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A 100-MeV INJECTOR RACE-TRACK MICROTRON FOR THE MAX STORAGE-RING/PULSE-STRETCHER

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Summary

A 100 MeV pulsed race-track microtron (RTM) has been in operation at the University of Lund since 1979[1]. The RTM will now be used as an injector for a storage-ring/pulse-stretcher currently being built. The RTM with its injection, acceleration and extraction systems are described and the beam characteristics are discussed.

Introduction

The 100 MeV RTM was chosen as an injector to a 550 MeV storage-ring/pulse-stretcher due to its compactness and the expected high quality of the beam. A similar injector choice was made for the Aladdin project[2].

The RTM project in Lund was approved in 1976 and the first 100 MeV beam was taken out 1979. During the work on the RTM we have had a fertile cooperation with the accelerator group at RIT, where a 50 MeV RTM was built simultaneously[3].

The 100 MeV RTM is shown in fig. 1 and its main parameter values are seen in table 1.

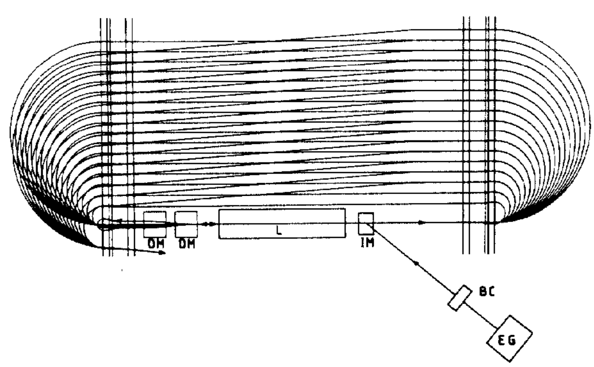

Fig. 1: The Lund RTM

Table 1: Microtron parameter values.

Emittance	< 10 eV rad-m
Electron energy	10-100 MeV
Pulse current	24 mA
Pulse length	0.5-2 μs
Energy spread	100 keV
Rf	3 GHz
Resonant energy gain	5.3 MeV
No. of turns	19
Total weight	6 t
Dimensions	2.5 x 1.5 x 1.5 m^3
Dipole magnet field	1.114 T

Injection, acceleration and extraction

The electron gun is of the spherical Pierce type with a sintered 8 mm dia. La B_6 cathode. The gun is operated in the temperature limited region. The beam from the electron gun can be bunched with a 3 GHz buncher before entering the linac. After the first transit, the beam is reflected back to the linac by one of the two 180^o-bending magnets and two small displacing magnets. The linac is of the side-coupled, $\pi/2$ mode standing wave type and can thus accelerate the beam in either direction. By moving the linac along its axis, we can freely choose the resonant phase angle for acceleration without interfering with the resonant condition for the higher orbits, which is a function of the distance between the two 180^o-bending magnets. The electron bunch phase angle at the second linac transit will in this way be de-coupled from the injection parameters like the electron gun voltage, the first orbit length and the linac field strengths.

After the second linac transit, the electrons are accelerated in the conventional way in a RTM.

The two displacing magnets will naturally also influence the beam in all orbits. This effect is compensated for by small correction windings at the linac axis in the 180^o-bending magnets.

For extraction, we are using a similar system to that in Mainz[4]. A moveable magnet can kick the beam in any orbit but the first four ones into an extraction channel.

Focusing

When focusing in a RTM, one can either put the focusing elements in the individual return paths or one can use the common orbit along the linac axis. In the former case, one can get similar betatron function values in all orbits, with an adiabatic shrinkage of the beam dimensions at higher energies as a consequence, but the number of focusing items will be relatively large. When focusing on the linac axis, the focusing effect will be relatively weak at higher energies since the focusing strength is limited by the particles at low energy and the focal length mostly increase with energy. We will then operate close to integer resonances at higher energies with a high sensitivity to dipole errors.

In a smooth approximation, it can be shown that the beam dimensions are roughly constant if the focal length is increasing quadratically with energy[5].

A computer code was written for the study of the focusing properties of the RTM. The discussion below is refering to these calculations and the computed beam dimensions are then compared to the measured beam size.

The linac is cylinder-symmetric and is slightly focusing for relativistic particles with a focal length increasing quadratically with energy. At injection, where the electrons are far from relativistic, the focusing properties are phase-dependent and the injected beam emittance will be diluted, this effect being a function of the injected bunch length. The focusing strength of the linac is however too weak for optimal operation in our case.

For the first few orbits, the fringing fields at the main bending magnets should, if not compensated for, introduce a severe vertically defocusing effect and they should also endanger the longitudinal stability. We have therefore used the Babic-Sedlacek method[6] with a reversed field in front of the bending magnet.

