SECRAL II Ion Source Development and the First Commissioning at 28 GHz

L Sun

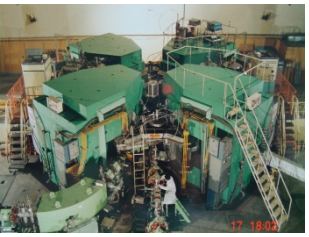
J. W. Guo, W. H. Zhang, X. Fang, W. Wu, Y. C. Feng, X. Z. Zhang, Y. M. Ma, H. Y. Ma, T. J. Yang, Y. Yang, B. Zhao, H. W. Zhao, L. Z. Ma

Institute of Modern Physics, CAS, 730000, Lanzhou, China

Outline

- Introduction
- Design of SECRAL II
- SECRAL II magnet construction
- 1st beam at 28 GHz
- Summary

Introduction: HIRFL



SSC(K=450)

100 AMeV (H.I.), 110 MeV (p)

SFC (K=69)

10 AMeV (H.I.), 17~35 MeV (p)

ECR Area

CSRe

RIBLL1

RIBs at tens of AMeV

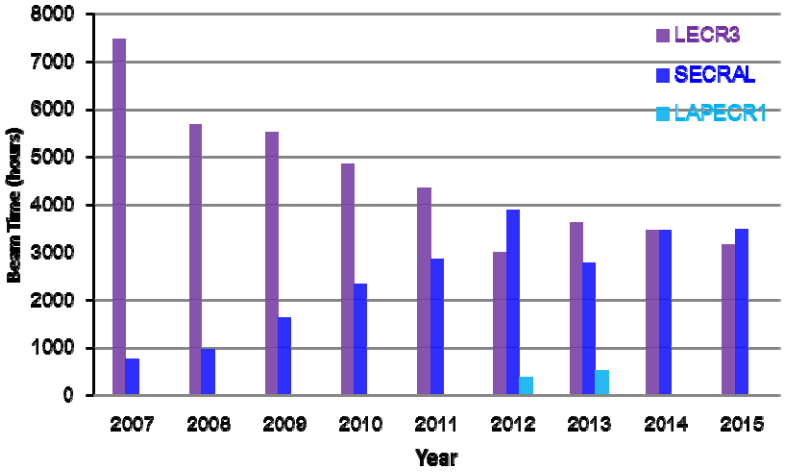
RIBLL2

RIBs at hundreds of AMeV

CSRm

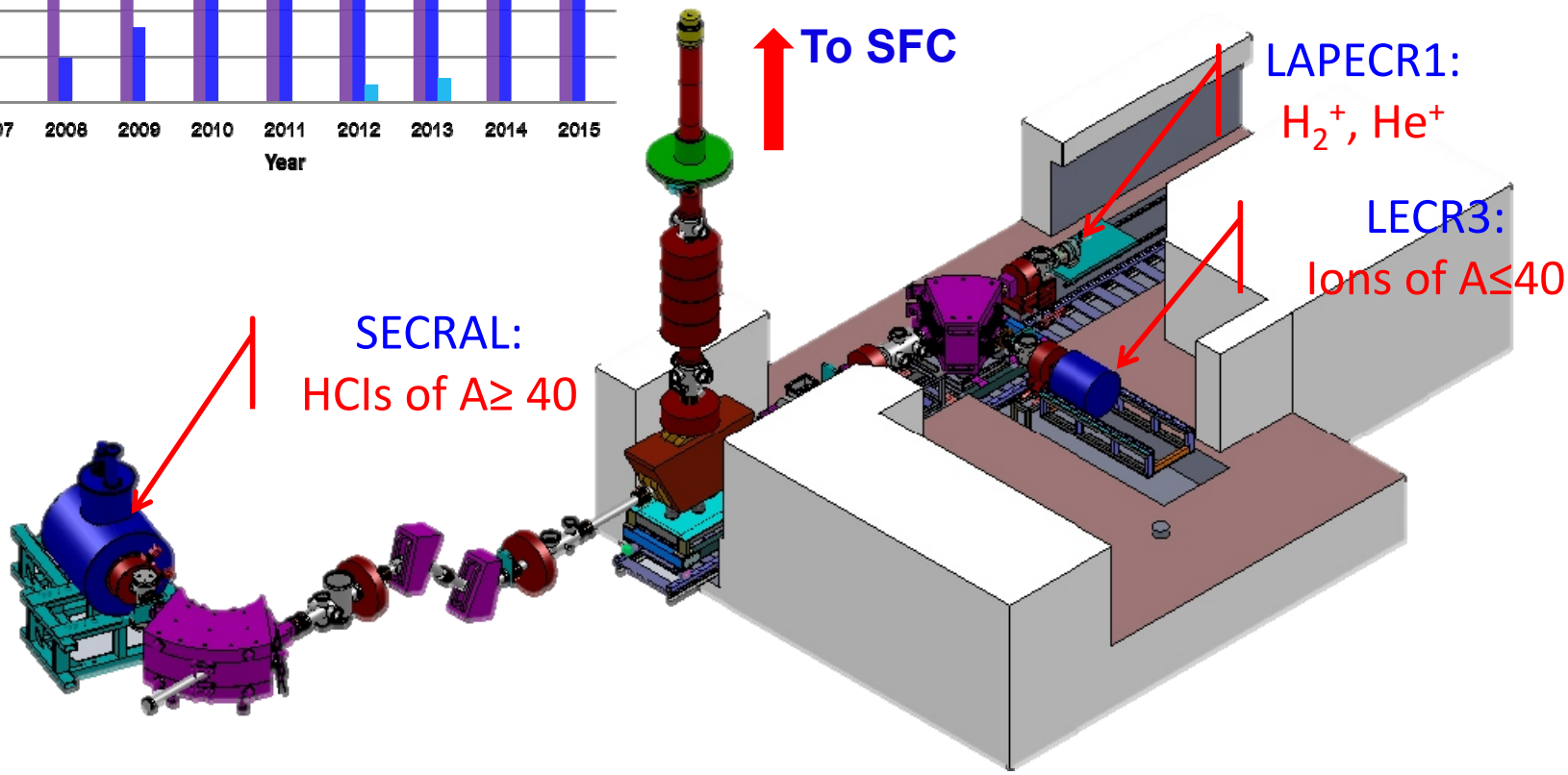
1000 AMeV (H.I.), ≤ 2.8 GeV (p)

