Interview
for Chung-Yao Fellowship 2018

Shaoqing Wei

2018.3.28

中国科学院高能物理研究所
Institute of High Energy Physics
Chinese Academy of Sciences

Resume

- Name: Shaoqing Wei (魏绍清)

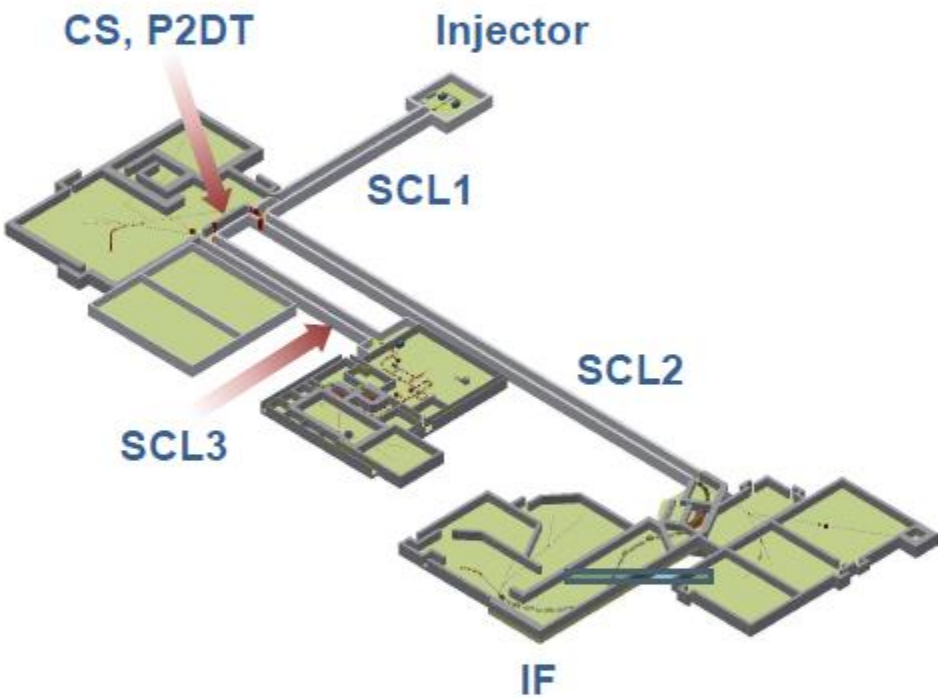
- PhD Education
  - ✓ 2014.03-2017.08, Uiduk University in South Korea, Doctor of Engineering
  - ✓ Main research area : Accelerator magnets design, Beam analysis
  - ✓ During PhD study, I participated in the development work about the **RAON** heavy ion accelerator development in IBS in South Korea.

- Work Experience

Time	Position	Mentor	Workplace
2015.10-2017.7	Assistant researcher	Sangjin Lee (이상진)	Uiduk University in South Korea
2017.12-now	Postdoc	王贻芳	IHEP CAS

RAON Heavy Ion Accelerator

- Layout of RAON heavy ion accelerator for the Rare Isotope Science Project of Institute for Basic Science in South Korea

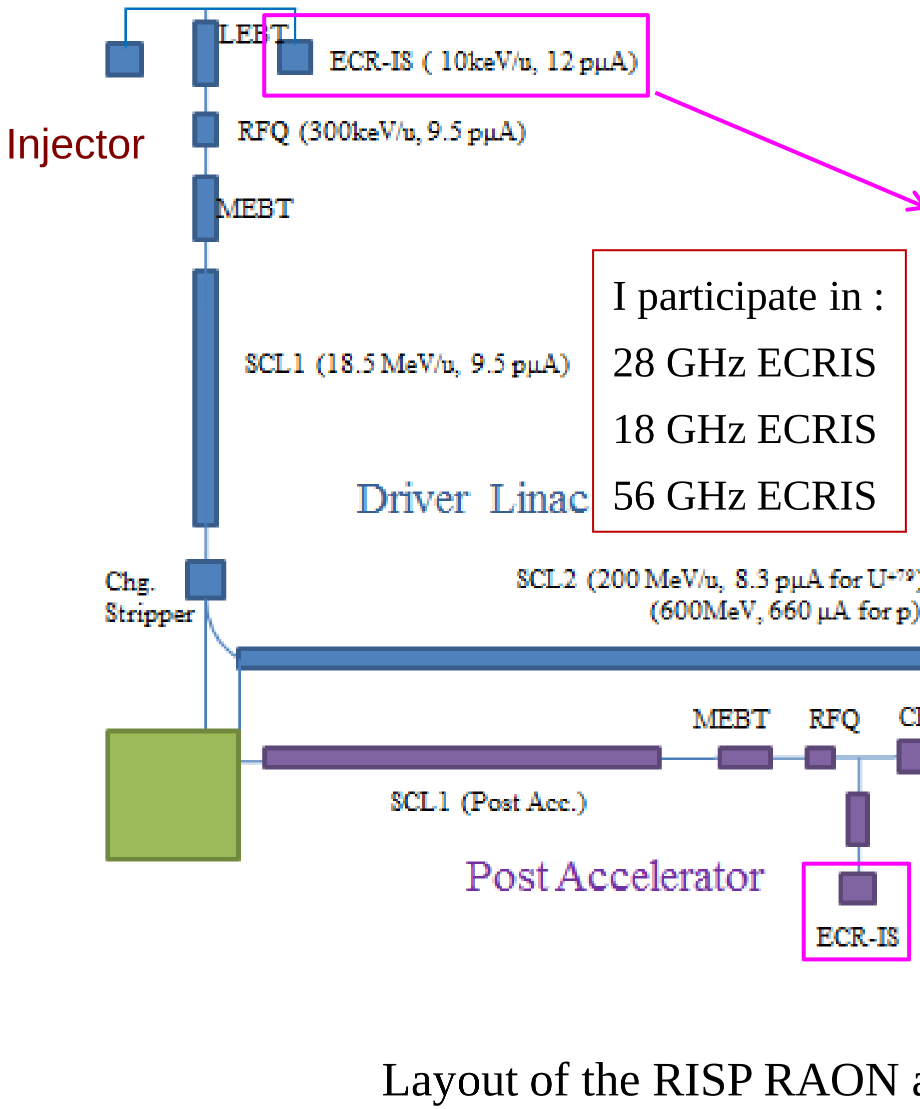
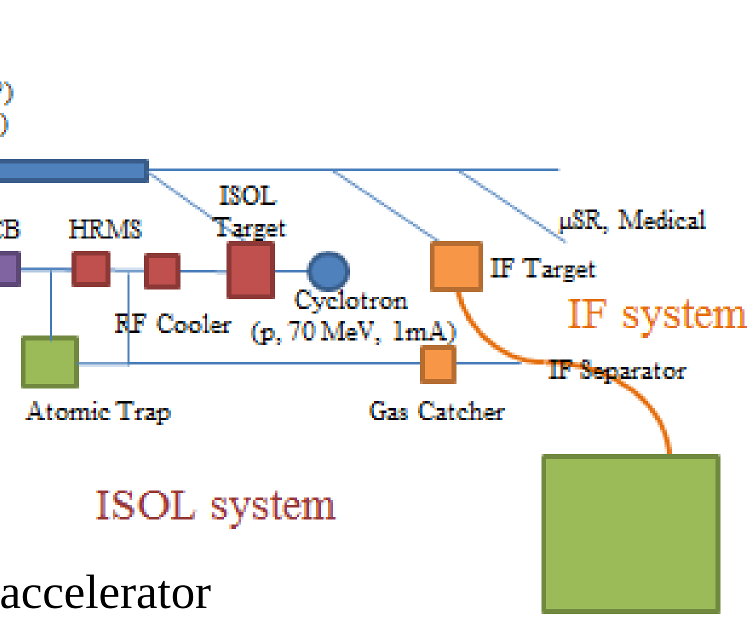


