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Unique Origin Unique Future

Development of RF pick-up for the cyclotron

Dong-Hyup Ha[1],SangChul Mun, Ho Namgoong, Jong-Seo Chai[*], College of Information & Communication Engineering, Sungkyunkwan University, Suwon, KOREA
Jongchul Lee[2], SeungWook Shin, Hui-Su Kim , Department of Energy Science, Sungkyunkwan University, Suwon, KOREA

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Abstract

The radio-frequency (RF) pick-up for RFT-30 cyclotron which is located in the Korea Atomic Energy Research Institute (KAERI) is designed by Sungkyunkwan University in Korea. This paper covers proper position of RF pick-up and things to consider when designing. Our RF pick-up is designed for RFT-30. However, approach to design process can be used any RF pick-up design. This paper provide some tendency graph according to position of RF pick-up

Modeling

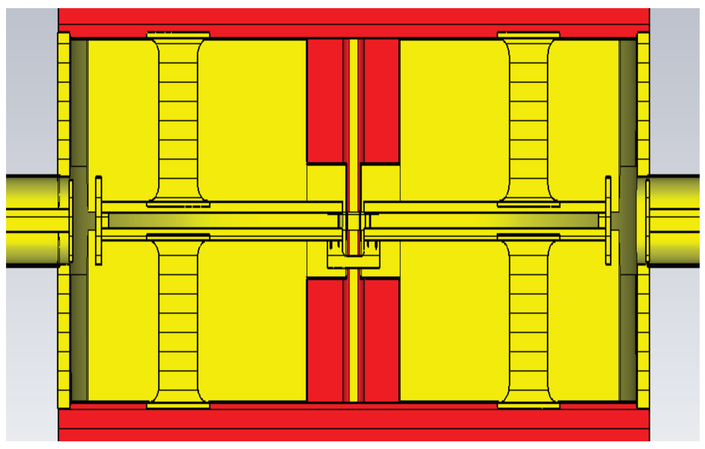

Fig.1 Inside of RFT-30 Cyclotron

Ion source	Ion source type	Multicusp type
	Max. extracted beam current	Max. 10 mA
	Extracted ion	Negative Hydrogen ion(H^-)
Extracted beam	Extraction method	Carbon stripper foil
	Extracted ion	Proton (H^+)
	Max. extracted beam current	500 μA(Max.)
	Extracted beam energy	15~30 MeV
	No. of extraction ports	2
RF system	RF frequency	64.05 MHz
	No. of dees	2
	Dee angular width	39 deg
	RF amplifier power	50 kW
	No. of harmonics	4
Magnet system	Field	10.50 kG(kilogauss)

Fig.2 Specification of RFT-30 Cyclotron

- RFT-30 cyclotron is already development. So, position of RF pick-up is limited.
- It would be significant to take the appropriate location of the RF pick-up and not to affect the performance of the RF cavity when designing the RF pick-up.
- Simulation results were performed by CST microwave studio.

Type of RF pick up selection

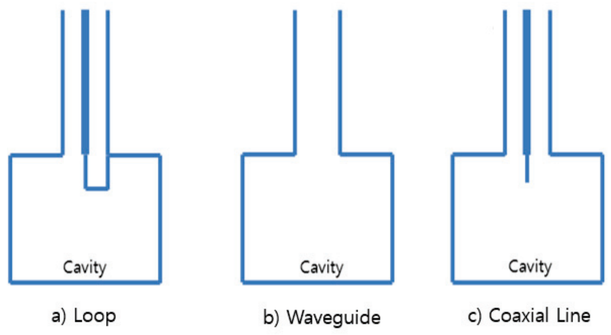

Fig.3 Type of RF power coupler

- There are 3 type RF power coupler as shown in Fig. 3. Loop type usually is used in magnetic field, waveguide type is directly connected to RF cavity and waveguide performs a RF pick-up, coaxial line type usually is used in electric field.