Introduction: ECRISs for HIRFL



A backup source:

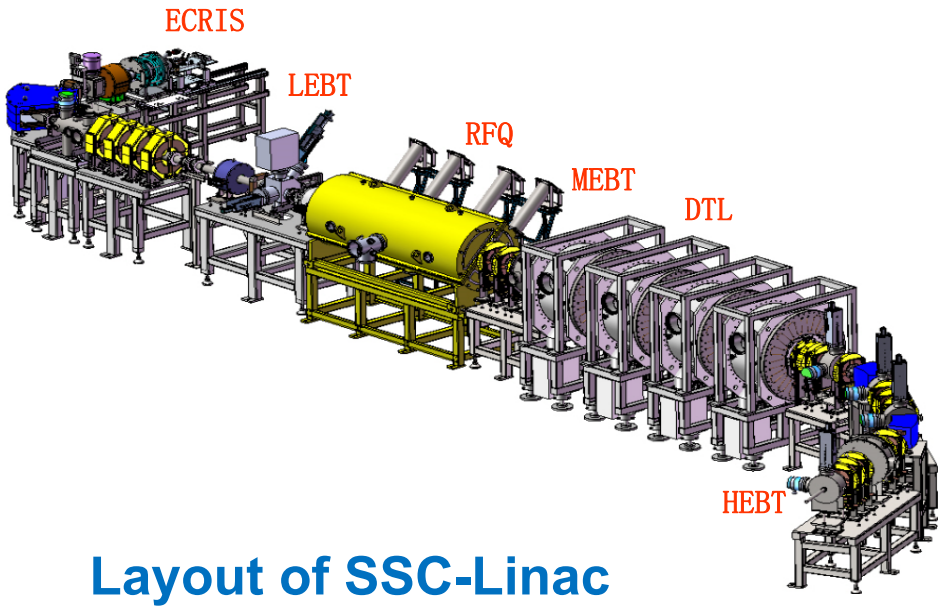
- **For the redundancy of SECRAL**



Introduction: ECRISs for HIRFL

A HCI source:

- **For the new injector Linac**



Layout of SSC-Linac

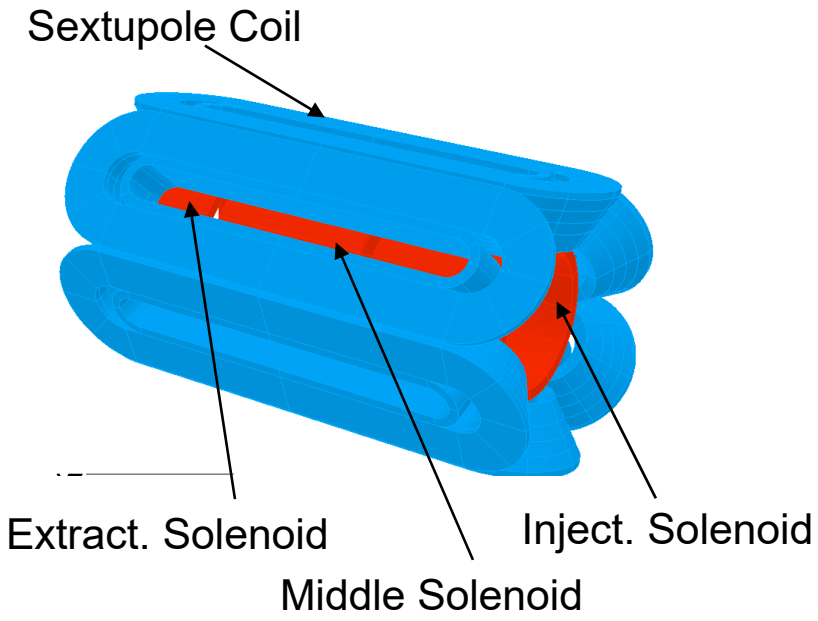
Main parameters of SSC-Linac

Parameters	Values
Designed ion	$^{238}U^{34+}$
Preferred ion	$^{238}U^{37+}$
RFQ	4-rod
Frequency	53.667 MHz
Input energy	3.728 keV/u
Output energy	143 keV/u
Inter-electrode voltage	70 kV
RF power	35 kW
Max. current	0.5 emA
IH-DTL	KONUS
Frequency	53.667MHz
Input energy	0.143 MeV/u
Output energy	1.025 MeV/u