Conceptual Design of the RAON

ibS 기초과학연구원 Institute for Basic Science

Bird's-eye View of the RAON

ECR Ion Source

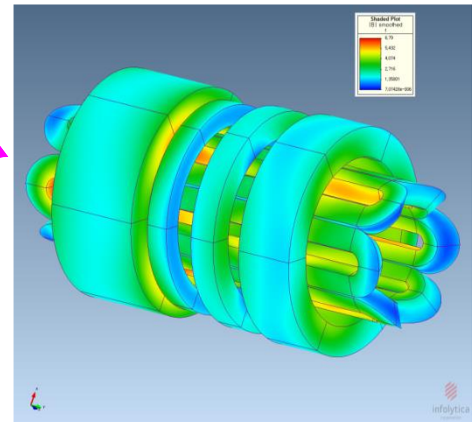



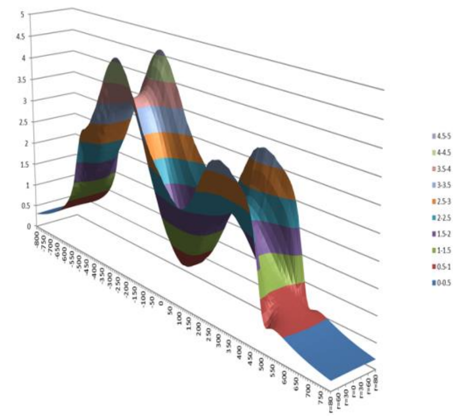
I participate in :

28 GHz ECRIS

18 GHz ECRIS

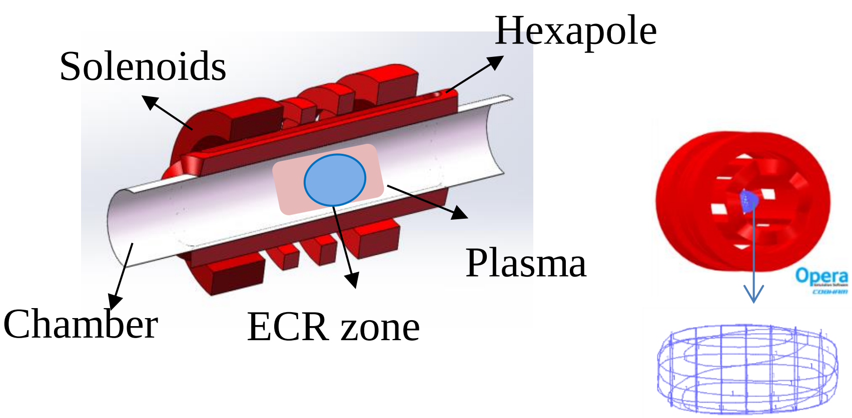
56 GHz ECRIS

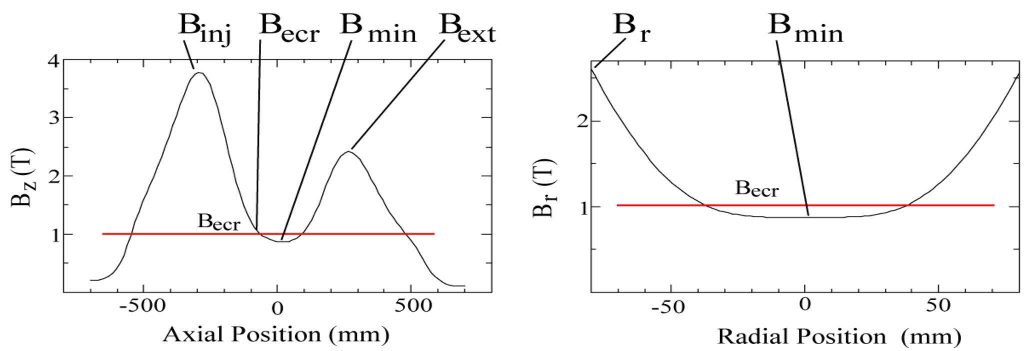




Layout of the RISP RAON accelerator

Research on 28 GHz ECR Ion Sources





$$B_{ECR} = \frac{f_{ECR}[GHz]}{28}\ Tesla$$

<Optimization results for coil performance[1] >

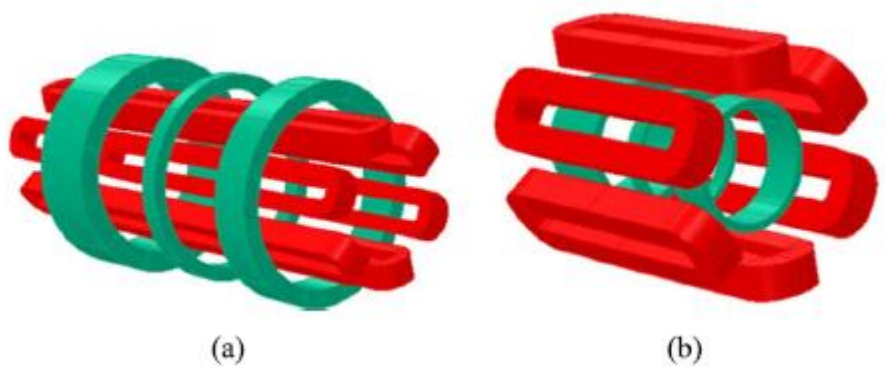
N	V_{ECR} (mm^3)	V_{coil} (mm^3)	V_{ECR}/V_{coil}	object function 1
3	818563	34433278	0.02377	46.65
4	858977	36070784	0.02381	47.71
6	1138372	38304303	0.02972	47.09

<Optimization results for ECR zone volume[1]>

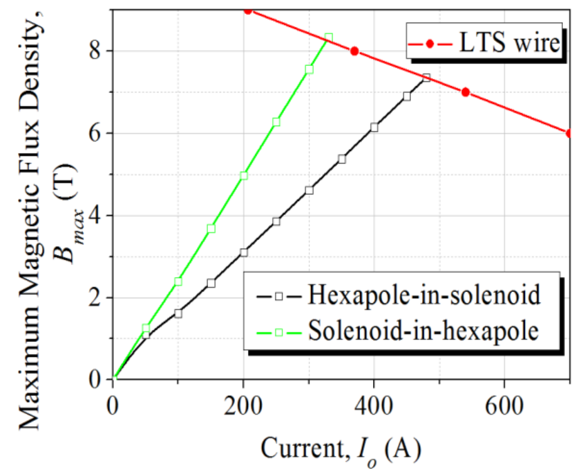
N	V_{ECR} (mm^3)	V_{coil} (mm^3)	V_{ECR}/V_{coil}	Object function 2
3	812733	36174552	0.0225	1.2304e-06
4	820212	41860113	0.0196	1.2192e-06
6	1298900	51674617	0.0251	7.6988e-07

[1] **Shaoqing Wei**, Sangjin Lee*, "*Comparison analysis of superconducting solenoid magnet systems for ECR ion source based on the evolution strategy optimization*," Progress in Superconductivity and Cryogenics, Vol.17, No.2, pp.36-40, 2015.

Design of 18 GHz ECR Ion Sources



(a) (b)



