SIMULATIONS FOR BUNCHER CAVITIES WITH LARGE APERTURE

P. Till, P. Kolb, A. Schempp, J. Schmidt, M. Vossberg
Institut für angewandte Physik
Johann Wolfgang Goethe-Universität, Frankfurt am Main

Abstract

Buncher-cavities can be used to bunch, rebunch or reaccelerate particle beams. A special form of these buncher-cavities is the spiral-structure. Its feature is the easy adjustable frequency. In this work two different spiral resonators were simulated and built for the EBIS facility at Brookhaven National Laboratory. These buncher-cavities have a remarkably large aperture with a drift-tube radius of 50 mm. To adjust the cavities to the required BNL frequency of 100.6 MHz, simulations have been carried out. The impact of changing the gap width, drift tube length, and spiral arm length on the design of the spiral cavities has been analyzed. Additionally simulations of the field distribution along the beamline will be presented. For such big drift-tube radii, it is especially interesting to compare the field on the beam axis to the field near the drift tube.

INTRODUCTION

A spiral structure can be applied to adjust a particle beam in the longitudinal direction, to bunch or reaccelerate it. In order to do so, it is typically placed between different accelerator units to ensure an ideal transition or at large beam ways to keep the bunch in a proper shape. The most simple variation of such a cavity is a $\lambda/4$ resonator. It is made of a drift tube, which is connected with the bottom plate over a spiral formed arm which can be turned without changing the orientation of the drift tube. It will always stay in the resonators center. That simplifies the frequency adjustment enormously. While the arm is turned the induction changes and that causes a frequency change. This effect can be increased by cutting the overlapping part. The longer the arm is, the lower is the frequency. For this reason the frequency of such a cavity is largely independent of its dimensions. Originally the spiral arm was designed as a combination of two radii in a 2:1 relation [1]. In order to simplify the fabrication we decided to modify the design, as shown in Fig.1.

The EBIS facillity at BNL will replace the Tandem Van de Graaf accelerators. It consists of an EBIS source, a RFQ and an IH LINAC [2]. As a part of the EBIS preinjector, the buncher cavities will be installed in the High Energy Beam Transport (HEBT) line from the linac to the Booster [3]. They are used to reduce the energy spread of the beam.

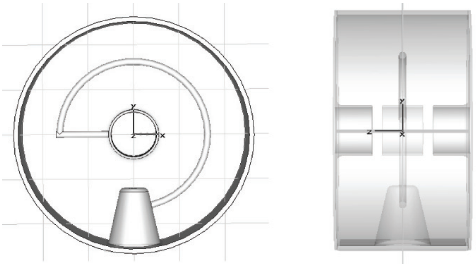

Figure 1: Front and side view of the spiral resonator

SIMULATIONS OF THE TWO GAP BUNCHER

Due to the long drift way in the HEBT, large drift tubes are necessary. The cavity was designed and simulated within CST Microwave Studio.
Essentially there are two options to tune the frequency of a spiral-buncher:

- Turning the arm
- Changing the gap width

Changing the arm, which is possible due to geometrical reasons, induces a change in induction and thus a change in frequency.
In our model a change of gapwidth about 1mm leeds to an frequency change of 1.2 MHz. When changing the gapwidth one has to keep in mind that only a small range is possible, otherwise side-effects occur and the field distribution will be altered. But it is a good method for presicion tuning of the frequency after cutting the arm.

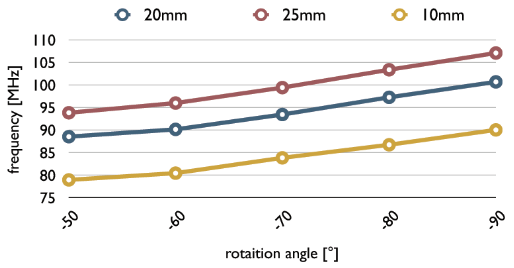

Figure 2: Frequency as a function of gap width and rotation angle for the two gap buncher.

We simulated the effects of those methods. The results of our analysis are shown in Fig. 2. One observes a monotonic increase as a function of rotation angle and an increase of frequency with larger gap width. Using this study we could reach the design frequency of 100.6 MHz by setting the rotation angle to 90 degrees and the gapwidth to 17 mm.

Field distributions

As expected the abslotute value of the electromagnetic field along the beamline has its peaks in the center of the gaps. In comparison the electromagnetic field near the drift tube boundary is much larger than in the center, which is necessary for bunching the beam (see Fig. 3).