Introduction: SECRAL

Fully superconducting magnet

- Axial field: 3.6, 2.2T
- Sextupole at the wall: 2.0 T
- RF frequency: 18-28 GHz
- Warm bore: Ø140 mm
- Extraction voltage: 25 kV
- 1.42 emA Ar^{12+}, 0.95 emA Xe^{27+}, 0.68 emA Bi^{31+}…
- >24,000 hours beam time for HIRFL



SECRAL II: Magnet Design

Parameters	SECRAL II	SECRAL
ω_{rf} (GHz)	18-28	18-24
Axial Field Peaks (T)	3.7 (Inj.), 2.2 (Ext.)	3.7 (Inj.), 2.2 (Ext.)
Mirror Length (mm)	420	420
No. of Axial SNs	3	3
B_r at Chamber Inner Wall (T)	2.0	1.7/ 1.83
Coldmass Length (mm)	~810	~810
SC-material	NbTi	NbTi
Magnet Cooling	LHe bathing	LHe bathing
Warm bore ID (mm)	~142 .0	140.0
Chamber ID (mm)	125.0	116.0/120.5
Dynamic cooling power (W)	~5	0

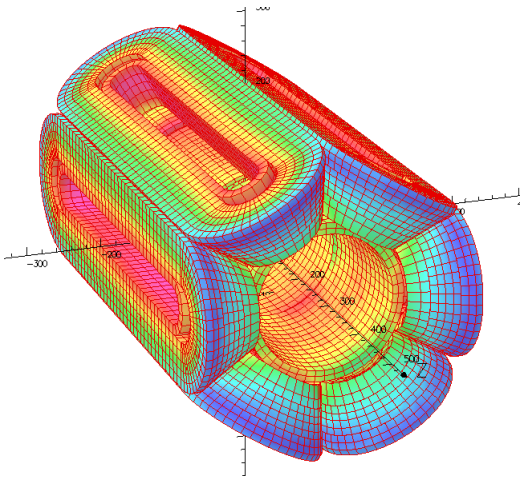
SECRAL II: Superconductor Choice

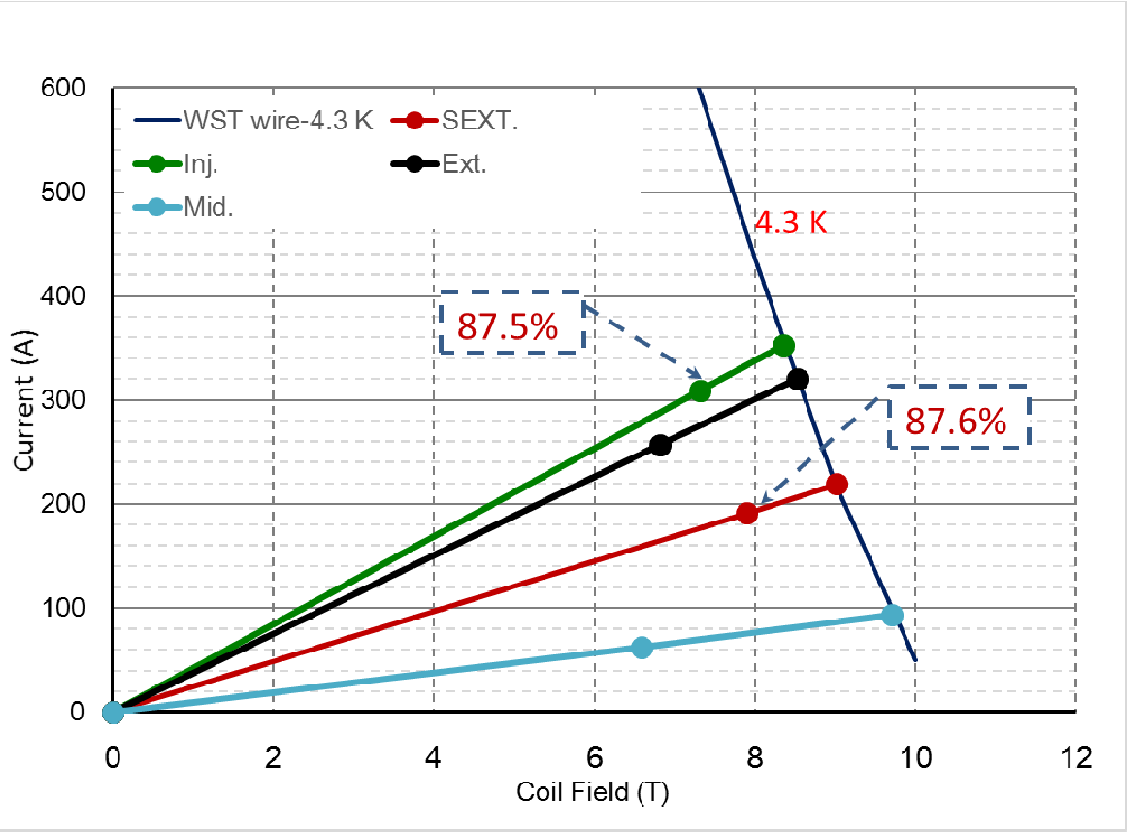
Typical Specs of the SC-wire

Material	NbTi/Cu
Type	Monolith
Insulation	Formvar
bare size (mm)	1.20×0.75
insulated size (mm)	1.28×0.83
nominal Cu/Sc ratio	1.3:1
RRR	>100
Number of filaments	630
filament size（um）	27.6
pitch size（mm）	15

- Rectangular cross section wire is used to improve the fill factor
- Domestic SC-wire from WST Co., Ltd