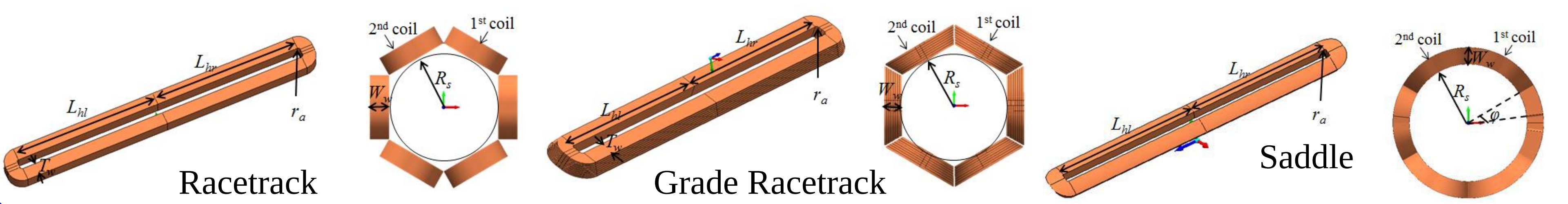
<Full LTS 18 GHz ECR ion sources >

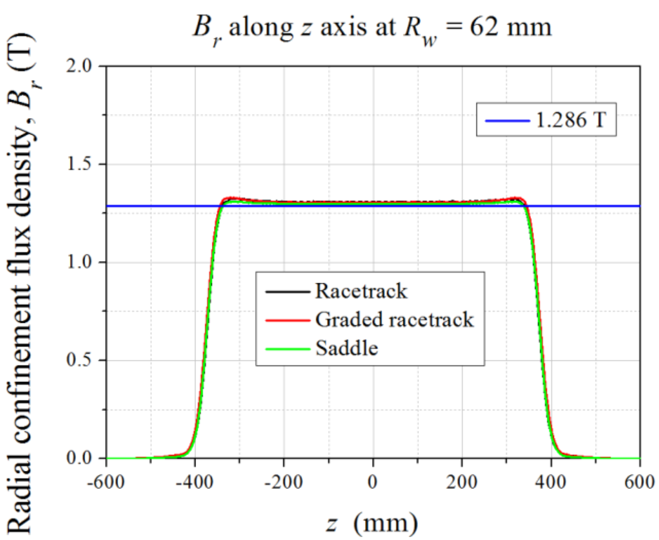
Number of solenoid	Model	I_o (A)	Hexapole B_{max} (T)	V_{coil} $\times 10^6$ (mm^3)	V_{ECR} $\times 10^6$ (mm^3)	Stored Energy (kJ)
3	Initial	250	4.24	11.535	0.49606	14.1
	Final	250	4.18	11.310	0.60821	13.2
4	Initial	250	4.29	12.044	0.50234	14.4
	Final	250	4.14	11.631	0.50862	13.4

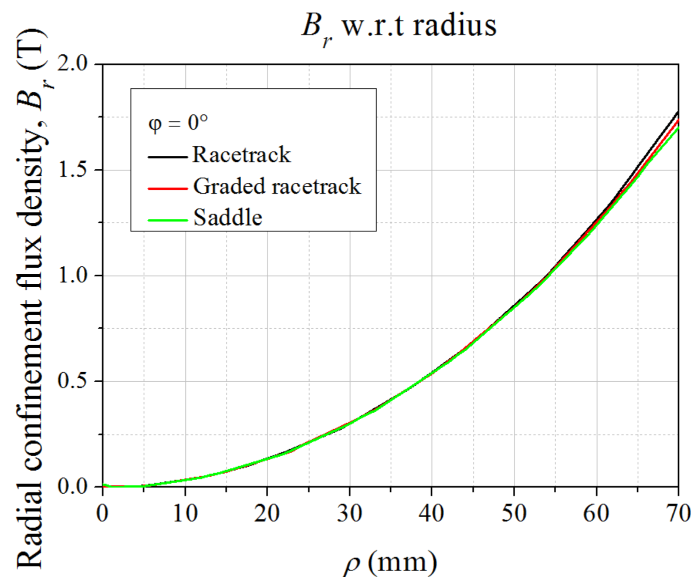
- If B_{max} in hexapole is more important, 4 solenoid system can be selected. However, if ECR zone volume is more important, 3 solenoid system seems to be better[2].

[2] **Shaoqing Wei**, Zhan Zhang, Sangjin Lee*, and Sukjin Choi, "*A study on the design of hexapole in an 18-GHz ECR ion source for heavy ion accelerators*," Progress in Superconductivity and Cryogenics, Vol.18, No.2, pp.25~29, 2016.

Research on Hexapole for 18 GHz ECR Ion Sources



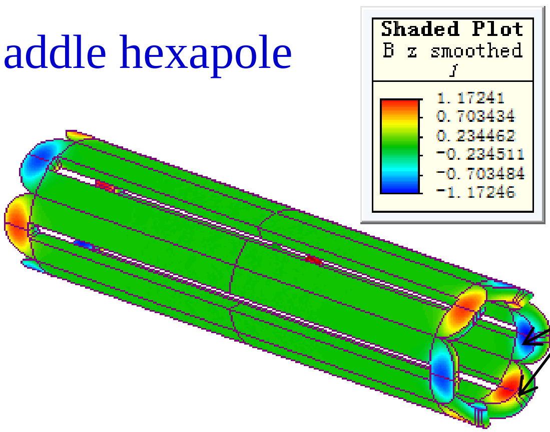


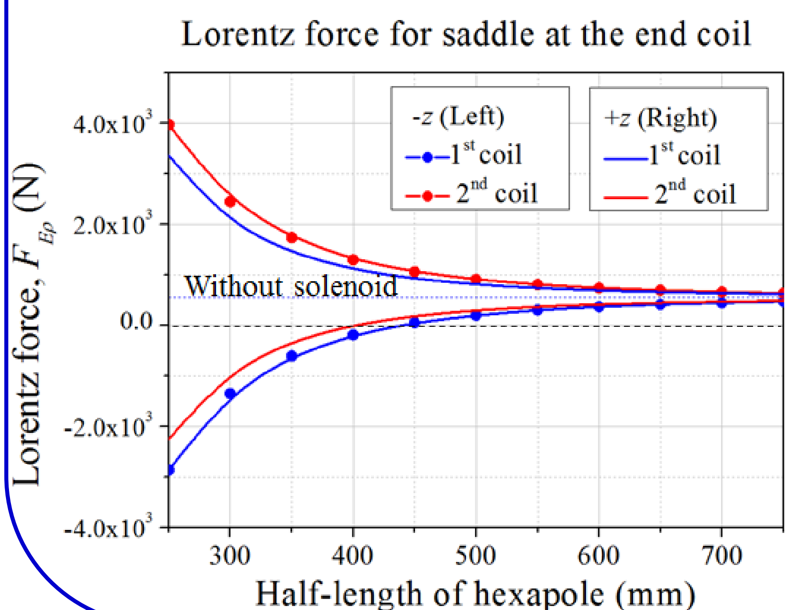


[3] **Shaoqing Wei**, Zhan Zhang, Sangjin Lee*, and Sukjin Choi, "*A study on the design of hexapole in an 18-GHz ECR ion source for heavy ion accelerators*," Progress in Superconductivity and Cryogenics, Vol.18, No.2, pp.25~29, 2016.

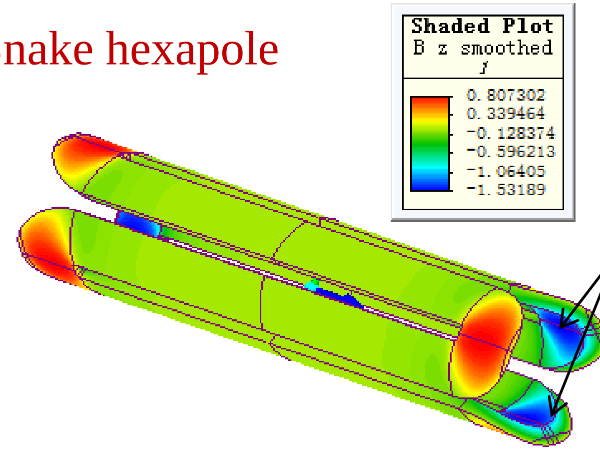
Research on Hexapole for 18 GHz ECR Ion Sources

