Present status of 20 MeV classical Microtron for the tabletop synchrotron "MIRRORCLE-20"

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Abstract

Study on the beam dynamics and the emittance measurements of the classical microtron are shown. This microtron is featured by the electron emitter positioned inside of the cavity. It is found that the observed emittance is satisfactory small for the injector of the smallest synchrotron.

1. INTRODUCTION

We have introduced the 20 MeV classical microtron as an injector of the world smallest synchrotron, "MIRRORCLE-20". The requirement on the beam quality for the beam injection is of 30x10^{-6} mrad emittance, and less than 1% energy spread. Also the same timing and the accelerating frequency between the injector and the synchrotron are recommended. This microtron was originally equipped with a magnetron microwave source, but we have replaced this to the klystron source because of the above requirements. The synchrotron is driven by the 2.45 GHz CW klystron.

We have studied the beam dynamics prior to this modification incorporating with the internal electron emitter and the rectangular shaped cavity. The commissioning of the microtron with the klystron and new cavity was successfully made. In this paper the emittance measurement is also reported.

2. PARTICLES DYNAMIC SIMULATION IN MICROTRON

Associated with the change in the microwave power source of the microtron from magnetron (2.8GHz) to klystron (2.4446GHz), we have changed the size of RF cavity. To do so the study on the microtron operating under the second type-accelerating mode was performed. The terminology and notations used here are typical for this type of accelerators [1]. The computer simulations were carried out in order to obtain an optimal emitter and slits positions. The simulation technique is based on the Macro Particles Approach.

1.2 The Results Of simulations

The cathode position ξ_c is the major concern. The curves in the Fig.1 demonstrate the capture coefficient versus the equilibrium phase φ_s for the different cathode positions.

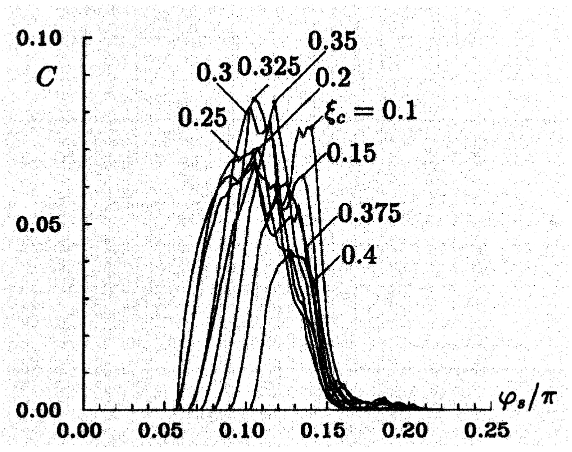

Fig.1 The capture coefficient vs the equilibrium phas φ_s. The curves are formed to the centre positio ξ_c.

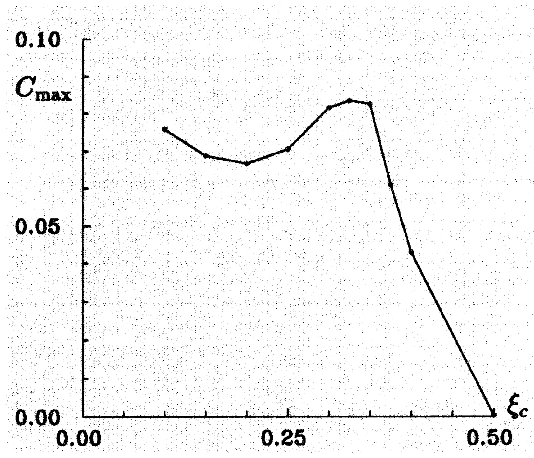

Fig. 2 The dependence of C_{MAX} vs. the cathode position ξ_c is shown. This curve is obtained from the results shown in Fig.1.

Using the results shown in Fig. 1, we have obtained the dependence of the capture C_{max} versus the cathode position ξ_c as shown in the Fig. 2. The maximum capture is obtained at the distance around ξ_c=0.32.

We have also studied the optimal cavity parameters. The question was the ratio between the horizontal size "a" and the vertical size "b" of the cavity. In the Fig. 3 the dependencies of capture C versus parameter φ_s are shown. The curves are constructed for different values of

$$\chi = \frac{b}{\sqrt{a^2 + b^2}},$$

where a is the half length of the cavity (along x axes), and b is the half width of the cavity (along y axes). The dependence of C_{max} versus the value of χ is shown in the Fig. 4.

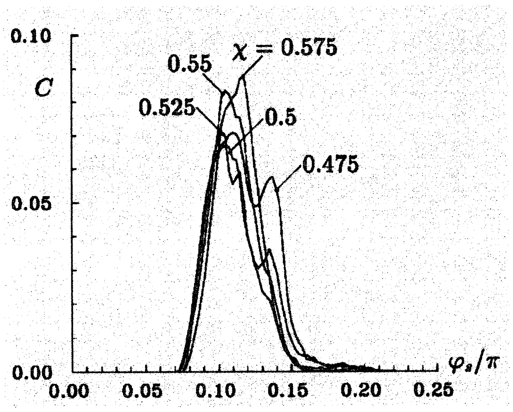

Fig. 3. The capture coefficient C vs. parameter φ_s.