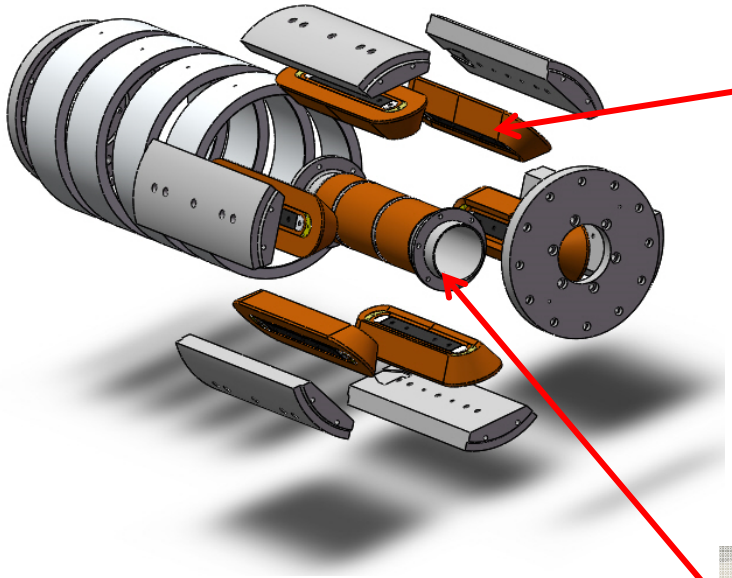
SECRAL II: Superconductor Analysis

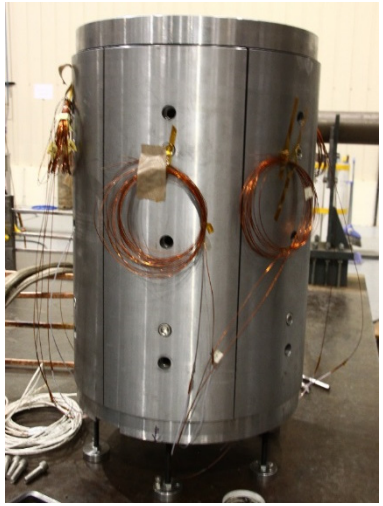


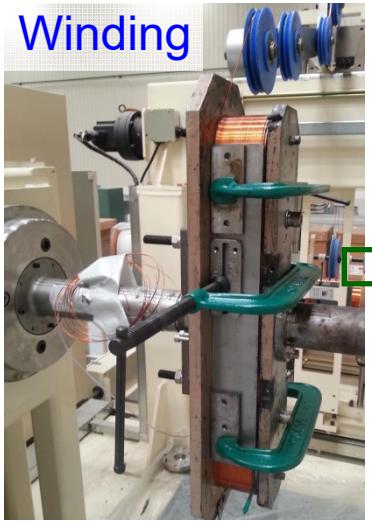


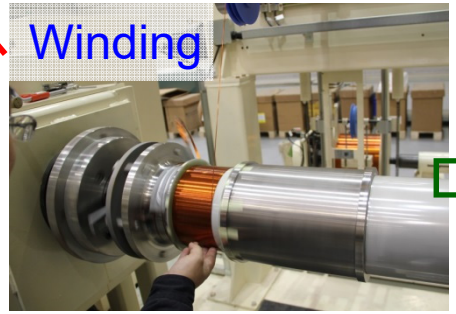
	SEXT.	INJ	EXT.	
SECRAL	89%	87%	78%	Ø0.9 mm
SECRAL II	87.5%	87.6%	80%	1.28×0.83 mm^2

