CONCEPTUAL DESIGN OF HELIUM ION FFAGS *

Huanli Luo#, Xiangqi Wang, Hao Hao, Yucun Xu
NSRL/USTC, P.O.Box 6022, Hefei 230029, Anhui, P.R.of China

Abstract

In recent years, Fixed Field Alternating Gradient (FFAG) accelerator is becoming a highlight in particle accelerator R&D area. This type of accelerator could accelerate ions with higher beam current than conventional strong focusing circular accelerator, which could be more useful for the study of radioactive material. In this paper, conceptual design of an FFAG with high Helium ion beam current and a few MeV energy which is dedicated to study the impact of Helium embitterment to fusion reactor envelope material is discussed, and the periodic focusing structure model is given, following which the calculation result of magnetic field is also presented.

INTRODUCTION

The initial concept of Fixed-Field Alternating-Gradient synchrotron (FFAGs) was originally put forward by the United States, Keith Symon, and Japan ,Tihiro Ohkawa,at the same time, in 1953[1].On account of the advantage, such as high intensity, FFAGs is once again becoming a highlight in particle accelerator R&D area fifty years later[2]. Helium ion beam with high current and a few MeV energy is required for studying the action which Helium ion effect on fusion reactor blanket materials. To meet this demand and draw lessons from theory and experience of conventional conceptual design of the circular accelerator, we preliminary carry out the conceptual design of the structure for Helium ion FFAGs. In the study, we fully taken movement characteristics of charged particles in accordance with FFAGs into account

During the design process, scaling radial sector FFAGs has eight super periods and two RFQ cavities originally. A triplet focusing magnet (DFD combination) is adopted for each cell structure, magnetic field configuration using variable focal intensity. In this article, the initial design process of the lattice structure for each unit is briefly described.

DESIGN OF FFAG PERIODIC STRUCTURE MODEL

Magnet Design

Main Ring of Helium Ion FFAGs is designed to eight cycles, and each cycle of magnet construction initially adopt DFD combination. Such a construction can provide sufficient free space, which is favorable to the installation of the RFQ cavity, the injection and extraction devices, and the beam diagnostics instruments[3].

The main F magnet is normal bending sector magnet, focusing for horizontal and defocusing for vertical. Upstream and downstream close to the main bending F magnet, install 2 bending D magnet respectively, which is reversed bending symmetrical magnet, defocusing for horizontal and focusing for vertical. Fig. 1 and Fig. 2 show the initial geometry structure of a cycle for Helium Ion FFAGs. Table 1 lists fundamental parameters of Helium Ion FFAGs.

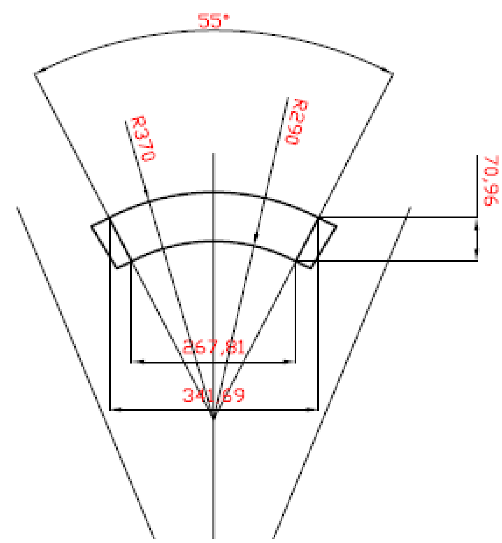

Figure 1: F magnet physical size of periodic structure.

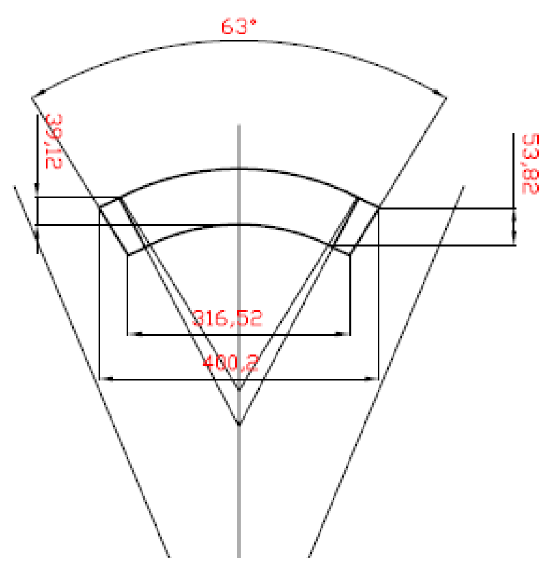

Figure 2: D magnet physical size of periodic structure.

