RF SYSTEM FOR RACCAM FFAG

Chihiro Ohmori KEK, Tsukuba, Ibaraki, Japan 305-0081
Francois Meot CEA, Gif-sur-Yvette, CEA&IN2P3, LPSC, Grenoble ,France
Jaroslaw Pasternak, LPSC, Grenoble, France

Abstract

This paper presents the RF systems of RACCAM FFAG for medical applications. Design of the RF system was updated to fit short and curved straight section of the spiral FFAG in view of preserving the compactness of the spiral lattice..

INTRODUCTIONS

The RACCAM (Recherche en ACCélérateurs et Applications Médicales) [1-3] project that has received a 3 years grant, 2006–2008, from the French National Research Agency. Objects of the project are to build a prototype magnet and demonstrating the potential of a spiral FFAG for medical application.

FFAG is one of promising candidates for the production of hadron beams for radiotherapy. It is a fast cycling machine which can deliver high dose rate and has less space charge effects. Because it uses DC magnets, the repetition rate is only limited by the RF voltage. The space charge effects are still a severe problem in the conventional medical synchrotrons because the typical injection energy is only several MeV. In case of FFAG scheme, the number of particles in a bunch is less than that in synchrotrons. Another advantage of FFAG is the extraction scheme using a kicker magnet. Comparing with other machines, fast extraction will cause small beam loss.

So far, two proton FFAG were built for around 100 MeV energy range [4]. These FFAG were using triplet-type radial sector magnets. Each magnet assembly consists of two defocusing and one focusing magnet. The defocusing magnets bend the beam to outside which is the opposite direction of the focusing magnets. The other solution for a FFAG is a spiral sector which is using magnet with spiral shape. The magnet has large injection and extraction angles to the beam. The strong focusing is realized by this edge focusing scheme. An advantage of the spiral sector FFAG is that to make the machine compact as opposite bend is not necessary to focus the beam. However, the large spiral angle limits the available space for rf cavity to accelerate the beam. For the high repetition rate, a large rf voltage is necessary although the limited space will also limit the performance of rf cavity. In this paper, a possible rf system design to fit the spiral FFAG.

RACCAM RF SYSTEM

Table 1 summarises the requirements for the rf system. Two rf cavities are necessary to achieve the 100 Hz operation. Each cavity generates 3 kV as a fundamental frequency component. Because allowed space is about 20 cm, MA (Magnetic Alloy) cavities will be used to fit the requirements. Usually, a MA cavity is operated with push-pull mode to avoid the effect by higher harmonics which are generated by the final stage amplifier. To fit to such a narrow space, a combination of single-end and class AB operation of vacuum tube is planned to reduce the waveform distortion. RACCAM FFAG has a variable extraction energy between 70 and 180 MeV to optimise the energy for radiotherapy. In the table, parameters for both 70 and 180 MeV operation are listed.

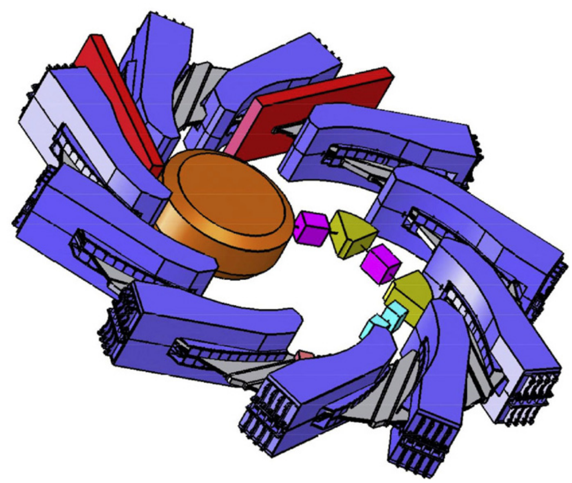

Figure 1: Layout of RACCAM FFAG assembly.