SECRAL II: Coldmass Fabrication

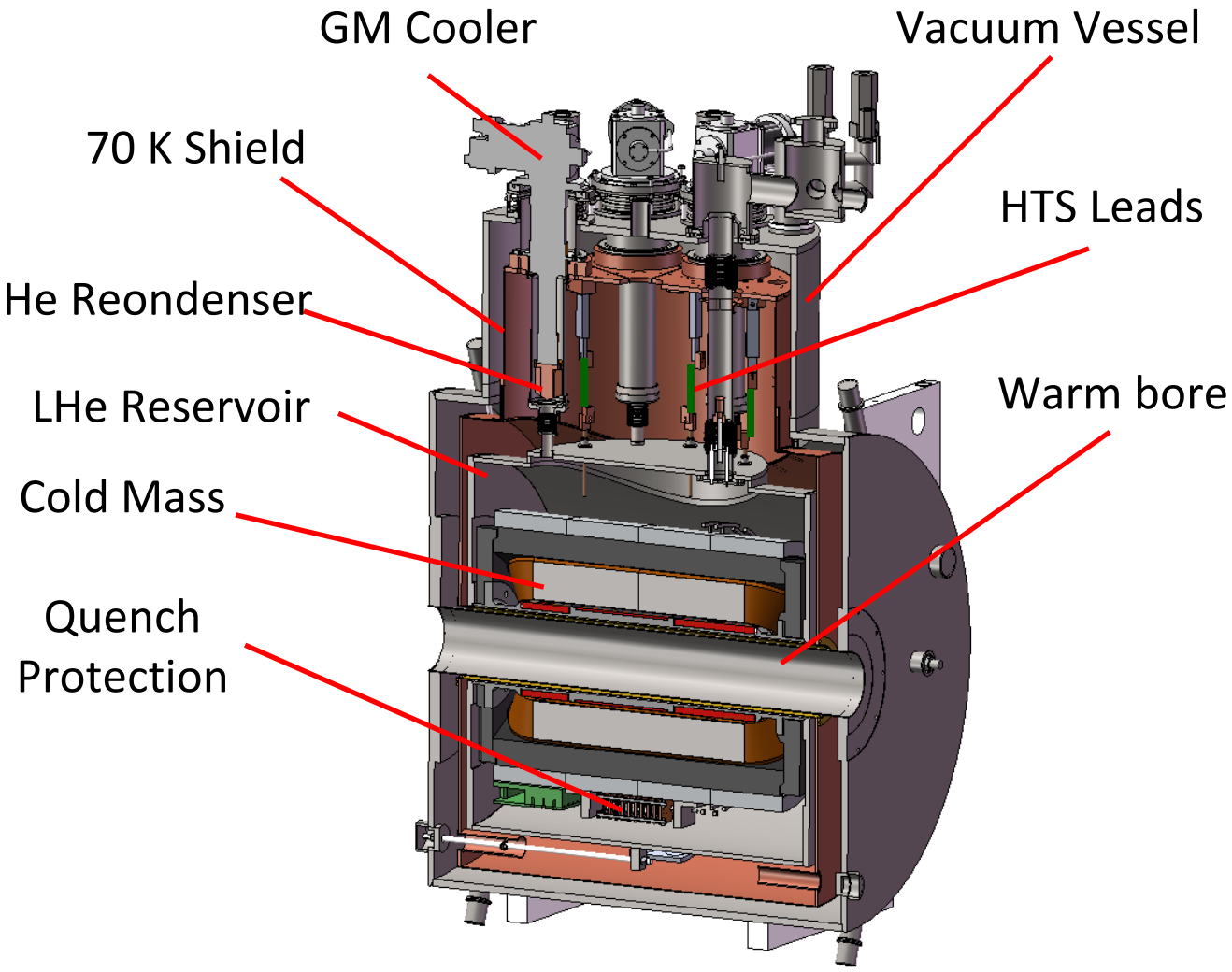








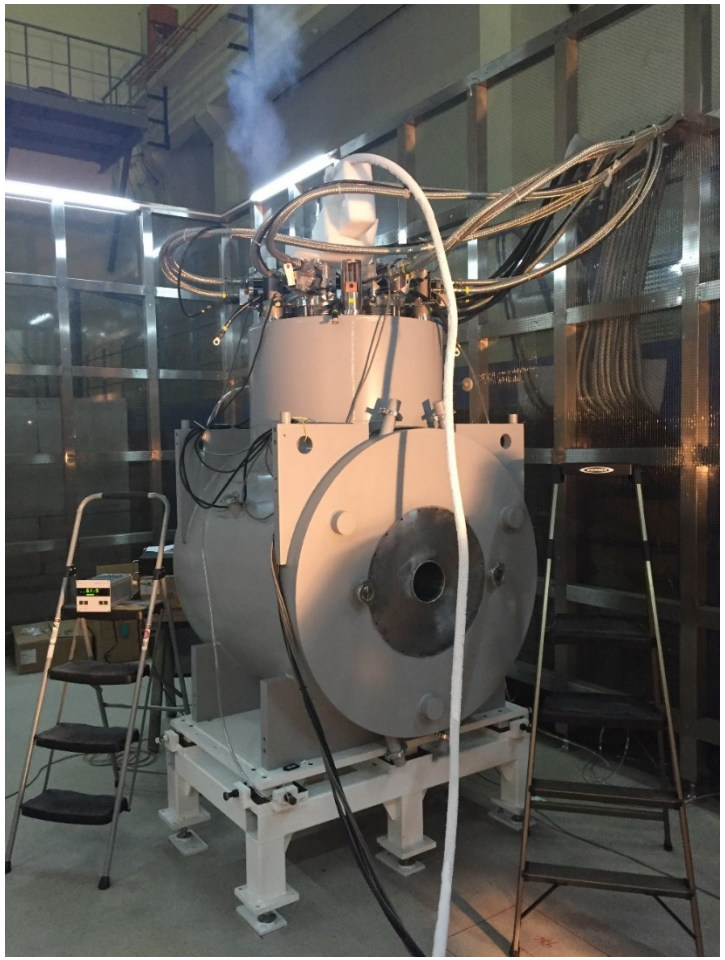
SECRAL II: Magnet Structure

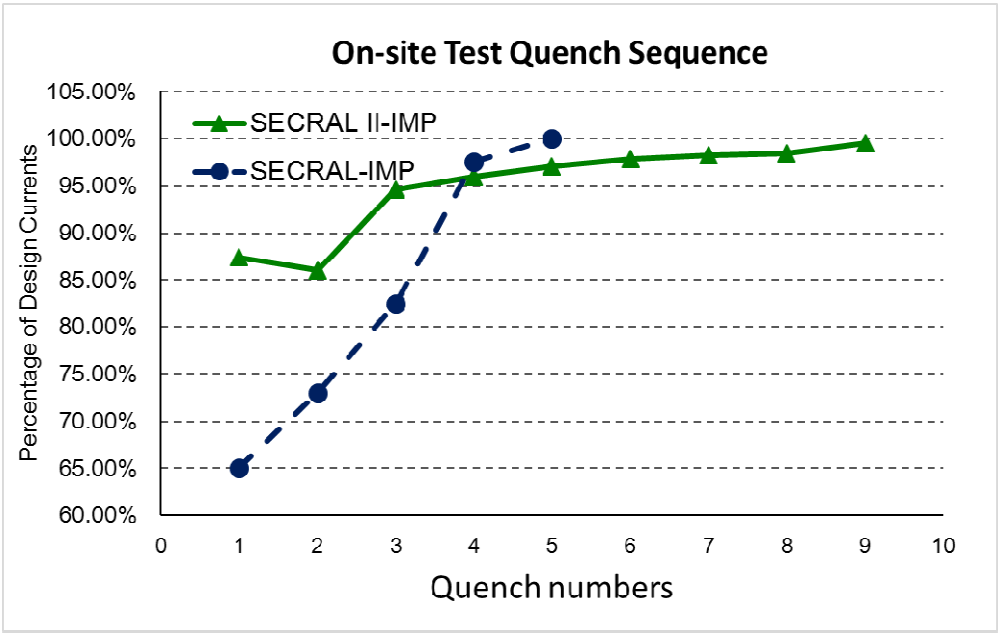


Based on SECRAL Design

5 × RDK-415 D

SECRAL II: Magnet Test