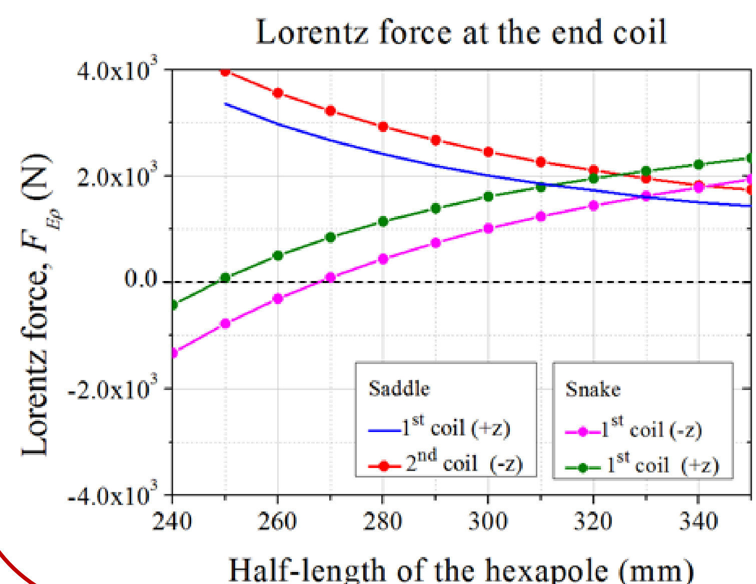
Saddle hexapole





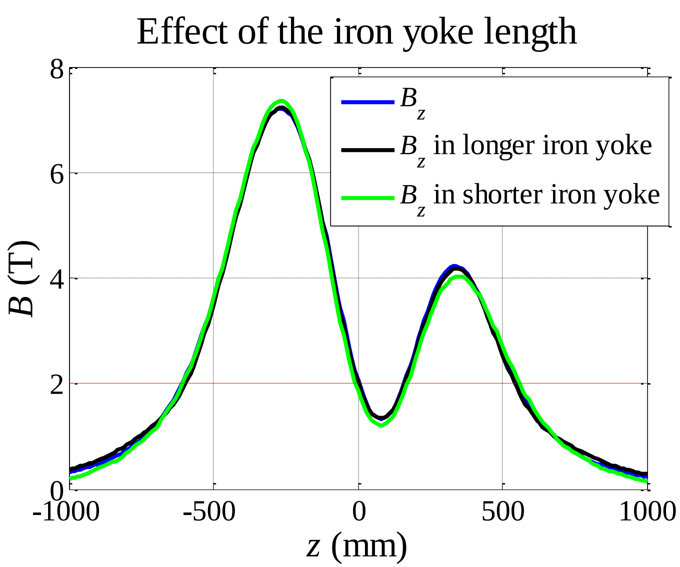
Snake hexapole

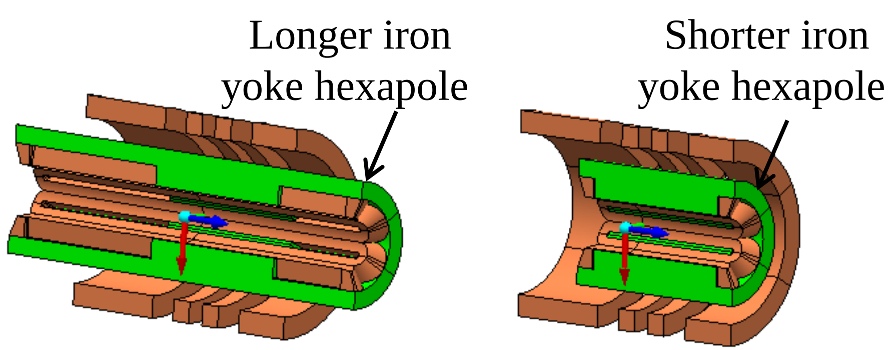




Design of 56 GHz ECR Ion Sources

- The iron yoke can **provide a structure** for the hexapole and can **clamp down the hexapole** coil.
- The hexapole length was reduced according to the range of $2B_{ECR}$ surface in z direction.
- The design of hexapole, a shorter hexapole surrounded by iron yoke inside solenoid, is proposed.



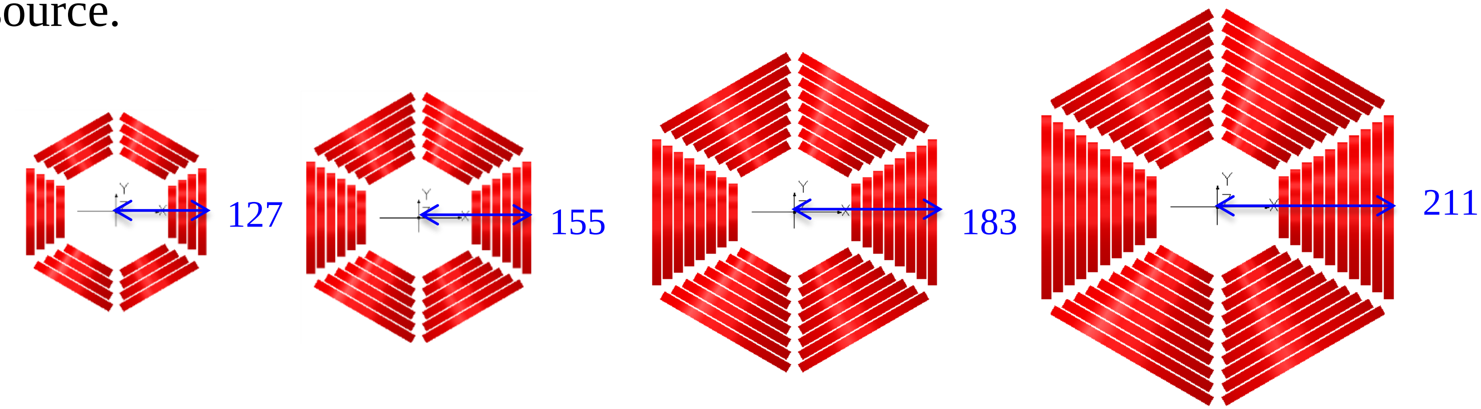


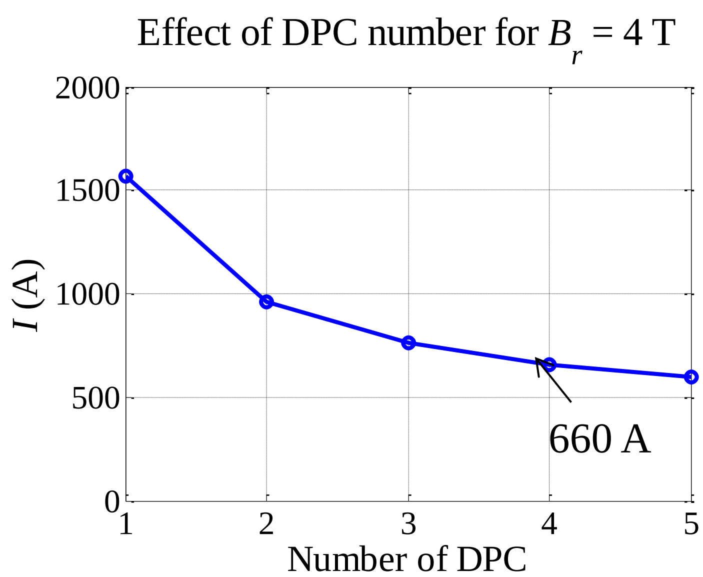
< axial confinement fields w.r.t yoke length >

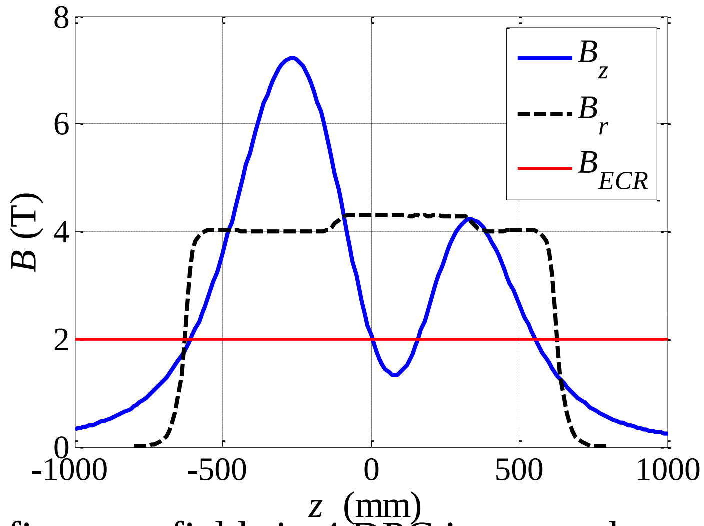
Models	B_{inj} (T)	B_{min} (T)	B_{ext} (T)
Only Solenoid	7.22	1.33	4.22
Longer iron yoke	7.23	1.34	4.18
Shorter iron yoke	7.35	1.21	4.03

HTS Hexapole Design

- Considering the hexapole size and current, 4 DPC hexapole was selected for the 56 GHz ECR ion source.







