BEAM EMITTANCE MEASUREMENTS ON THE RACE TRACK MICROTRON

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Abstract

Calculation and measurement of the beam emittance and maximum energy spread in the MAX-lab 100 MeV Racetrack Microtron (RTM) has been performed.

The injector in the MAX-Laboratory accelerator system is a 100 MeV racetrack microtron. In the design report, the emittance is roughly calculated to 0.1 mm mrad and the maximum energy spread to 100 keV. These values are to be verified.

The beam emittance is measured by detection of the synchrotron radiation emitted in one of the RTM bending magnets. The energy spread is detected by measuring the deviation of the beam position while varying the radio frequency (RF) power to its limits. The measured value of the normalised emittance is 20 mm mrad. The measured maximum energy spread is 90 keV.

1 INTRODUCTION

The racetrack microtron is ageing, commissioned in 1979. Plans for building a new injector scheme exist. To the design of the new injector it is of great importance to more exactly know the performance of the old one. But all beam parameters for the RTM have not been measured accurately. The values stated in table 1 are the known parameters. The parameters to be measured and calculated better are the emittance and the maximum energy spread. Too low emittance and too high energy spread decreases the performance of the rest of the accelerator system MAX.

Table 1: The main parameter values. [2]

Maximum energy	97 MeV
Pulse current	10 mA
Pulse length	0-1 µs
Nr of orbits	19
RF	3 GHz
Maximum energy spread	100 keV
Emittance	0.1mm mrad

2 THE RACE TRACK MICROTRON

An electron gun delivers a 100 keV, 4 µs long pulse to the microtron linac. Before entering the linac the electron beam is bunched by a subharmonic buncher. The beam is then recycled under resonant conditions, increasing its energy at each turn with the resonant energy gain ΔE=5.1 MeV, until the final energy is reached. A movable extraction magnet deflect the electron beam from any return orbit but the first few ones into an extraction channel. Figure 1.

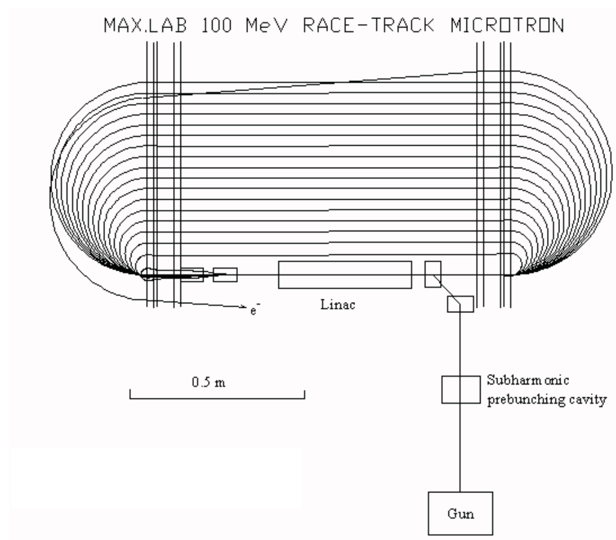

Figure 1. The Race Track Microtron.

For good injection it is important to have a small energy spread, a small beam size/emittance and good matching. The figure of merit is the electron brilliance *B*, this in analogy with photon brilliance for a storage ring, defined as

$$B_e \propto \frac{I}{\varepsilon_H \varepsilon_V \cdot \Delta E/E} \ ,$$

where *I* is the current, ε the horizontal and the vertical emittances and ΔE/E is the normalised maximum energy spread.

3 EXPERIMENT

The measurements are done by the detection of synchrotron radiation emitted in the racetrack microtron bending magnets. [1]

An ordinary CCD-TV camera is used to record the light. Since the camera is sensitive for ionising radiation it had to get out of the main radiation field. Therefore a mirror is used to reflect a certain beam spot for investigation. Figure 2.

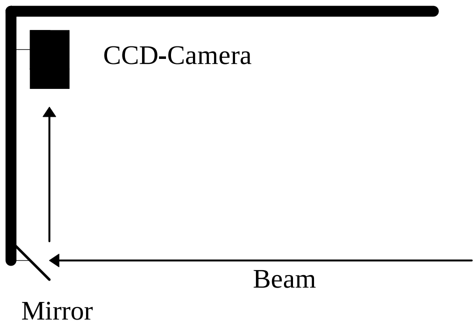

Figure 2. The experimental set-up I.

The signal from the camera is taken both to a TV-monitor and an oscilloscope. To the TV to be able to watch the picture to get the focus when calibrating, and during measurements to see that the right beam spot is measured. To the oscilloscope to measure the beam size. Figure 3. The β-functions for the racetrack microtron are easily obtained and the emittance for each track can be calculated. [1]

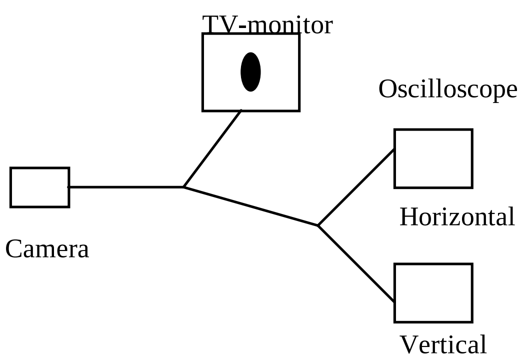

Figure 3. The experimental set-up II.

While varying the RF-power to the limits and thereby the energy of the beam, the maximum energy spread can be seen on the TV monitor. By recording the light from several tracks the maximum energy spread is measured. [1]

Similar set-ups and experiments have been used earlier at MAX, for the diagnostics of the storage rings [3] but it has never been used on the microtron.

4 RESULTS

The measurements gives the beam size's σ_H and σ_V as listed in table 2 and 3. Taking the square and dividing with the β-functions the emittances ε are calculated.

$$\varepsilon = \frac{\sigma^2}{\beta} \ ,$$

also listed in table 2 and 3. Multiplying the ε with γ, the normalised emittance ε_n, which is the most comparable factor with respect to the different energies, is obtained.

Table 2. The horizontal emittance.

Track	Horizontal σ (mm)	Horizontal ε (mm mrad)	γ	Horizontal ε_n (mm mrad)
16	0.80	0.088	160	14.2
17	0.78	0.081	170	13.4
18	0.76	0.073	180	13.1
19	0.66	0.053	190	10.1

Table 3. The vertical emittance.

Track	Vertical σ (mm)	Vertical ε (mm mrad)	γ	Vertical ε_n (mm mrad)
16	1.04/1.19	0.17/0.23	160	27.6/36.0
17	1.19	0.22	170	37.8
18	1.18	0.22	180	38.9
19	0.773/1.3	0.091/0.24	190	17.4/45.4

The results are quite constant except for the 19'th track which differs. The beam size suddenly diminish enormously especially in the vertical direction. The beam is cut somewhere in the 18'th orbit.

The maximum energy spread is measured to ΔE=90 keV.

Using these results the quality factor electron brilliance can be calculated and compared during the design of a new injector.

REFERENCES

[1] M. Georgsson, "Beam Diagnostics on the MAX-lab 100 MeV Race Track Microtron", ISSN 0284-1258 ISRN LUNDTDX/NTMX--7026--SE

[2] M. Eriksson, "Focusing And Beamloading In A Race-Track Microtron", Max publications (NTMX-7071) 1991

[3] Å. Andersson, J. Tagger, "Beam Profile Measurements At MAX", NIM A 364 (1995).