*Work supported by the NSFC of China under Grant No.10575100
Graduate student, huanli@mail.ustc.edu.cn

Table1: Helium Ion FFAGs Model Parameters

Parameter	Design goal
Type of magnet	DFD
Cell number	8
Beam Energy	Injection:1.826MeV Extraction:10.891MeV
Magnetic Field	Injection:0.6319T Extraction:1.3500T
Field index	Injection:$7.5m^{-1}$ Extraction:$8.0\ m^{-1}$
Beam Radius	Injection:0.3080m Extraction:0.3523m
total orbit length	Injection: 4.2606m Extraction: 4.8414m
RFQ voltage	90keV

The Design of the Magnetic Field Configuration

Magnetic field configuration with variable focused intensity is adopted for DFD combination magnet, magnetic field and focal intensity for the main magnet vary with radius of the magnet geometry, for ideal particle closed orbit neighborhood and Zero-dispersion,which is determined in linear theory by the equation (1) and (2)

$$B = \frac{R_0}{r} e^{\frac{K_0}{2\xi} r^{2\xi}} \quad (1)$$

$$K = \sqrt{K_0 r^{2\xi-2}} \quad (2)$$

Where r is geometric radius of the magnet, R_0 the magnetic field configuration constant, K_0 magnetic field focal constant, ξ the index of non-dimensional correction factor, deduced from the need of the magnetic field. In the calculation, $\xi = 1.5$, $K_0 = 182.5$ m^{-3} and $R_0 = 0.0329$ Tm. Fig. 3 shows the relationship curvature

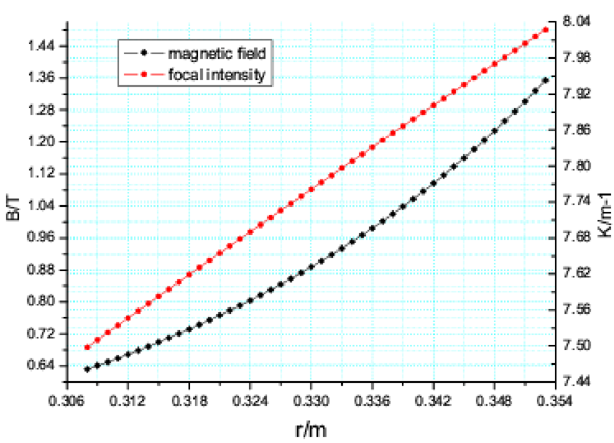

Figure 3: The changes of F magnetic field and focal intensity with the radius of curvature

In FFAGs, particle closed orbit is a function of energy, as magnetic field is static for permanent magnet. The closed orbit for beam with various energies between 1.826 MeV and 10.891 MeV were simulated, using the particle tracking procedures. Fig4 shows particle closed orbit of a cycle for eleven energies, color represents different energies, changing uniformly-spaced from 1.826 MeV to 10.891 MeV

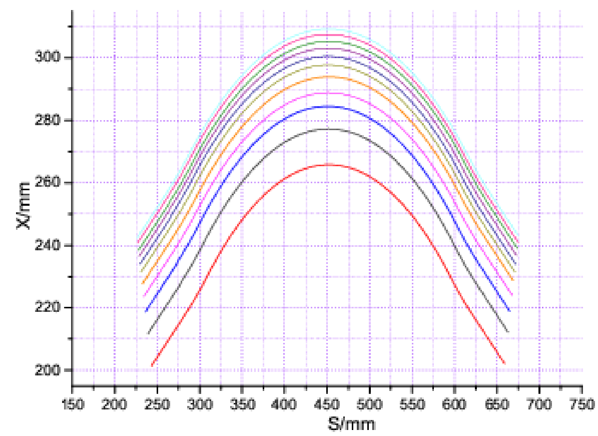

Figure 4: Closed orbit of one cell for different energies.

In the main ring magnet for FFAGs, this magnetic field configuration design is favorable for Helium ion injection in small radius with lower magnetic field and Helium ion extraction in large radius with higher magnetic field.

Tune and Physical Aperture

In tracking, it is found that tune is a function of energy too, we believe, which is permitted, because particles are accelerated shortly to high energy in FFAGs, having not time to form a resonant.

In scaling FFAGs, large physical aperture in the horizontal direction is an essential requirement for Helium ion not lost, as Helium ion closed orbit is a function of energy.

SUMMARY

The focusing structure of a cell for Helium ion FFAGs is presented initially and theoretically in this article. The above data is only a preliminary design, which remains to be the rationality of research. With respect of other theoretical calculations, such as particle horizontal movement, vertical movement and phase shift amount of movement simulation for the main ring and dynamic aperture simulation, this research is in progress.

REFERENCES

[1] http://cern.ch/AccelConf/c01/cyc2001/paper/D-1.pdf
[2] EDWIN CARTLIDGE. A Half-Century Late, Alternative Accelerator Takes Off. SCIENCE, Vol. 315, 16 February 2007, p.933.
[3] M. Aiba, et al., "A 150MeV FFAG Synchrotron with return-yoke free magnet ", PAC'01,Chicago, p.3254 (2001).