



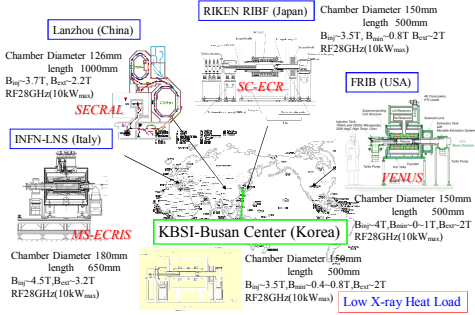
The Design Study of Superconducting Magnet System for a Advanced ECR Ion Source

ByoungSeob Lee*, MiSook Won*, JinYong Park*, DongJun Park*, JongPil Kim*, JangHee Yoon*, JongSeong Bae*, JungKeun Ahn**
 * Korea Basic Science Institute - Busan Center, **Pusan National University
 *E-mail : bslee@kbsi.re.kr

Abstract

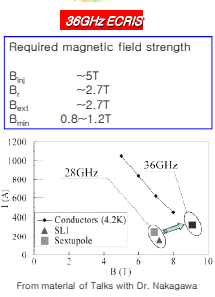
The Korea Basic Science Institute is developing a superconducting magnet system for 28 GHz Electron Cyclotron Resonance Ion Source (ECRIS). We are investigating in order to realize compact size, economic operation and generation of high current beam. Although companies and researchers have valuable experience, skill and ability in designing of superconducting magnet for ECRIS, they did not exactly proposed a excellent superconducting magnet system for ECRIS because many superconducting magnets were not required. Of course they do if we required many magnets for the various application of ECRIS. In this presentation, we have filed reports of former researcher and we have discussed the realization of ECRIS over 35 GHz.

28 GHz ECRIS in The World

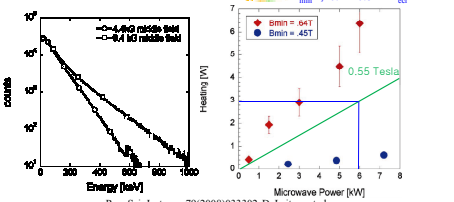


Critical Problems of ECRIS Magnet

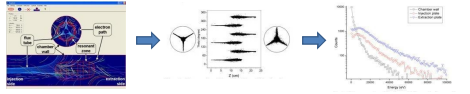
- X-ray Irradiation
 - Large Heat Source of Magnet
 - Degradation, Erosion
- Critical Current & Field of Superconducting Wire
 - HTS Wire
 - Nb3Sn LTS Wire
 - Hybrid Magnet
- Reinforcement of Structural Strength for Hexapole Magnet
 - Liquid Metal
 - Special Structure
- Cooling Method
 - Recondensed Cooling Method ; Low Temperature
 - Conduction Cooled Method ; Simple



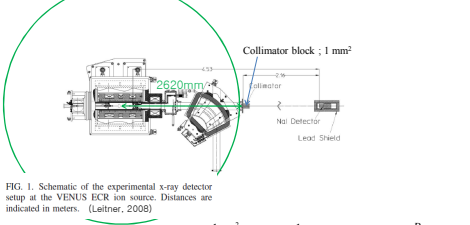
Heat Load & X-ray Irradiation



TrapCAD simulation for electrons

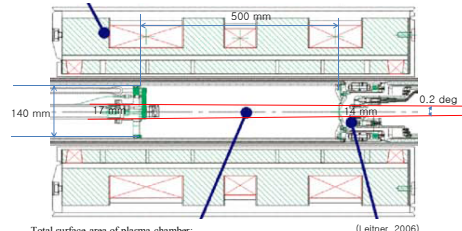
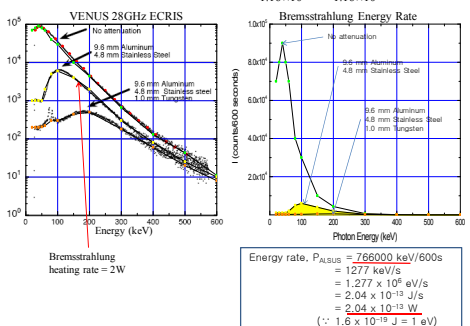


Ref. : First Results for the 28GHz Operation of the superconducting ECRIS VENUS (Leitner, 2004)



$$\frac{1\text{mm}^2}{4\pi(2620\text{mm})^2} = \frac{1}{8.63 \times 10^7} = 1.16 \times 10^{-8} = \frac{P_{\text{Al,SUS}}}{P_{\text{Al,SUS,corrected1}}}$$

