HIGH CURRENT CIRCULAR MICROTRON WITH THE RECTANGULAR RF CAVITY FOR THE TABLETOP SYNCHROTRON "MIRRORCLE-20"

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Abstract

The 20 MeV microtron with the rectangular cavity is used as an injector of the world smallest synchrotron "MIRRORCLE-20". The careful investigations of the electron beam dynamics in the present 20MeV microtron has been carried out to increase the capture efficiency. We have find out, that the microtron cavity design should be based on the beam trajectory numerical modeling. It was shown, that this requirement is determined by the so call "first orbit tracing problem", which is typical for the microtron with high current and high energy gain.

We have experimentally demonstrated, that for the microtron with the second type acceleration mode and rectangular cavity it is possible to obtain the 4% capture coefficient and get 30mA beam current.

The beam dynamic and the cavity design

In the MIRROCLE-20 Project, the rectangular waveguide type cavity is used for the microtron [1], [2], [3]. This is well known, that the rectangular cavity has some advantages in comparison with the conventional cylindrical one. As it was shown in [4] and [5], using the rectangular cavity we can use the larger values of energy gain Ω as well as to decrease the gap between the magnet poles. The further microtron cavity improving is based on the ideas, suggested in the paper [6]. The authors find out, that the acceleration modes with an increased cavity thickness are of practical interest. There are at least two reasons for such conclusion. The first one is that the increasing the cavity thickness lead to the increasing the efficiency of using microwave power. The next one is the Q-value increasing. All of this must result in an increase in current of the acceleration beam without an increase in the microwave power.

At the same time, using the thick rectangular cavity result in some difficulties, caused by the passing the beam on the first external orbit. As it was shown in [5] and [6], in the case under consideration, the beam passes in the immediate vicinity of the cavity corner. This phenomena apparently is the reason why the advantages of using rectangular thick cavities practically does not realized yet.

In the papers [2] and [3] the new method of particles dynamic simulation was suggested. The method is based on the macroparticles approach. It is necessary to underline, that our approach allow us to calculate the accelerating current directly. The method, used in [9], need the integration procedure over the captured are, which, in general, not obvious. Indeed, as it was shown in [3] and [5], in some cases the structure of the capture region is very complicated. We do not dwell on this question and said only that the correct analysis need some special approach.

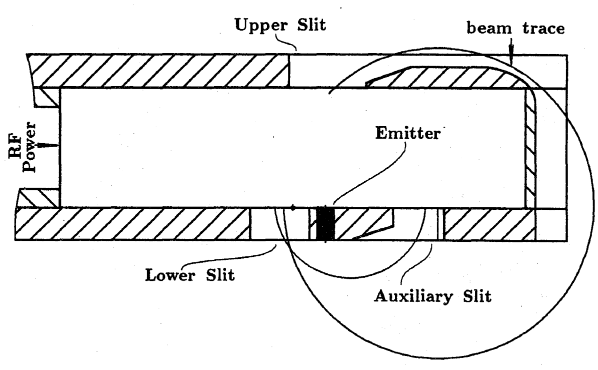

Fig. 1. The microtron cavity structure and the first and auxiliary beam orbit.

In the Fig. 1 the results of microtron cavity design, based on the orbit tracing is shown. During our simulations, we took into account all orbits, but in this figure, we show (for simplicity) only the beam envelope, corresponding the auxiliary and first orbits. This result demonstrate, that the orbits pass very close to the cavity corner and so the careful design, based on the beam tracing is quite desirable for the successful realization the advantages of the thick rectangular microtron cavity.

Experimental results: Emittance and current measurements.

In this section we present the last experimental results of the MIRRORCLE-20 microtron investigation. The cavity, shown in Fig.1 was used for the particle acceleration. The system of the electron beam transport in "MIRRORCLE-20" is shown in Fig. 2 (see also the details in [1]).

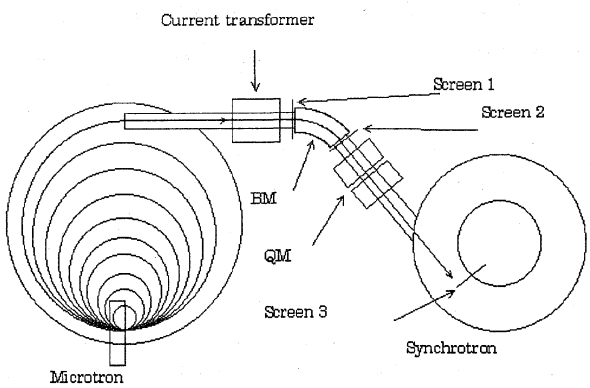

Fig. 2. The "MIRRORCLE-20" beam transport system.

The electron beam was detected with the fluorescent screens 1 - 3. The fluorescence from the screens was captured by CCD camera. The typical electron beam images is shown in Fig. 3. We have measured the emittance of microtron beam by scanning the quadrupole magnet (QM) force [1].

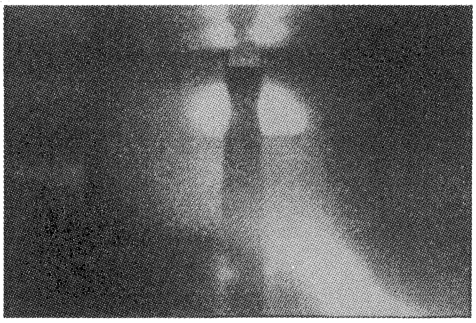

Fig. 3 (a) . The typical electron beam images on the screen 1

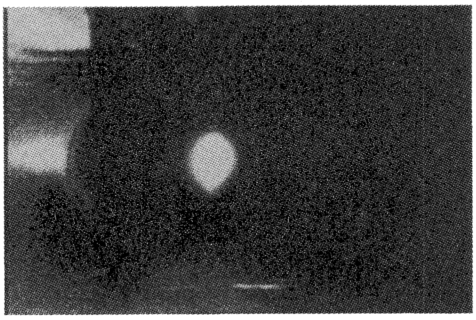

Fig. 3 (b) . The typical electron beam images on the screen 2

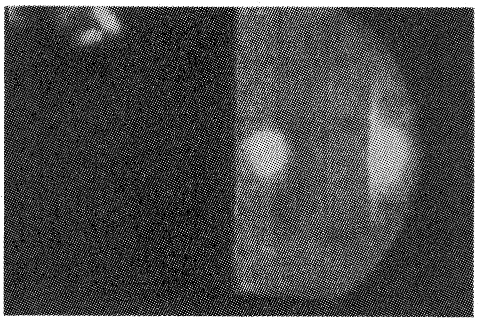

Fig. 3 (c). . The typical electron beam images on the screen 3.

The measurements show, that the horizontal emittance is 1.17π mm·mrad while the vertical emittance is 1.36π mm·mrad. We have measured the beam current with current transformer. The maximum current recorded 32mA and so we enlarge the previous value (see [1]) more than 20 times. In this case, the emission current of the electron source was 1100mA, and the capture coefficient was 2.9%. The maximum capture coefficient was 3.5% (the beam current is 28mA, the emission current is 800mA).

These results demonstrate, that using the thick rectangular cavity is possible in the classical circular microtron. However, high efficiency and high current can be obtained after very careful design: the accurate beam tracing should be performed.

References

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