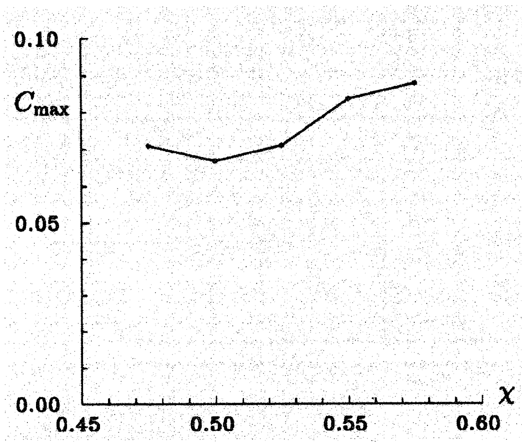

Fig. 4. The dependence of C_{MAX} vs. the value of χ, according to the results, shown in the fig. 3.

In the Fig. 5 the dependencies of capture C versus parameter φ_s are shown. The curves are constructed for different values of ζ_h, where ζ_h is the dimensionless cavity height. The dependence of C_{max} versus the value of ζ_h, corresponding to these results is shown in the Fig. 6.

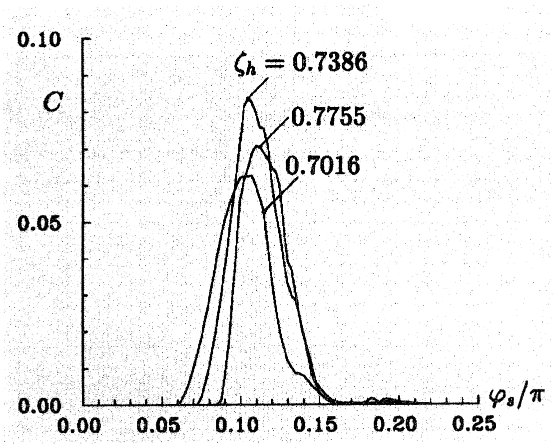

Fig. 5. The dependencies of capture C vs. parameter φ_s. The curves are constructed for different values of ζ_h.

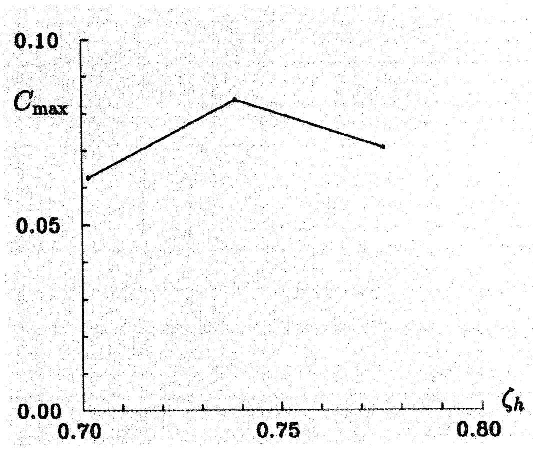

Fig. 6. The dependencies of C_{MAX} vs the values of ζ_h, corresponding to the results, shown in the fig.5.

3. EMITTANCE MEASURMENTS

3.1 Beam size and Emittance

We have measured the emittance of microtron beam by scanning the quadrupole magnet (QM) force. The beam transport system is shown in fig. 7. We have used the QM after the bending magnet.

The emittance is calculated by investigating the change of the electron beam size caused by alternating the QM force. The square of beam size is given by the following relation.

$$\sigma^2 = A(K - B)^2 + C,$$

where σ is the beam size, K is the resistive force by QM, A, B, and C are the parameters related to the emittance by the following formulas:

$$\varepsilon = \frac{1}{L^2}\sqrt{AC}.$$

In this relation L is the distance to the screen from QM. So the emittance can be calculated after finding the constant A and C, using the dependence of the beam size vs QM force.

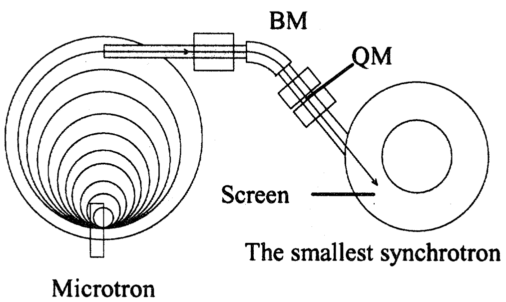

Fig. 7. The beam transport system of MIRRORCLE-20. The screen for electron detection is set at the injection point after passing the QM.

Electron beam was detected with the fluorescent screen monitor. The fluorescence from the screen was captured by CCD camera, and digitised. The size of electron beam was measured by analysing the projections of beam profile. The profile of electron beam is shown in fig. 8. According to this beam size measurement, the beam emittance was obtained. Table. 1 shows the latest results. The obtained value is much better than the expected value 8 π mm mrad. On the other hand the present beam current (2 mA) is not yet reached to the designed value 10mA peak current. This could be caused by the low Q-value of the cavity. The training of the cavity is under progress.

Table. 1. The latest emittance of microtron.

Horizontal	Vertical
0.82 (π mm mrad)	1.50 (π mm mrad)

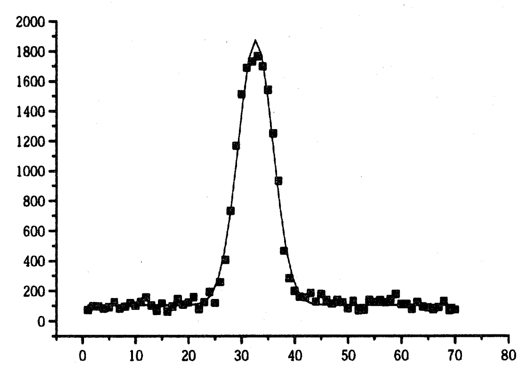

Fig. 8 The observed beam profile

4. REFERENCES

[1] S.P.Kapitza and V.N.Melekhin. The Microtron, ed. by E.M.Rowe, Harwood Acad. Pubs, London, 1978