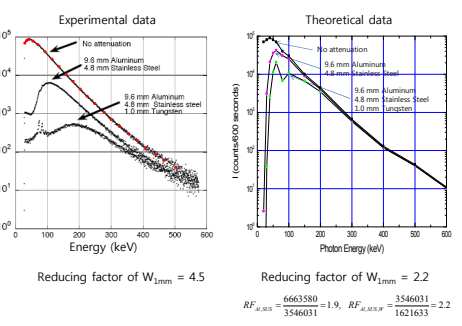
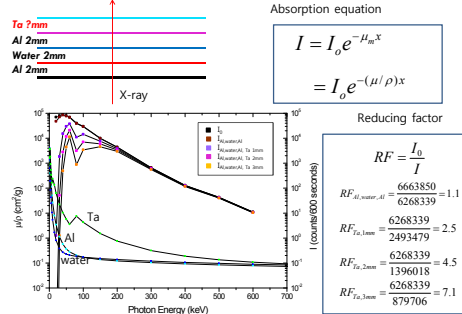
$$\frac{P_{\text{Al,SUS}}}{P_{\text{Al,SUS,corrected1}}} = \frac{P_{\text{Al,SUS}}}{1.16 \times 10^{-8}} = \frac{2.04 \times 10^{-13} \text{ W}}{1.16 \times 10^{-8}} = 1.76 \times 10^{-2} \text{ W}$$



Total surface area of plasma chamber:
 $\pi(70^2-4^2)+\pi(70^2-5^2)+2\pi \cdot 70 \cdot 500 = 250,470 \text{ (mm}^2\text{)}$
 Active surface area for bremsstrahlung: $\pi(7^2-4^2) = 104 \text{ (mm}^2\text{)}$
 Active surface ratio: $\frac{104}{250470} = 4.15 \times 10^{-4} = \frac{P_{\text{Al,SUS}}}{P_{\text{Al,SUS,corrected1}}}$
 $P_{\text{Al,SUS,corrected1}} = \frac{P_{\text{Al,SUS}}}{4.15 \times 10^{-4}} = \frac{2.04 \times 10^{-13} \text{ W}}{4.15 \times 10^{-4}} = 4.24 \times 10^{-2} \text{ W}$

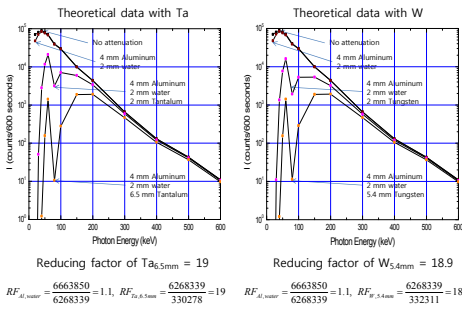
- Bremsstrahlung heating rate = 2W
- X-Ray Energy Rate from Bremsstrahlung spectrum of VENUS
 - Energy rate, $P_{\text{Al,SUS}} = 766000 \text{ keV}/600\text{s} = 2.04 \times 10^{-13} \text{ W}$
 - Energy rate corrected by solid angle
 $\frac{P_{\text{Al,SUS}}}{1.16 \times 10^{-8}} = \frac{2.04 \times 10^{-13} \text{ W}}{1.16 \times 10^{-8}} = 1.76 \times 10^{-2} \text{ W}$
 - Energy rate corrected by solid angle and surface area
 $\frac{P_{\text{Al,SUS,corrected1}}}{4.15 \times 10^{-4}} = \frac{1.76 \times 10^{-2} \text{ W}}{4.15 \times 10^{-4}} = 4.24 \times 10^{-2} \text{ W}$
- Energy rate difference
 $\frac{4.24 \times 10^{-2}}{2} = 2 \times 10^{-2} = 2\%$