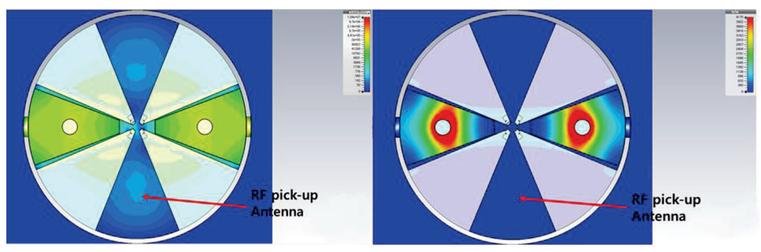

Fig. 4 Electric field (left) and magnetic field (right) at RF pick-up position

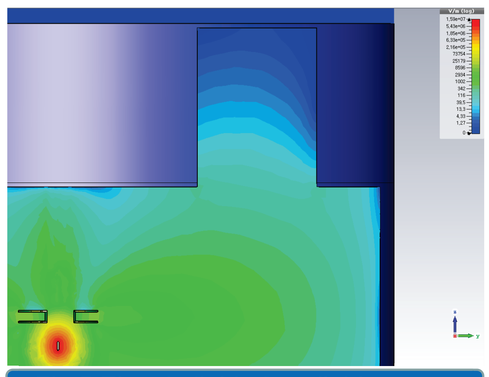

Fig.5 Electric field of available space

- In available area ,electric field exists in this region whereas magnetic field rarely exist.
- Fig. 5 represents the side view of Fig. 4 electric field.
- In this reason, coaxial line type RF power coupler is proper.
- The closer to the beam acceleration plane, the closer to the beam acceleration plane, the stronger intensity of electric field is generated. And the closer to the electromagnet yoke

Position and Penetration depth

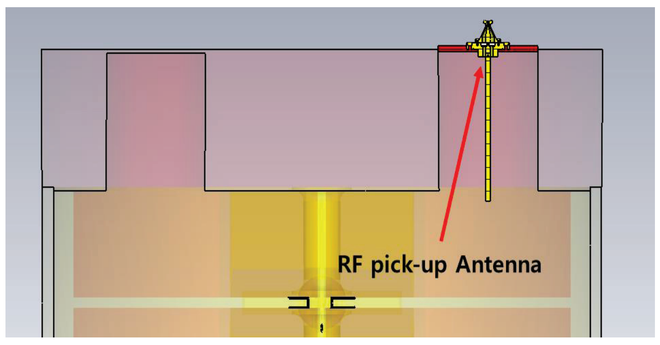

Fig. 6 Position of RF pick-up

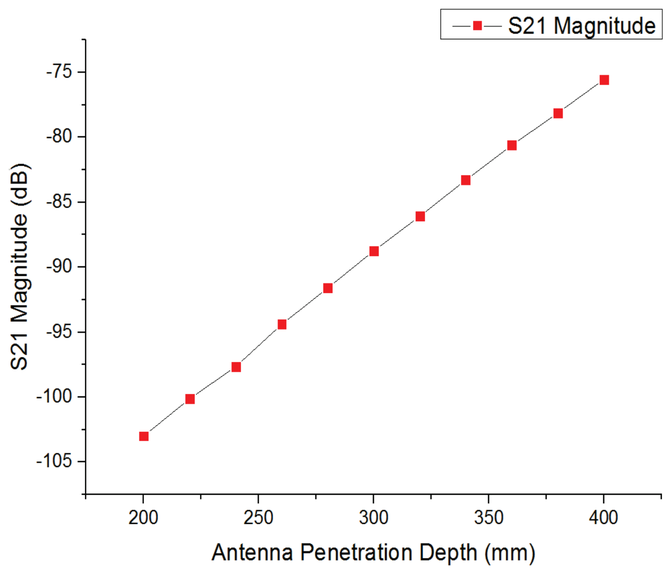

Fig. 7 Relationship between Penetration depth and S21 magnitude

- The result of simulation is checked by S-parameter S21. S21 is defined by

$$S21[\text{Magnitude, dB}] = 10 \times \log_{10}\frac{P2}{P1}$$

P2 means power coming into port 2. In other words, it means pick-up signals intensity at RF pick-up antenna. P1 means power coming into RF cavity from RF coupler. Therefore S21 means ratio of delivered power in RF cavity to pick-up power at RF pick-up antenna. We can calculate real electric power at RF pick-up antenna to use S21 data.

