STATUS OF 150MeV FFAG SYNCHROTRON

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Abstract

The 150MeV proton FFAG (Fixed Field Alternating Gradient) synchrotron has been developed for aiming to investigate the possibilities of various applications such as proton beam therapy. The construction started in September 2002, and almost completed recently. In the proceedings, the overview of construction and status of commissioning is to be reviewed.

INTRODUCTION

Based on the achievements of PoP FFAG(Fixed Field Alternating Gradient), the project to construct a 150MeV proton FFAG started in 2000[1]. The project aims to build a prototype of FFAG synchrotron for a practical usage and to investigate the possibilities of FFAG for various applications such as proton beam therapy[2].

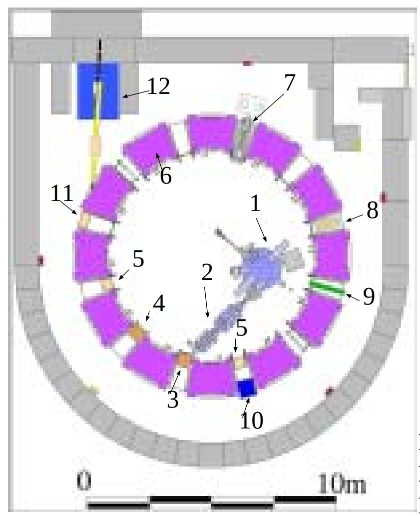
OVERVIEW OF 150MEV FFAG

The main parameters of the 150MeV FFAG are summarized in Table 1, and Figure 1 shows the schematic layout of the accelerator. Compared to the PoP FFAG, in the 150MeV FFAG, two technical challenges are to be tried. One is the employment of the yoke free magnet for the FFAG magnet[2]. The employment of the yoke free magnet is expected to make the beam injection and extraction easier than the case of the conventional FFAG triplet magnet. The other challenge is the beam extraction from the ring. The completion of them should be a milestone for a practical FFAG accelerator.

Table 1: Main Parameters of 150MeV FFAG

Type of Magnet	Triplet Radial (DFD)
Num. of Sector	12
k-value	7.6
Beam Energy (MeV)	12→150 (proton)
Average Radius (m)	4.47→5.20
Betatron Tune	Hor. 3.69∼3.80 Ver. 1.14∼1.30
Maximum Field (T) (on orbit)	Focus 1.63 Defocus 0.78
Repetition (Hz)	250

As the beam injector, a cyclotron which can generate 10MeV proton beam was employed. Because of the pulse operation of the FFAG accelerator, the duty factor of the cyclotron was reduced to, typically, 1/100, by modulating the RF voltage of the cyclotron to reduce the beam loss at the injection stage. With the treatment, a pulsed beam of about 100 μsec wide was injected into the ring.



1. Injection cyclotron
2. Injection line
3. Injection septum magnet
4. Injection ES septum
5. Bump maget
6. Triplet magnet
7. RF cavity
8. Beam position monitor
9. Current monitor
10. Extraction kicker
11. Extraction septum
12. Beam dump

Figure 1: Schematic view of 150MeV FFAG

CONSTRUCTION

The construction of the 150MeV FFAG has started in September 2002 at the east counter hall in KEK, and almost completed in March 2003. Figure 2 shows a picture of the 150MeV FFAG ring and the injection cyclotron.

In the construction of the accelerator, one of the most important issues is careful alignment of the accelerator elements, especially of the sector magnets. From beam tracking simulation, it was found that the misalignment of magnet position should be suppressed below 0.5mm in order to avoid a serious COD.

To achieve such an accuracy, magnet alignment with laser theodolites was carried out. After the alignment, it was found that the positioning accuracy of the markers for the magnet alignment was below 0.2mm. From the accuracy, the final accuracy of the magnet position is expected to below 0.5mm. This is within a satisfactory level for the

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Figure 2: 150MeV FFAG ring and injection cyclotron

initial stage of the commissioning. The final, more precise, alignment will be done using a laser tracking system in this summer.

As the radiation shield, concrete shield walls covers the accelerator. The thickness of the shield is 1m for the side wall and 0.5m for the ceiling. Even with these shields, the beam intensity of 40nA is allowed.

COMMISSIONING

After the construction of the ring was completed, the beam commissioning has started. In the commissioning, the first thing to be done is to beam injection. Figure 3 shows the injection orbit of the 150MeV FFAG and the location of the elements for the beam injection.

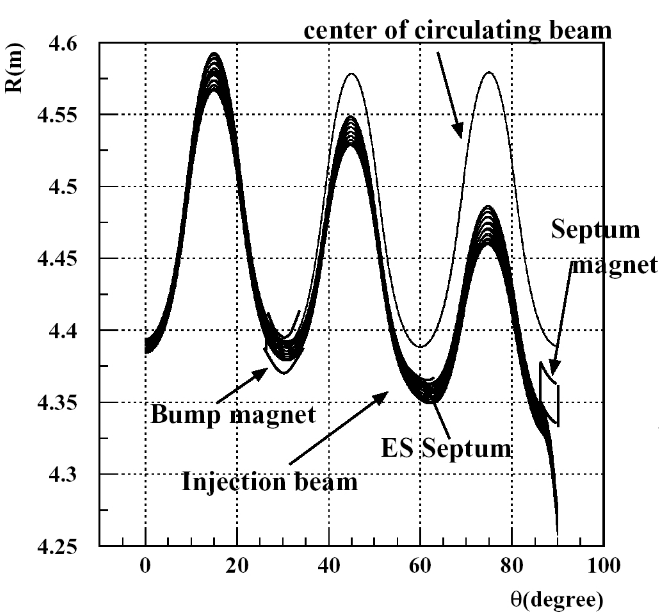

Figure 3: Injection Orbit of 150MeV FFAG

Three elements are installed for the beam injection. Those are, from upstream, injection septum magnet, injection electrostatic(ES) septum and a pair of bump magnet. Required field strength of the injection septum magnet is 1 Tesla for 10MeV injection, and for the ES septum, 35kV/cm. The required field of the bump magnet is 300 gauss and it decays with the time constant of 5μsec. With these apparatus, the multi-turn injection with phase space painting for 10 turns is capable .

To find out the injection condition, the beam position was measured by a Faraday cup from the upstream of the injection orbit. For each step, the field strength of the septum magnet and the setting of injection beam line was tuned so that beam passed through the correct position with maximum intensity.

Finally, after tuning the injection condition by measuring the beam position at the bump magnet, the circulating beam of one turn was observed with the Faraday cup installed outside of the injection septum magnet. In this time, to measure the beam position at the bump magnet, in the position of the bump magnet, a Faraday cup was installed and the bump magnet itself was not installed. Figure 4 shows the signal observed with the Faraday cup. It should be noted that the beam intensity after one turn was almost the same as that observed at the position of the bump magnet. That means there observed no beam loss along one turn.

Figure 4: Beam signal observed by Ring Faraday Cup at the point of 1turn

From the result, we found that the FFAG magnet and the injection system are working mostly as expected.

The beam commissioning is still going on intensively. The next step is to install the bump magnet and to accelerate the beam. The preparation for the study is now undergoing.

SUMMARY

The construction of the 150MeV FFAG was completed in March 2003. After that, the commissioning run is under going. Up to now, the circulating beam for one turn was successfully observed.

REFERENCES

[1] Y. Sato et al. ’Development of a FFAG proton synchrotron’, Proceedings of EPAC 2000, p.299.

[2] M. Aiba et al., ‘A 150MeV FFAG with return-yoke free magnet’ Proceedings of PAC 2001