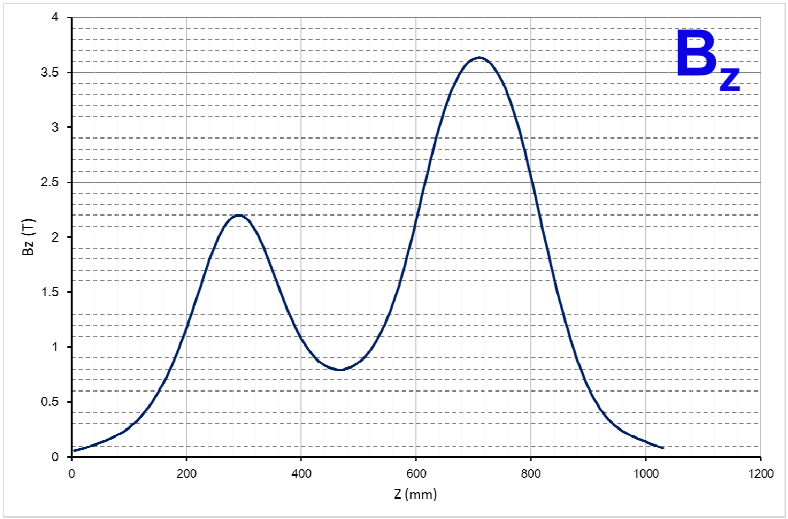
User's site test:

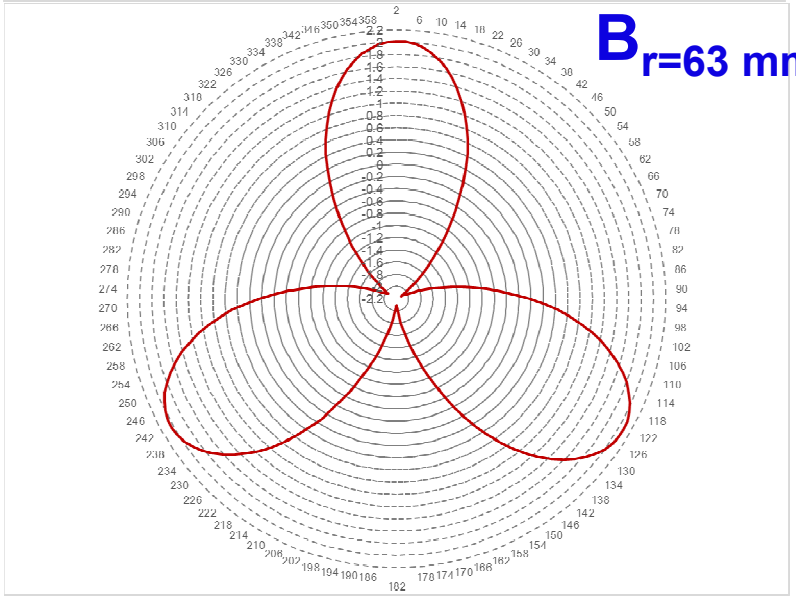
- 3 quenches to reach 95% design currents
- 9 quenches to reach 100% design currents
- No quench happens during beam commissioning

SECRAL II: Magnet Specs.