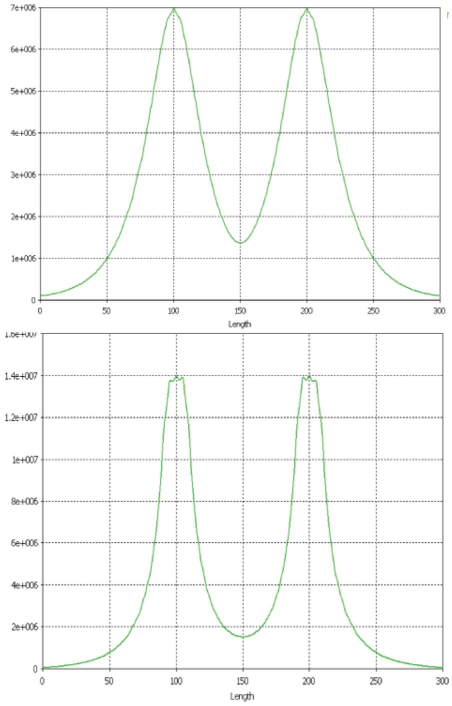

Figure 3: Field distributions along the beamline in the center (top) and near the drift tube boundary (bottom)

SIMULATIONS OF THE FOUR GAP BUNCHER

The second buncher, which is shown in Fig. 4, is made of 3 with a spiral arm connected drift tubes. The properties of the buncher can be found in Table 1. In this design the frequency tuning is realized by turning or shortening the arm. We analyzed these effects with CST Microwave Studio simulations. For different parameters of the opening angle of the spiral arm (depiceted in Fig. 4 it is an angle of 180°) we obtained the following results:
Adjusting the frequency by turning results in only 2 MHz per 10° turn. Shortening the arm by 10° results in a change of frequency of 2.2 MHz , which is not much more effective but it allows us to keep the field distributions as shown in Fig. 5. The measured value of the frequency fits to these results. The field distributions in Fig. 5 show comparable effects to the distributions of the two gap buncher. The fields near the boundary are remarkably larger than in the center, but not as large as the fields along the beamline. The reason for this structure is that the fields differ in the x- and y-components, which leads to field distributions depicted in Fig. 5

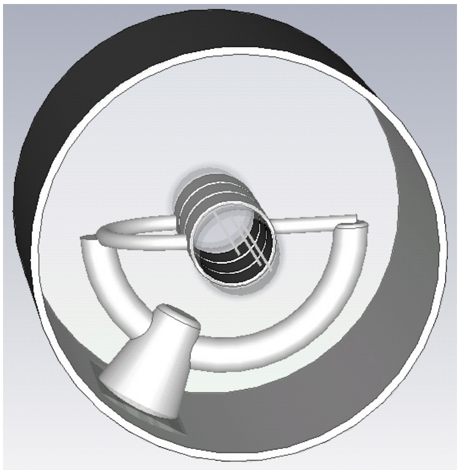

Figure 4: Setup of the four gap cavity

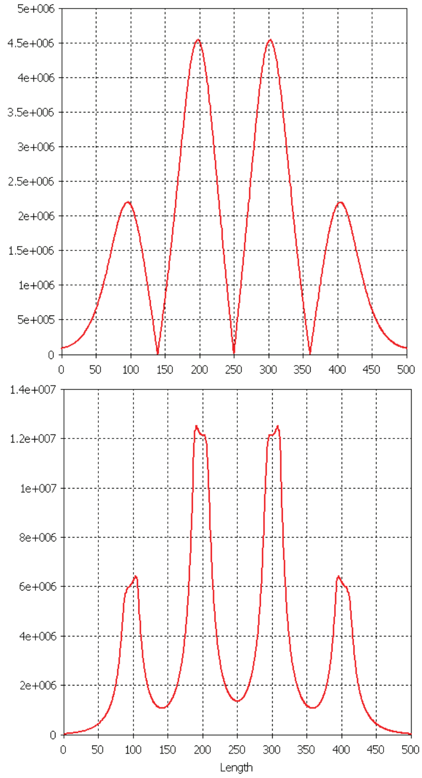

Figure 5: Field distributions of the four gap buncher

Table 1: Buncher properties

tank length	500 mm
tank radius	250 mm
spiral arm radius	162,5 mm
radius of drift tube	50 mm
gap width	20 mm
frequency (sim.)	100 MHz
frequency (exp.)	100.6 MHz
Q-factor	3071

STATUS

The two gap buncher was build at the IAP and sent to BNL in 2009. The four gap buncher was tuned and build recently and will be prepared for transport in the near future.

REFERENCES

[1] A.Schempp and H.Klein, "Properties of spiral loaded cavities", Nuclear Instruments and Methods 135 (1976)

[2] J. Alessi et al., Status of the EBIS Project at Brookhaven, Proc. of the 2006 LINAC Conf., Knoxville, Tennessee, USA, p.385

[3] J.Alessi et al. ,"Construction of the BNL EBIS preinjector", Proc. of PAC09, Vancouver, BC, Canada