- the more deeply penetration depth of the antenna is able to get more magnitude at RF pick-up antenna.

Confirm the Influence to RF cavity

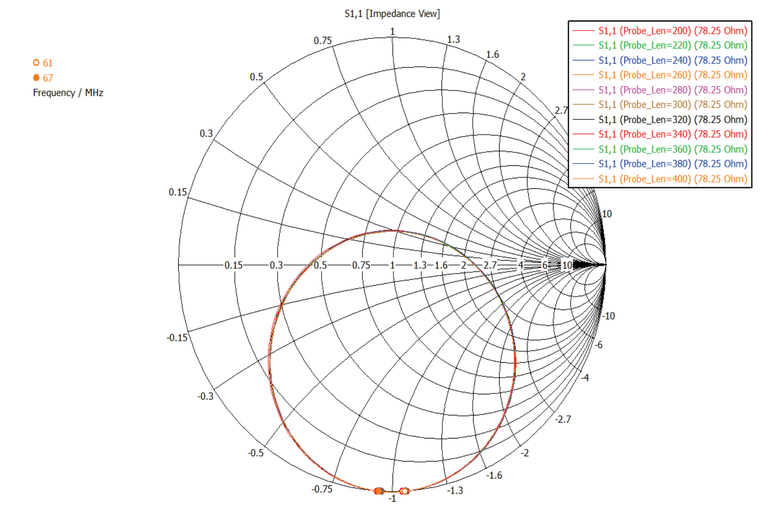

Fig. 8 Smith chart according to RF pick-up penetration depth

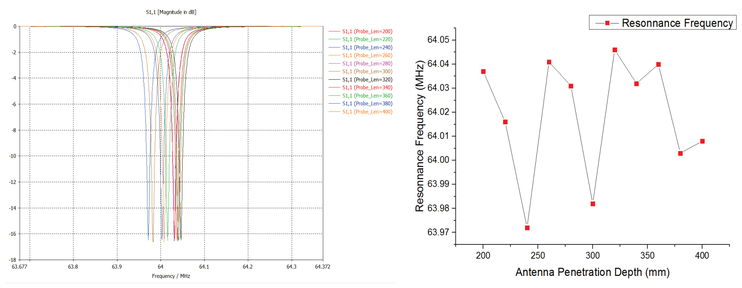

Fig. 9 Relation between Antenna penetration depth and resonance frequency (MHz)

- RF pick-up antenna should minimize effect on RF cavity systems.
- Figure 9 shows Relation between Antenna penetration depth and resonance frequency (MHz)
- There are some changes in frequency (±0.03MHz). RFT-30 cyclotron's resonance frequency is 64.05 MHz, 0.03 MHz is just 0.05%, so this value is negligible.
- Figure 8 shows coupling state. Smith chart is usually expressed circle. If the circle passing through exactly smith chart center (50Ω), this state is called critical-coupled state. Under critical-coupled state called under-coupled state, over critical-coupled state called over-coupled state.
- In General, RF cavity for particle accelerators is designed over-coupled state, and when beam enter into RF cavity, over-coupled state moved critical-coupled state.

Conclusion

- Fig.9 shows RF pick-up deeply, RF cavity has little effect. However antenna length becomes longer, it can cause structurally unstable.
- If high power enter into measuring instrument and control systems, it can cause equipment failure. So, we must know exactly pick-up power.
- When length of the antenna is 400mm, S21 magnitude is -75dB . It means that if inputting power is 50 kW, pick-up power is 1.58mW. 1.58mW is proper to control systems and is not dangerous to the measuring instruments and control systems.

* Corresponding Author, jschai@skku.edu

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