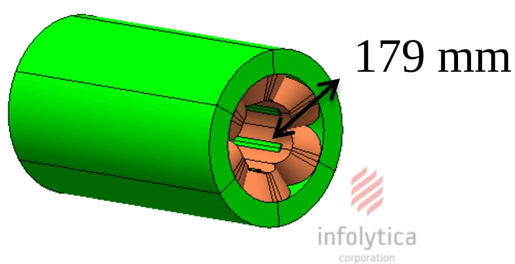
<onfinement fields in 4 DPC iron core hexapole >

Hexapole Design for 56 GHz ECR Ion Sources

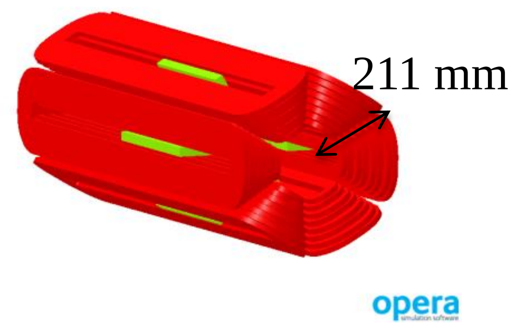
< Comparison between LTS and HTS hexapoles for 56 GHz ECRIS >

Hexapole-in-solenoid Structure								
Hexapole	J_e (A/mm^2)	B_{max} (T)	$B_{//c}$ (T)	Safety margin (%)	Outer radius (mm)	L_{hl}/L_{hr} (mm)	V_{hex} ($\times 10^6$ mm^3)	Iron weight (kg)
LTS shorter yoke hexapole	188.64	10.06	/	36.3	179	122/356	15.73	258.7
HTS shorter core hexapole	238.64	13.01	5.54	29.8	211	600/600	69.5	37.55

< LTS shorter yoke hexapole >



< HTS shorter core hexapole >

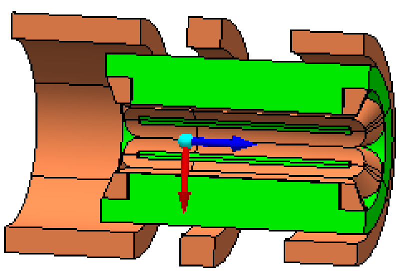


[4] **Shaoqing Wei**, Zhan Zhang, Sangjin Lee*, "*A Study on the Sextupole Design with Iron Yoke inside Solenoids for 56 GHz ECR Ion Sources*," IEEE transactions on applied superconductivity, Vol. 28, No. 3, November 2017.

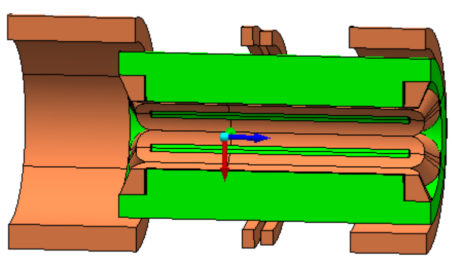
56 GHz LTS ECR Ion Sources

< Comparison of Final LTS ECRISs >

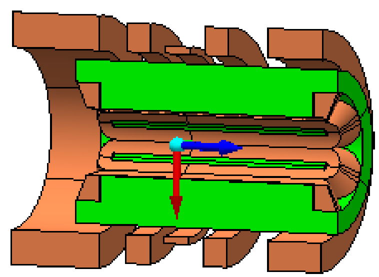
Solenoid number	V_{ECR} (mm^3)	V_{coil} (mm^3)	Iron weight (kg)	Solenoid			Hexapole		
				J_e (A/mm^2)	B_{max} (T)	Safety margin (%)	J_e (A/mm^2)	B_{max} (T)	Safety margin (%)
3	64.48×10^6	55.5×10^6	255.6	200	9.75	37.0	188.64	10.13	35.5
4	73.48×10^6	51.2×10^6	294.5	200	9.48	37.7	188.64	9.74	38.1
5	79.48×10^6	64.0×10^6	274.2	200	11.45	28.3	188.64	10.30	34.9
6	80.91×10^6	63.4×10^6	273.0	200	11.49	28.1	188.64	10.07	36.1



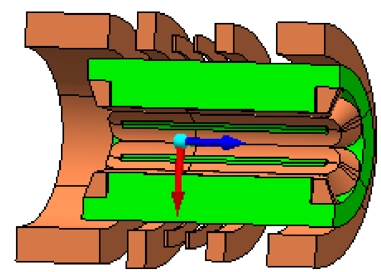
< Final model for 3 solenoid LTS ECRIS >



< Final model for 4 solenoid LTS ECRIS >



< Final model for 5 solenoid LTS ECRIS >

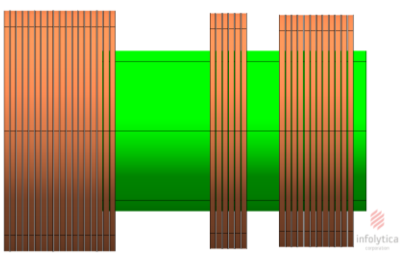


< Final model for 6 solenoid LTS ECRIS >

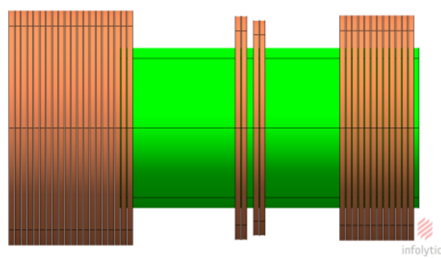
56 GHz Hybrid ECR Ion Sources

< Comparison results of final hybrid ECRISs >

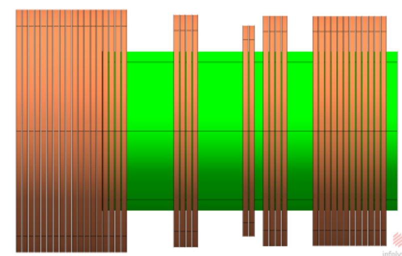
Hybrid Final models	V_{ECR} (mm³)	V_{coil} (mm³)	Solenoid				Hexapole		
			I (A)	B_{max} (T)	$B_{//c}$ (T)	Safety margin (%)	J_e (A/mm²)	B_{max} (T)	Safety margin (%)
3 solenoid	63.35×10^6	57.14×10^6	528	10.08	7.60	25.6	188.64	9.85	37.6
4 solenoid	74.72×10^6	53.38×10^6	528	9.54	6.54	30.4	188.64	9.75	37.7
5 solenoid	80.76×10^6	62.99×10^6	528	10.38	7.27	27.3	188.64	10.15	35.8