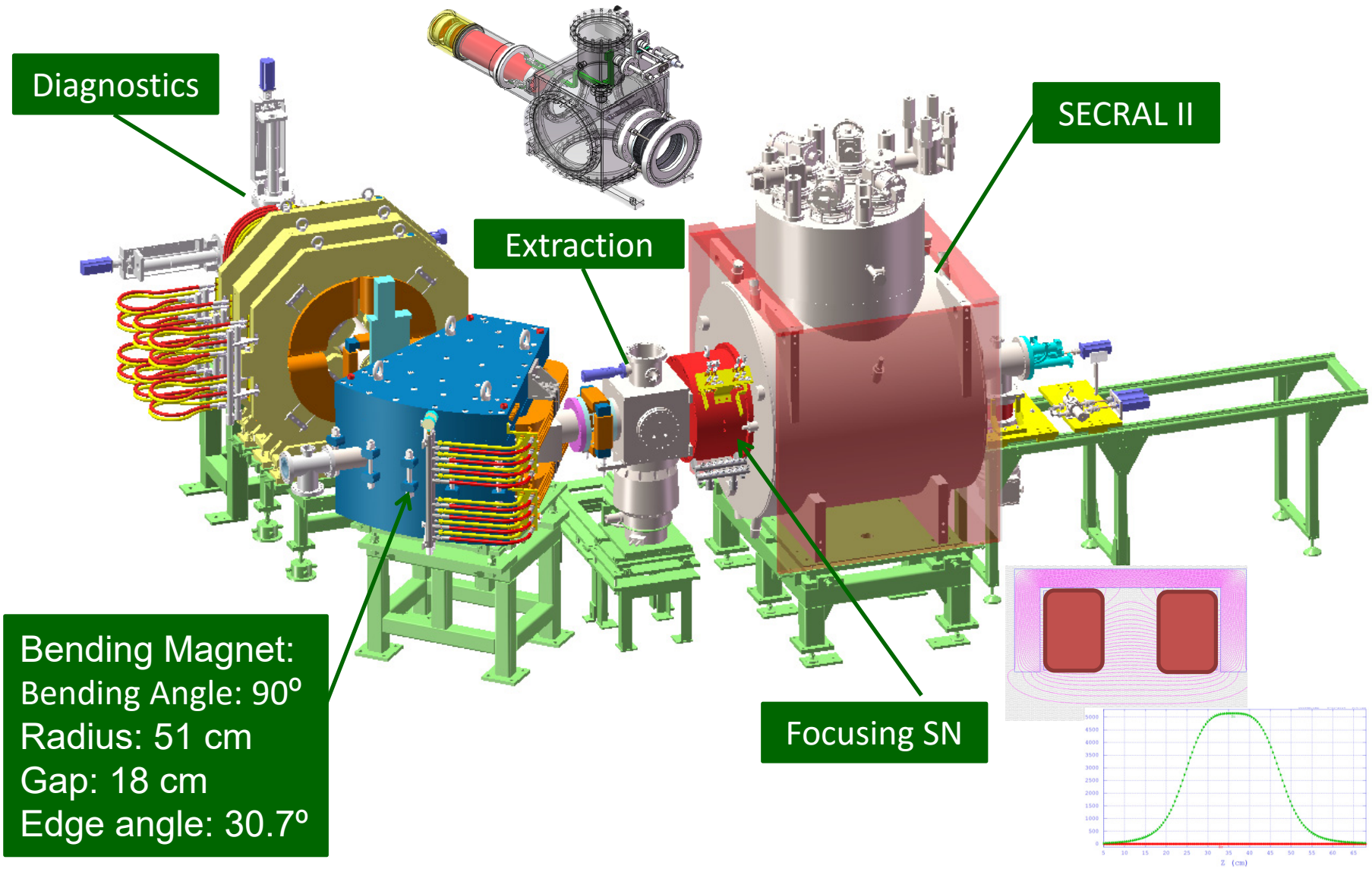
Parameters	SECRAL II
ω_{rf} (GHz)	18-28
Axial Field Peaks (T)	3.7 (Inj.), 2.2 (Ext.)
Mirror Length (mm)	420
No. of Axial SNs	3
B_r at r=63 mm (T)	2.06
Coldmass Length (mm)	810
SC-material	NbTi
Magnet Cooling	LHe bathing
Warm bore ID (mm)	142 .0
Chamber ID (mm)	125.0
Dynamic cooling power (W)	6.0*