An example of this focusing is seen in fig. 2. Focusing with this method is a second order effect[4]. Due to the strong non-linearitets at the fringing fields, the effective vertical aperture is just around 5 mm in the first orbits.

To get a focusing stronger than that given by the linac in the horizontal direction, we have introduced a quadrupole on the linac axis. This quadrupole will give us a beam with slightly decreasing horizontal dimensions.

The vertically defocusing effect of this quadrupole will dominate the focusing from the linac and the reversed fields at higher orbits. The main magnets fields in the 180^o-bending magnets have therefore been

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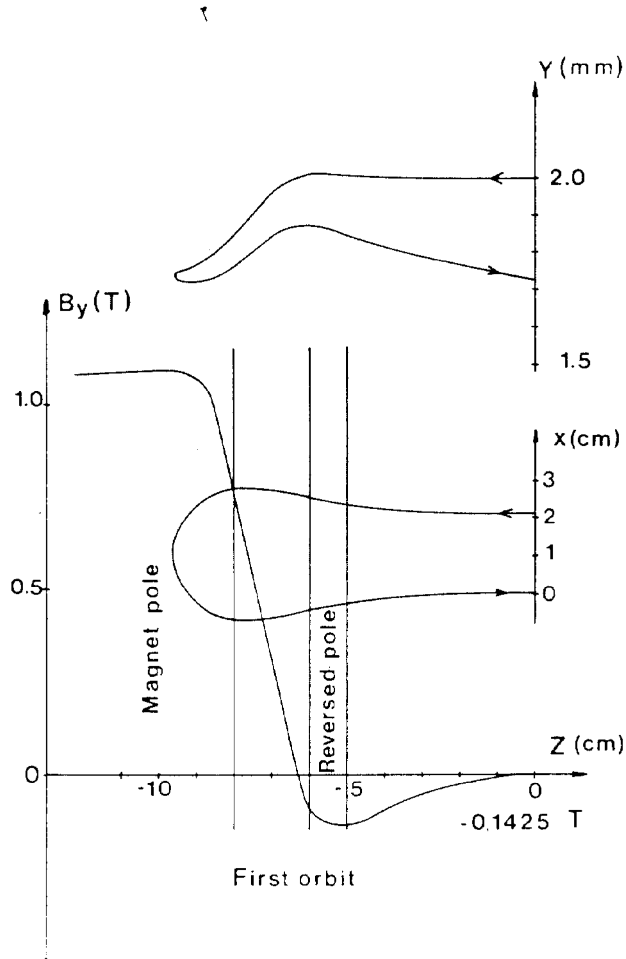

Fig. 2: Focusing in the RTM

tayloed to give a small negative gradient inwards the magnets. This will give us a constant vertical focal length at higher orbits while leaving the horizontal focusing unchanged.

One example of the calucalted emittance is seen in fig 3.

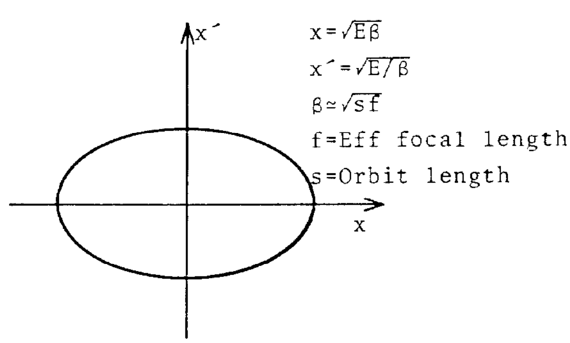

Fig. 3: Emittance ellips at higher orbits.

To measure the beam dimensions, a TV camera was used to monitor the synchrotron radiation from the different orbits. The beam dimensions were found to be around 2 mm in both directions in orbit 7-14 in agreement with the calculations. The TV camera proved to be a valuable tool when operating the machine and the effect of the focusing devices could be seen clearly. Fig. 4 shows the beam with the main magnet pole-face windings giving the vertical focusing effect switched off. The distances between the orbits are 20 mm and the highest orbit seen is no. 14.

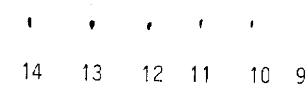

Fig. 4: Synchrotron radiation from orbit 9-14

Corrections

As mentioned above, the focusing is rather weak at higher energies and the beam is sensitive for dipole errors. To relax the tolerance demands on the magnets, we have introduced dipole corrections in all return paths. We are adjusting in the horizontal direction with small windings at the reversed field poles and in the vertical direction with individual steering magnets in the vacuum chamber between the two 180°-bending magnets.

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