DEVELOPMENT OF FFAG ELECTRON ACCELERATOR

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Abstract

Electron Beam (EB) Accelerators have been used in the many industrial fields to improve physical properties of the material. Examples are wire and cable industries, rubber tire industries, foam industries, etc. EB is also widely used for medical device sterilization as a popular tool. High power, high reliability, compactness and low cost are key requirements to get popularity of the technology and to open up its application fields. The paper will present FFAG electron accelerator to meet these requirements that NHV Corporation recently developed and some of the interesting performance such as beam extraction efficiency will be discussed in the paper.

INTRODUCTION

Since the acceleration for 500keV proton beam using pop-FFAG accelerator was achieved at KEK in 2000[1], FFAG accelerator is prospective as a compact and versatile accelerator. We hope that FFAG electron accelerator will be used in the many industrial fields to improve physical properties of the material with some features which are high power, high reliability, compactness and low cost. So we have developed the prototype of FFAG electron accelerator. Its acceleration system is based on induction acceleration. In this case very long pulse beam can be accelerated, but the beam extraction from the FFAG ring is difficult normally. In our prototype FFAG accelerator we succeeded in the beam extraction from the FFAG ring using a combined septum system.

PROTOTYPE OF FFAG ELECTRON ACCELERATOR

The specifications of the prototype of FFAG electron accelerator are shown in table 1. The features of the prototype of FFAG electron accelerator are

a) Compactness by reason that the magnet is the spiral type [2],

b) Induction acceleration.

Table 1: Specifications of the prototype of FFAG electron accelerator

Energy	50-500 keV
Cell number	6
K value	0.6
Radius	0.19-0.44 m
Packing factor	0.4
Spiral Angle	30 deg
Tune	1.3 / 1.2
Acceleration frequency	10 kHz
Duty	20 %
Outer diameter (size of acc.)	1.1 m

BEAM EXTRACTION FROM THE FFAG RING

The length of pulse beam is 15 microseconds because the time that the beam can be accelerated is 20 microseconds and the time that the beam is accelerated from injection energy to extracted energy is 5 microseconds. This length of the pulse beam is longer than the length of outside orbit path. So pulse beam is same as well as DC beam in case of the consideration for the beam extraction. The turn separation of beam is very small also. So a kicker system can not be used in this beam extraction and we use a combined system which is consisted of a mass less septum[3], a electrostatic septum and a static magnetic septum.

A mass less septum makes the betatron tune shift horizontally and the betatron tune come close to the third resonance. The results of beam tracking are shown in Figure 1. The beam is extended by the working of the mass less septum and the part of the extended beam is cut and deflected by a electrostatic septum using a thin foil. The electrostatic septum is arranged to next drift space over a magnet because the phase advance per one cell is almost 90degree and the shift of beam gradient by the mass less septum change to the shift of beam position. Finally the beam is deflected to 30degree by a static magnetic septum. The profile of pulse beam measured at external faraday cup is shown in Figure 2. The efficiency of the beam extraction is 90% and above.

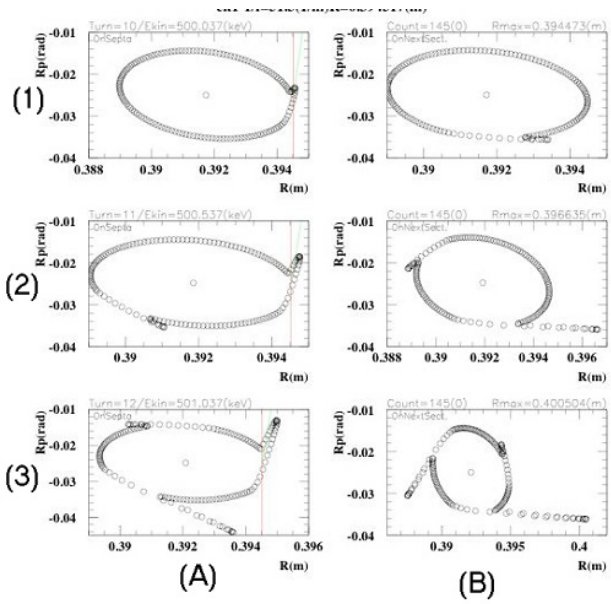

Figure 1: The results of beam tracking. (A) is the beam phase diagram at mass less septum and (B) is at electrostatic septum. (1) is the beam phase diagram at certain turn number near the 500keV beam energy, (2) is at next turn and (3) is at after next turn.

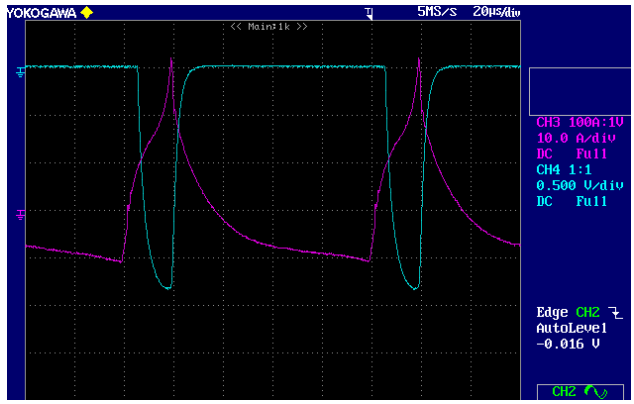

Figure 2: The profile of pulse beam measured at external faraday cup. The blue line is beam profile.

SUMMARY

We developed the prototype of FFAG electron accelerator and succeeded in the beam extraction from the FFAG ring using a mass less septum. In addition the extracted beam is transported to a bending magnet for a measurement of the beam energy and we measured the specified energy.

REFERENCES

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[3] Y. Yonemura et al., Proc of PAC 2003, Oregon, USA, May (2003) 1679