< Final model for 3 solenoid Hybrid ECRIS >

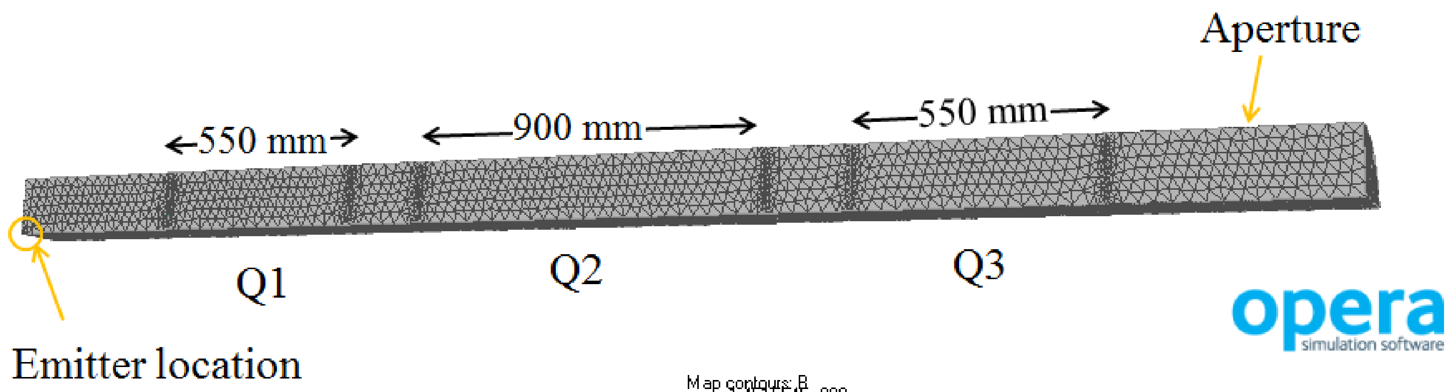


< Final model for 4 solenoid Hybrid ECRIS >

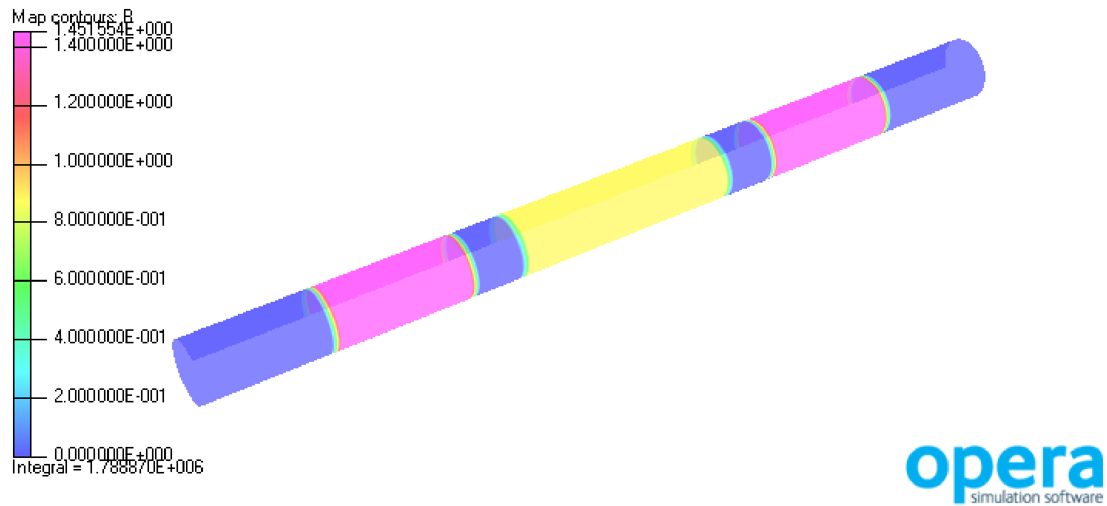


< Final model for 5 solenoid Hybrid ECRIS >

Beam Analysis for Triplet



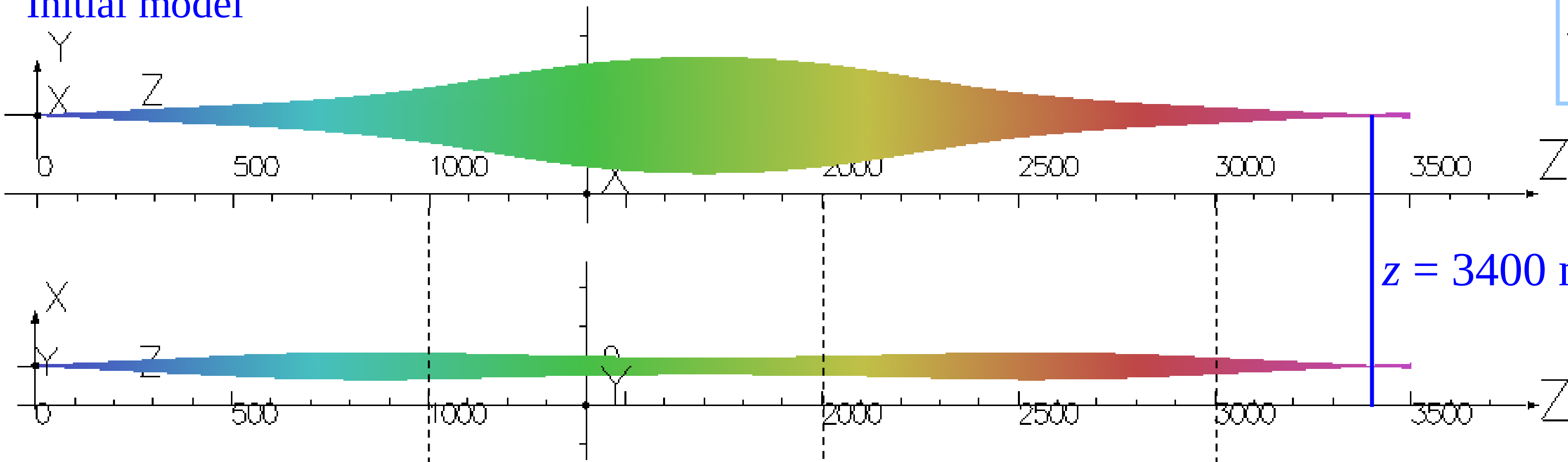
- The quadruple triplet which was consisted of three consecutive quadrupoles, Q1, Q2 and Q3, is used to control beam trajectory at a focused position.



[5] **Shaoqing Wei**, Zhan Zhang, Sangjin Lee* , Do Gyun Kim, and Jang Youl Kim, "*Control the length of beam trajectory with a quadruple triplet for heavy ion accelerator*," Progress in Superconductivity and Cryogenics, Vol.18, No.4, pp.40~43, 2016.