Table 1: Requirements for RF systems

	Requirements	
Length	0.2 m	
Beam excursion	0.667 m	
Transition gamma	2.45	
Total rf voltage	6 kV	
Number of cavity	2	
	High	**Low**
Energy Range	15-180 MeV	5.549-70 MeV
Frequency	3.032-7.538 MHz	1.858-5.072MHz
Power dissipation	16.8 kW	14.2 kW
Repetition rate	102 Hz	169 Hz
Repetition time	9.7 ms	5.9 ms
Number of turns	55,000	21,500

Figure 2 shows the frequency pattern for beam acceleration. The maximum speed of frequency change is 708 MHz/s. The cross section of the MA cavity to be installed in the narrow drift space is shown in Fig. 3. In the cavity, two MA cores as large as that for PRISM FFAG are used [5]. Cavity impedance and power dissipation are estimated by using parameters measured for the PRISM project. The cavity impedance is shown in Fig. 4. Because the cavity is wideband, both high and low frequency ranges are covered. One unknown parameter is floating capacitance which comes from the structure of cavity and tube amplifier. The high frequency side of bandwidth is mainly determined by the total capacitance which determine the resonant frequency of a parallel circuit with an inductance of MA cores. It is estimated to be around 100 pF [6]. In the figure, two cases with 100 pF and 150 pF are shown.

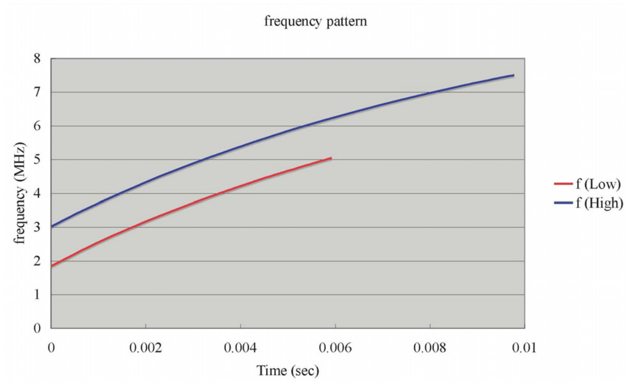

Figure 2: Frequency pattern of RACCAM FFAG. Red and blue lines mean low and high energy operations, respectively.