Calculation Concept of X-ray Shield



Calculating the Thickness of X-ray shielding material for KBSI 28GHz ECRIS

- When $B_{\text{min}}/B_{\text{cur}} = 0.45$ or 0.5 ,
 - Bremsstrahlung heating from VENUS data of Fig. 5 in Leitner et al. (2004)
 - ~1W/kW of 28GHz rf at no attenuation
 - ~6W/6kW of 28GHz rf at no attenuation
 - Using 2-mm-thick Ta tube, reducing factor for x-ray, RF ~ 4.5
 - With 2-mm-thick Ta tube, the final bremsstrahlung heating ~ 0.2W/kW of 28GHz rf
 - ~1.3W/6kW of 28GHz rf
 - The limit of heat loading by bremsstrahlung for KBSI 28GHz ECRIS, ~ 3W
 - Therefore, 2-mm-thick Ta tube is O.K. in operating 6kW of 28GHz rf.
- When $B_{\text{min}}/B_{\text{cur}} = 0.64$,
 - Bremsstrahlung heating from VENUS data of Fig. 11 in Leitner et al. (2008)
 - ~10W/kW of 28GHz rf at no attenuation
 - ~60W/6kW of 28GHz rf at no attenuation
 - Using 6.5/5.4-mm-thick Ta/W tube, reducing factor for x-ray, $RF_{\text{Ta,W}} \sim 19$
 - Using 4-mm-thick Al tube, 2-mm-thick water and 6.5/5.4-mm-thick Ta/W tube, total reducing factor for x-ray, $RF_{\text{Ta,W,water,Ta,W}} \sim 20$
 - With 6.5/5.4-mm-thick Ta/W tube in our system, the final bremsstrahlung heating ~ 0.5W/kW of 28GHz rf
 - ~3W/6kW of 28GHz rf
 - The limit of heat loading by bremsstrahlung for KBSI 28GHz ECRIS, ~ 3W
 - Therefore, we need 6.5 or 5.4-mm-thick Ta or W tube in operating 6kW of 28GHz rf.

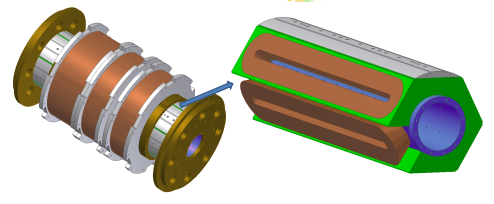


LHe no Boil off Cryostat

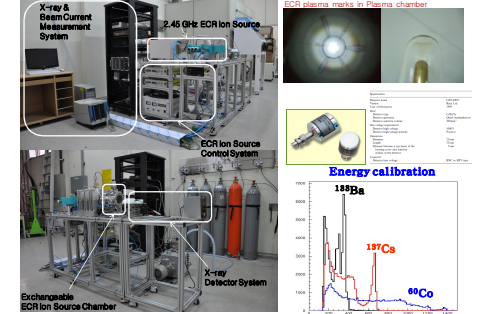
Spec	Unit	Value
Weight of Cryostat (without iron yoke)	kg	<1500
Vacuum Rate of Cryostat	torr	<~9x10⁻⁵
He Leak Rate of Cryostat	cc atm/sec	<~9x10⁻⁹
Volume of He Vessel	liter	<~950
Cooler Capacity (Hea)	W	200
Number of 4.2K Cooler Port	ea	4
Number of HTS 500A Current Lead	pair	4

Shield Radiation	Value
Current Lead (4pair) Conduction	80
Access Port Conduction	5
Access Port Radiation	3
Support (Sea) Conduction	3
Total Heat Loss of Thermal Shield	<126 W
LHe Vessel Radiation	0.3
HTS Current Lead (4pair) Conduction	0.5
Access Port Conduction	0.4
Access Port Radiation	0.2
Support (Sea) Conduction	0.2
X-ray Heating	3 W
Total Heat at Loss of LHe Vessel	<4.6 W

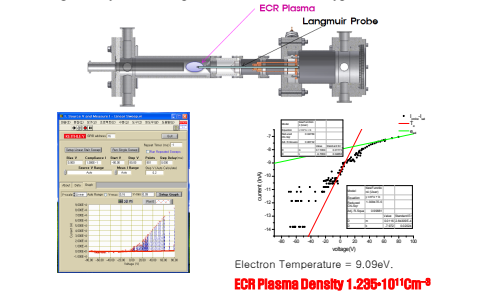
Reinforced Hexapole Coil Structure



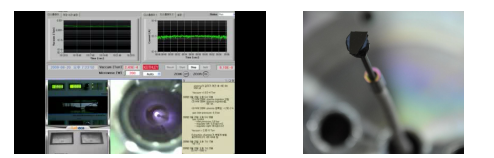
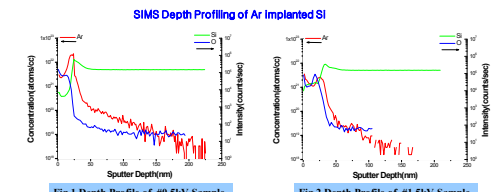
Prototype ECR Ion Source System



Langmuir system & experimentation of Prototype



Implantation of Ar in B-doped SiO2/Si silicon wafer



Concluding Remark

- The main heat load of superconducting magnet system for ECR ions source generated by x-ray irradiation.
- The estimation method of x-ray was presented.
- The x-ray heat load for 28GHz ECR ion source was estimated.
- The heat load of magnet system was calculated and The conceptual cooling system was designed.
- Also, we were trying the study about reinforced structural system and some basic experiments were performed.