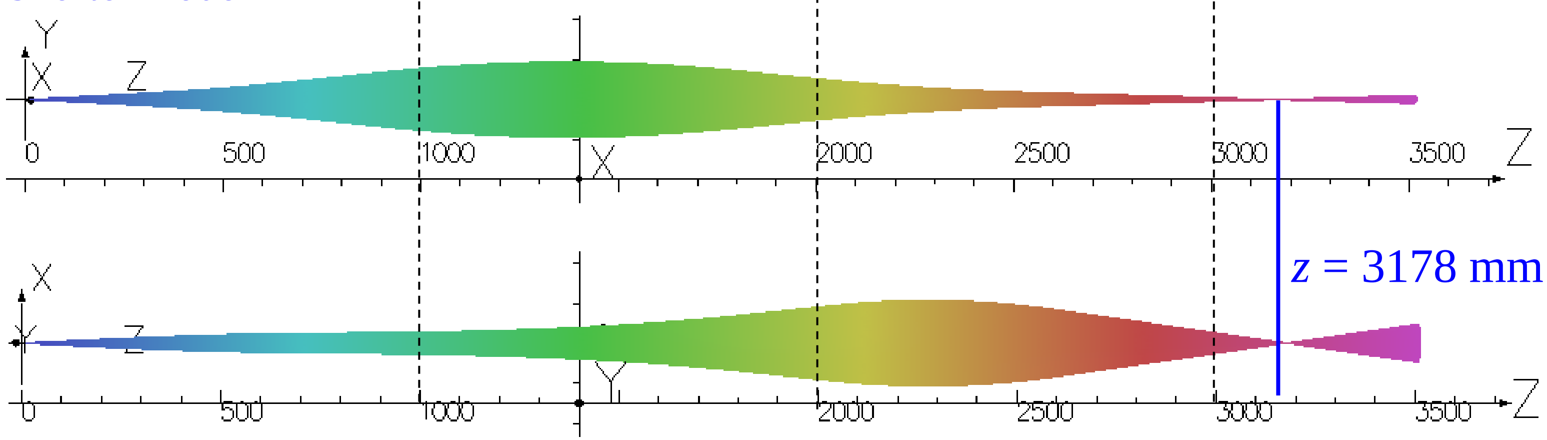
Beam Analysis for Triplet

Initial model

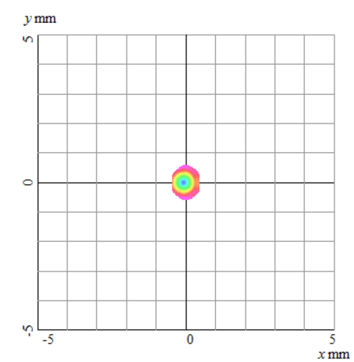


$$\begin{cases} Xmax = 0.20\ \text{mm} \\ Ymax = 1.43\ \text{mm} \end{cases}$$

Shorter model

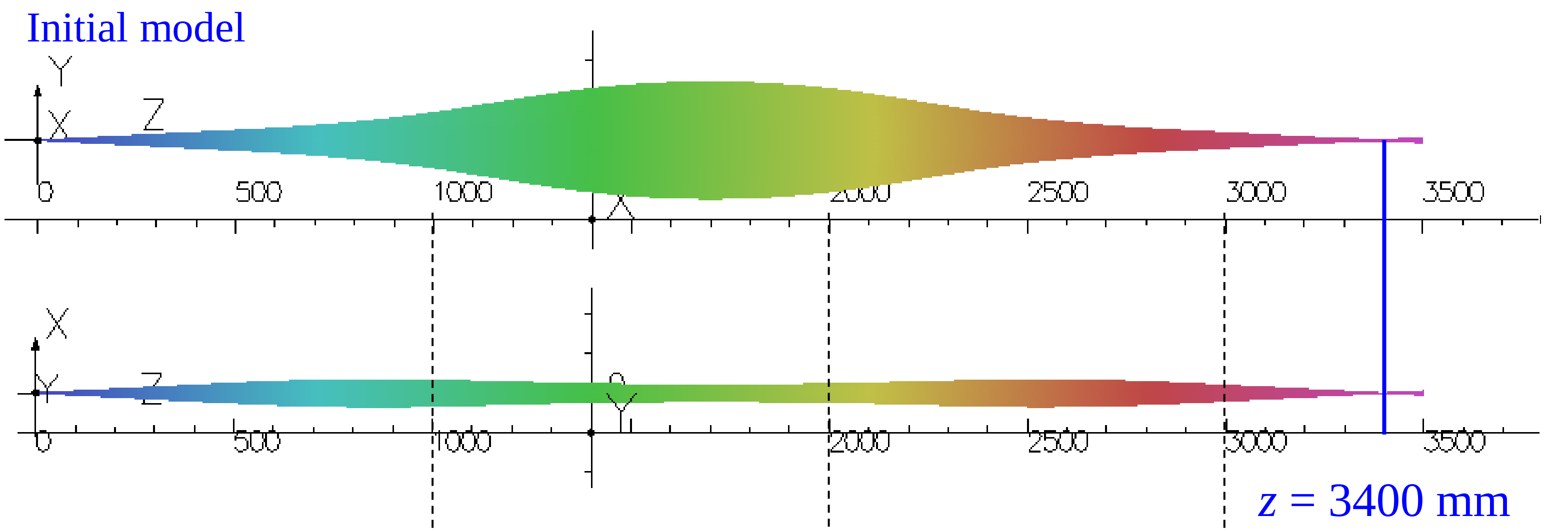


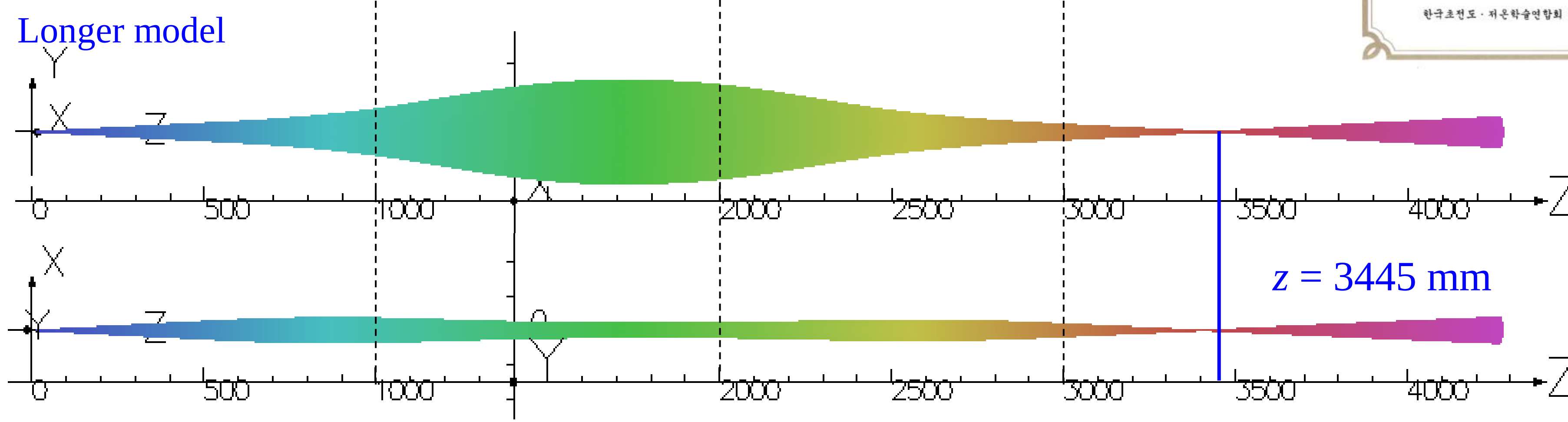
$$\begin{cases} Xmax = 0.41\ \text{mm} \\ Ymax = 0.51\ \text{mm} \end{cases}$$

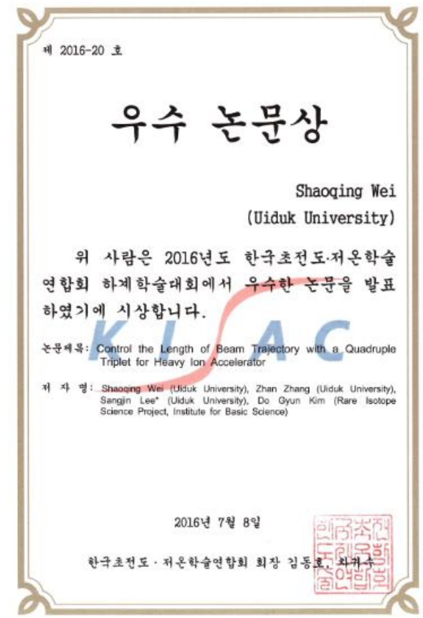


Result for shorter triplet model

Beam Analysis for Triplet







제 2016-20 호

우수 논문상

Shaoqing Wei
(Uiduk University)

위 사람은 2016년도 한국초전도·저온학술연합회 하계학술대회에서 우수한 논문을 발표하였기에 시상합니다.

논문제목: Control the Length of Beam Trajectory with a Quadruple Triplet for Heavy Ion Accelerator

저 자 명: Shaoqing Wei (Uiduk University), Zhan Zhang (Uiduk University), Sangjin Lee* (Uiduk University), Do Gyun Kim (Rare Isotope Science Project, Institute for Basic Science)

