.5 cm from the cavity axis. This simplified the design of the guide field for a variable energy gain, but resulted in the relatively low shunt resistance of the accelerating structure. Power is coupled from the waveguide into the main cavity at the center. The entire accelerating structure is bolted to a port cover of the central module of the accelerator. This arrangement allows the cooling and RF connections to be relatively simple.

The magnetic guide field is provided by the two magnet modules, which are designed to produce an induction of up to 0.6 T (6000 gauss) across a gap of 1 cm, over an area sufficiently large to accomodate six orbits. Each magnet module consists of a yoke and two coils, which are situated outside a wedge shaped vacuum chamber, and moveable pole-piece supports, pole-pieces and magnetic shields which are situated inside the chamber. Plates made of 1020 steel which are welded into the walls of the vacuum chamber pass the magnetic flux into the chamber. The magnetic field is monitored by two rotating coil gaussmeters.

The basic guide field configuration consists of two main sectors separated by a field free region which contains the accelerating structure. Beam focusing is maintained by fringe fields between high and low field regions within the main sectors.

A simple magnetic shield which reduces the field in the extraction region to zero is used to extract the beam.

A tunable, 3.5 M.W. peak pulse power magnetron (Raytheon QKH 327 A) is used as the

S band RF power source. A 2 microsecond pulse at 300 pulses per second is produced by an FPS-6 radar modulator triggered from a pulse generator. A variable delay circuit is used to synchronize the electron gun pulse and the RF pulse.

The magnetron is located outside the shielded room housing the microtron, and power is fed to the microtron cavities via a 25 ft. waveguide run. Two ferrite isolators are used, one at the output of the magnetron (20 db isolation) to protect the magnetron against waveguide malfunction and one at the input to the microtron (10 db isolation) to protect the waveguide from excessive standing wave ratios if the cavity is detuned. A variable power divider[2] is used to vary the power fed to the cavities and a phase shifter is mounted between the power divider and the microtron. The phase shifter is necessary to reduce the loading effects of the high Q accelerator cavity on the magnetron. Loading effects are observed even though considerable isolation exists between these two components. Under present operating conditions only a fraction of the available power is required to drive the accelerator.

Operating Characteristics

The energy of the extracted electron beam can be varied by changing the energy gain per orbit and by switching the mode in which the accelerator is operating. The latter refers to the number (n) of RF periods by which the orbit time increases from one orbit to the next. The energy gain per traversal of the accelerating structure can, at the present time, be varied from 1.5 to 3 MeV, by changing the fraction of the available RF power that is used for acceleration. In order to satisfy the condition that the orbit time for each orbit be close to an integral number of RF periods (resonance condition)[3], the average induction of the guide field as well as the length of the drift space between the two main magnet sectors must be adjusted to match a given energy gain. The latter adjustment is accomplished by moving the magnet pole-pieces inside the vacuum chamber. When the accelerator is operated in the basic n = 1 mode extraction takes place in mid-orbit after six traversals of the accelerating structure, giving a final energy range of 9 to 18 MeV. Operation in the n = 2 mode with three traversals allows the energy to be varied between 4.5 and 9 MeV. In addition the beam can be extracted after a single traversal at energies of 1.5 to 3 MeV.

The accelerator is designed for final beam currents of up to 50 mA in the pulse (25μA average). In the tests performed so far the current was, however, kept below 1 mA in the pulse since high currents are not required for the adjustments and modifications that are still in progress.

In tests performed so far the final energy of the electron beam has been varied throughout the ranges given above, thus demonstrating the feasability of using racetrack microtrons to achieve a wide range of beam energy. It has also been demonstrated that multiple cavity accelerating structures can be used in racetrack microtrons.

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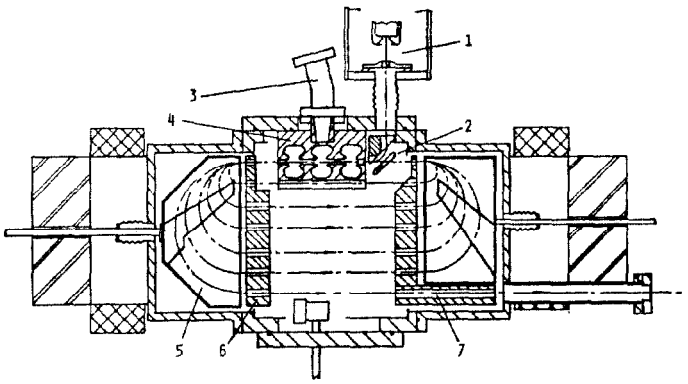


Fig. 1. Schematic diagram of the Variable Energy Racetrack Microtron.

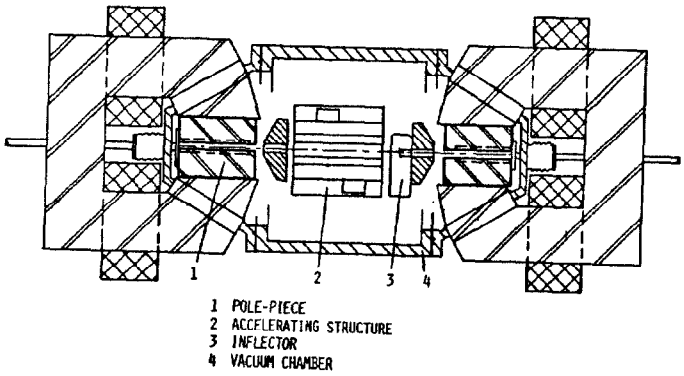


Fig. 2. Section of the Microtron

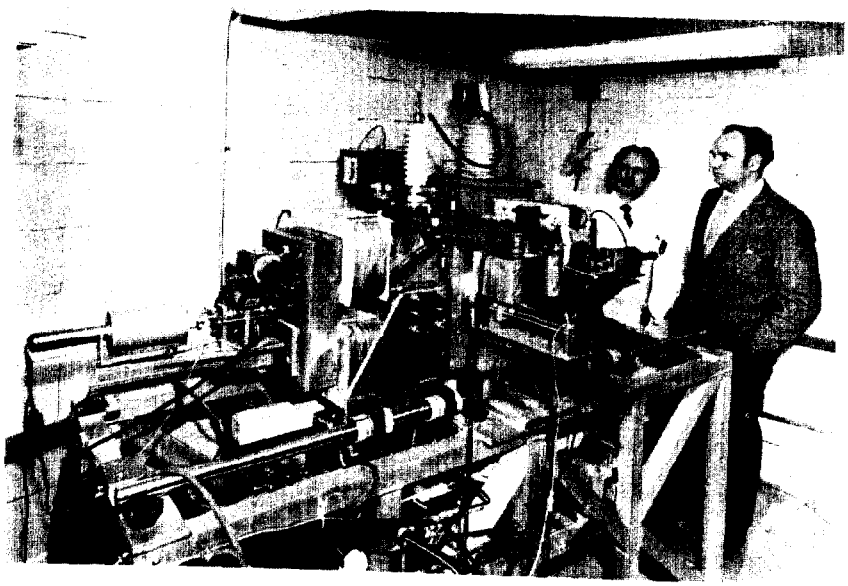


Fig. 3. 4.5 to 18 MeV Racetrack Microtron