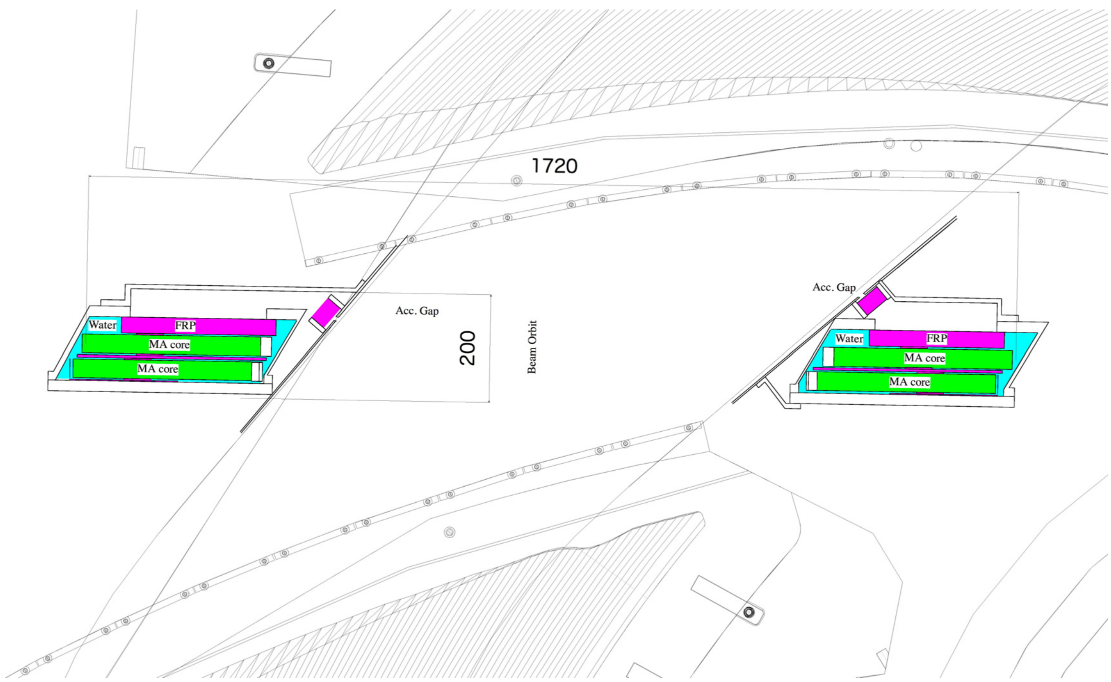

Figure 3: Cross section of a MA cavity implemented between two magnets.

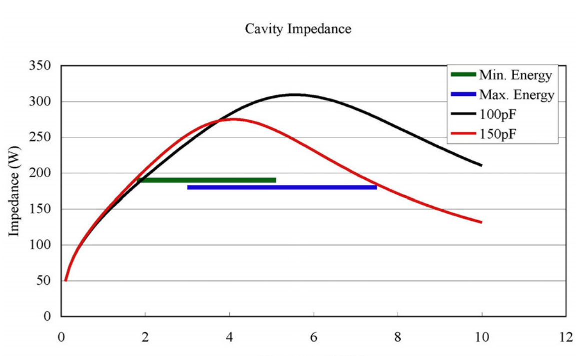

Figure 4: Cavity impedance and frequency ranges for beam acceleration. It depends on floating capacitance of whole system. Green and light blue lines mean the frequency bandwidth for low and high energy operations.

Table 2 shows parameters of the rf system. The MA cores in the cavities will be cooled using a direct water cooling scheme which is used in J-PARC ring rf systems. The cores will be molded and coated using epoxy resin to use in water tanks. The maximum power density in a core is about a half of that in J-PARC cavities [7,8].

CONCLUSIONS

The design of RACCAM FFAG rf system is presented. It fits to the narrow space between spiral FFAG magnets. It is designed to deliver the proton beam with the repetition rate of 100-170 Hz.

Table 2: Requirements for RF systems

	Cavity
Number of gaps	1
Peak rf voltage	3 kV
Size of cavity	2.0 m x 1.2 m x 0.2 m
Size of core	1.7 m x 1.0 m x 0.03 m
Aperture of core	1.0 m x 0.3 m
Q	0.6
Power density in core	< 0.5 W/cc
	Amplifier
Output power	25.0 kW
Operation class	Class AB
Plate voltage	6 kV
Anode Current	10 A
Tetrode	RS1084CJ

REFERENCES

[1] "Fixed Field Synchrotrons, Application to a second generation medical synchrotron", ANR Contract NT05-1_41853, 2005 hhttp://lpsc.in2p3.fr/service_accelerateurs/raccam.htmi.

[2] "Principle design of a protontherapy, rapid-cycling, variable energy spiral FFAG" S.Antoine et al,, Nuclear Inst. and Methods in Physics Research, A, 602 (2), p.293-305, Apr 2009 .

[3] "Spiral FFAG lattice design tools. Application to 6-D tracking in a proton-therapy class lattice ",J. Fourrier et al., ,Nuclear Inst. and Methods in Physics Research, A, 589 (2), p.133-142, May 2008.

[4] M. Aiba, et al., Development of a FFAG proton synchrotron, in: Proceedings of the EPAC 2000 Conference, Vienna, 2005.

[5] C. Ohmori, et al., High field gradient RF system for bunch rotation in PRISM-FFAG, MOPP103, in: Proceedings of the EPAC 08 Conference, Genoa, July 2008.

[6] R. Garoby et al., "THE LEIR RF SYSTEM", Proc. of PAC05, p1619-1621

[7] M. Yoshii, et al., The status of the J-PARC RF systems, MOPC134, in Proceedings of the EPAC 08 Conference, Genoa, July 2008

[8] M. Yamamoto, et al., High power test of MA cavity for J-PARC RCS, TUPAN063, in: Proceedings of the PAC 07 Conference, Alburquerque, 2007.