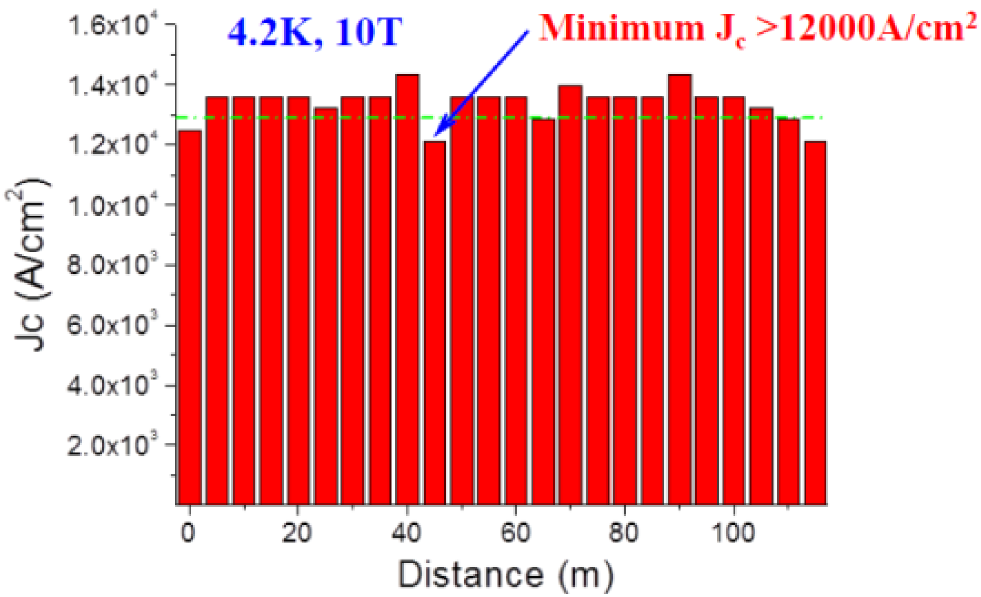
2016년 7월 8일

한국초전도·저온학술연합회 회장 김동호, 최귀수

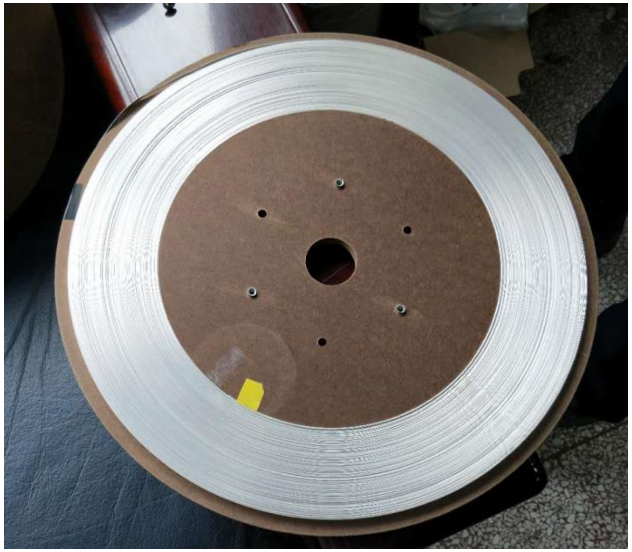
Result for longer triplet model

Future Plans

- Iron-based superconducting material is a new type of superconducting material following the 1986 copper oxide superconducting material (or copper-based superconducting material) and 2001 MgB_2 superconducting material.
- Its average transmission current **exceeds 1.3 × 10^4 A / cm^2** at a magnetic field of 10 T, which has met the basic requirements of industrial applications.

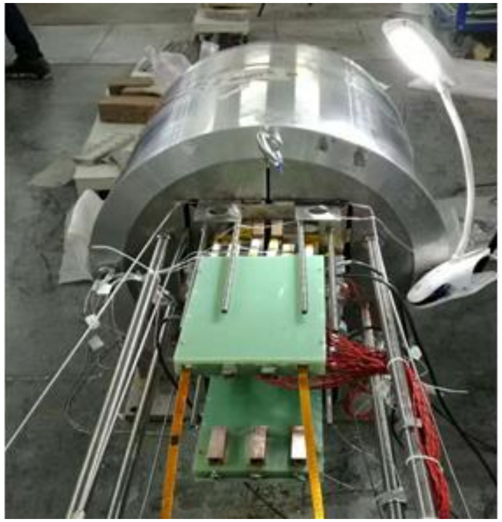


World's first 100-m class iron-based superconducting wire

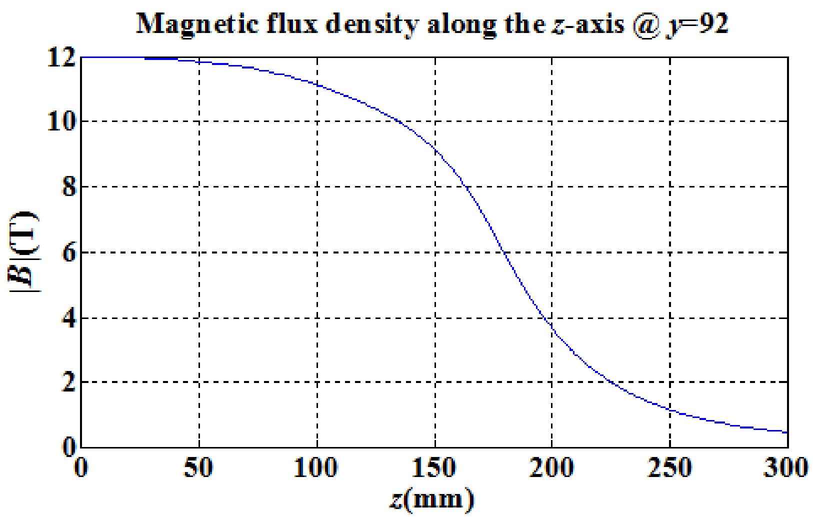


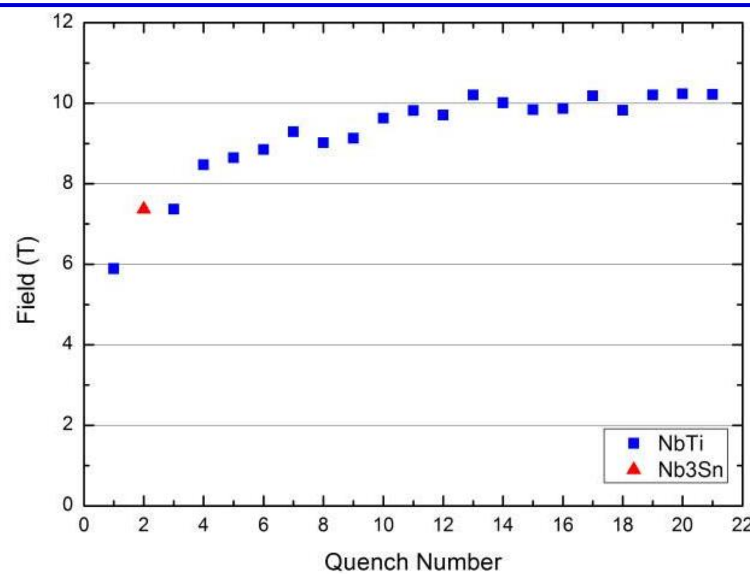
Iron-based superconductivity

Future Plans



- The filed of the dipole magnet is over 10 T, which can provide the high field for Iron-based superconductor.
- I plan to test the **quenching behavior** of 100 m-class 122 iron-based superconducting tapes at high field, and then to design the **insert iron-based coil** in high background field.





Published List

- [1] **Shaoqing Wei**, Sangjin Lee*, "*Comparison analysis of superconducting solenoid magnet systems for ECR ion source based on the evolution strategy optimization*," Progress in Superconductivity and Cryogenics, Vol.17, No.2, pp.36-40, 2015.
- [2] **Shaoqing Wei**, Zhan Zhang, Sangjin Lee*, and Sukjin Choi, "*A study on the design of hexapole in an 18-GHz ECR ion source for heavy ion accelerators*," Progress in Superconductivity and Cryogenics, Vol.18, No.2, pp.25~29, 2016.
- [3] **Shaoqing Wei**, Zhan Zhang, Sangjin Lee*, and Sukjin Choi, "*A study on the design of hexapole in an 18-GHz ECR ion source for heavy ion accelerators*," Progress in Superconductivity and Cryogenics, Vol.18, No.2, pp.25~29, 2016.
- [4] **Shaoqing Wei**, Zhan Zhang, Sangjin Lee*, "*A Study on the Sextupole Design with Iron Yoke inside Solenoids for 56 GHz ECR Ion Sources*," IEEE transactions on applied superconductivity, Vol. 28, No. 3, November 2017.
- [5] **Shaoqing Wei**, Zhan Zhang, Sangjin Lee* , Do Gyun Kim, and Jang Youl Kim, "*Control the length of beam trajectory with a quadruple triplet for heavy ion accelerator*," Progress in Superconductivity and Cryogenics, Vol.18, No.4, pp.40~43, 2016.
- [6] Zhan Zhang, **Shaoqing Wei**, and Sangjin Lee*, "Harmonic analysis and field quality improvement of an HTS quadrupole magnet for a heavy ion accelerator," Progress in Superconductivity and Cryogenics, Vol.18, No.2, pp.21-24, 2016.
- [7]Zhan Zhang, **Shaoqing Wei**, and Sangjin Lee*, "Design of an Air-Core HTS quadruple triplet for a heavy ion accelerator," Progress in Superconductivity and Cryogenics, Vol.18, No.4, pp.35-39, 2016.

Thanks for your attention!

欢迎指正