***Static heat load @4.2 K: ~1.0 W**



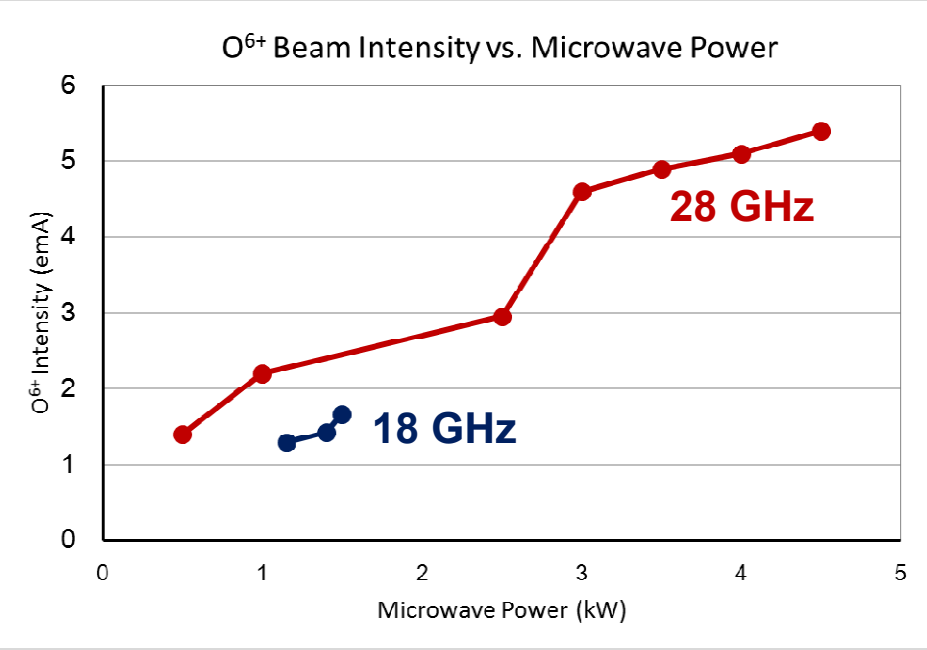


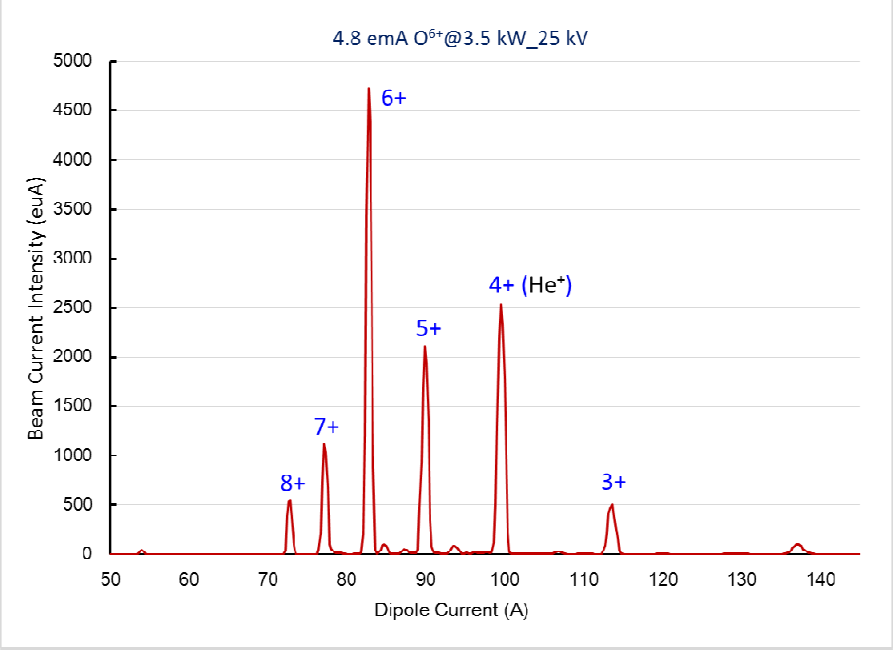
SECRAL II: Test Bench Design



SECRAL II: Test Bench Layout

Beam Commissioning: Oxygen

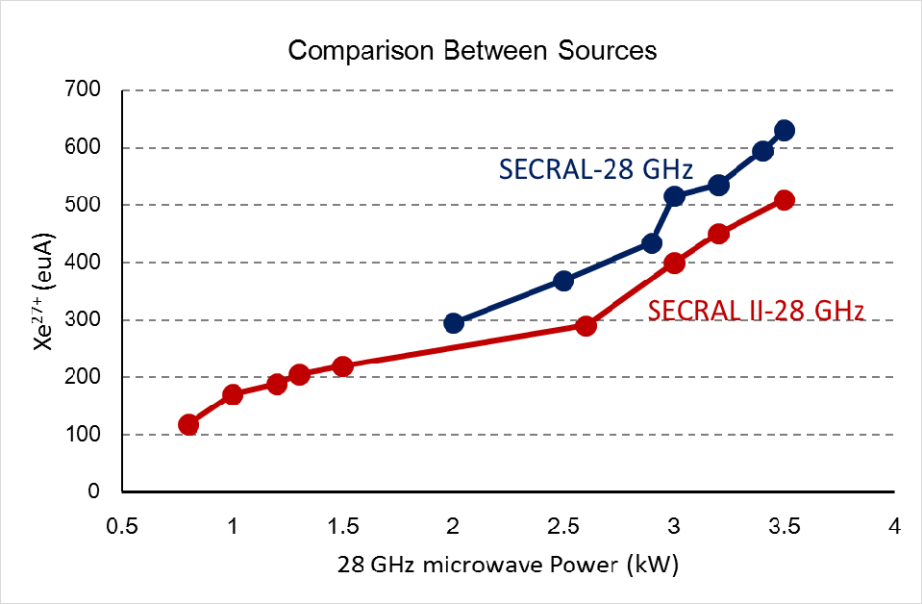


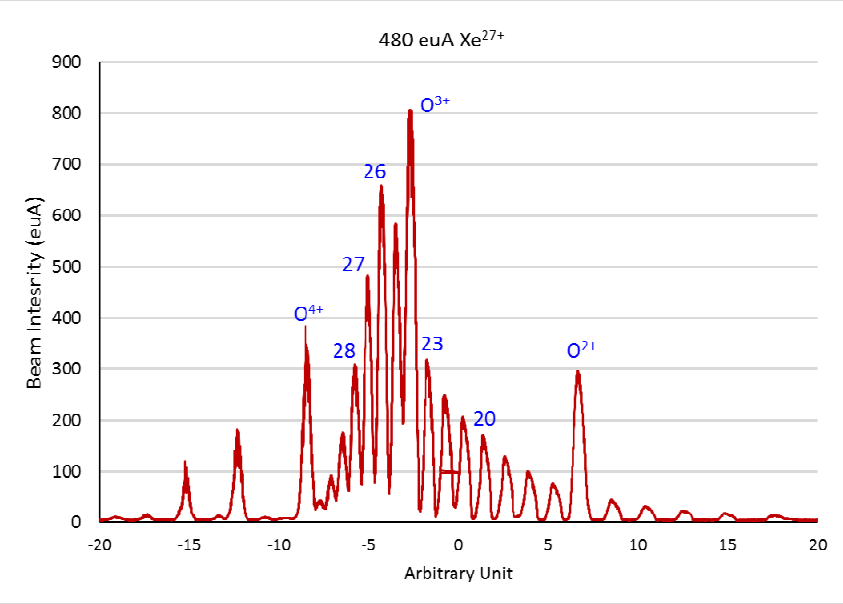


	$P_{28\ GHz}$ (kW)	I_{drain} (emA)	I_q (emA)
O^{6+}	4.5	20.0	5.4
O^{7+}	3.5	13.0	1.57

- **Total beam transmission efficiency is 84% (1.8 emA O^{6+}, 8.0 emA drain current)**

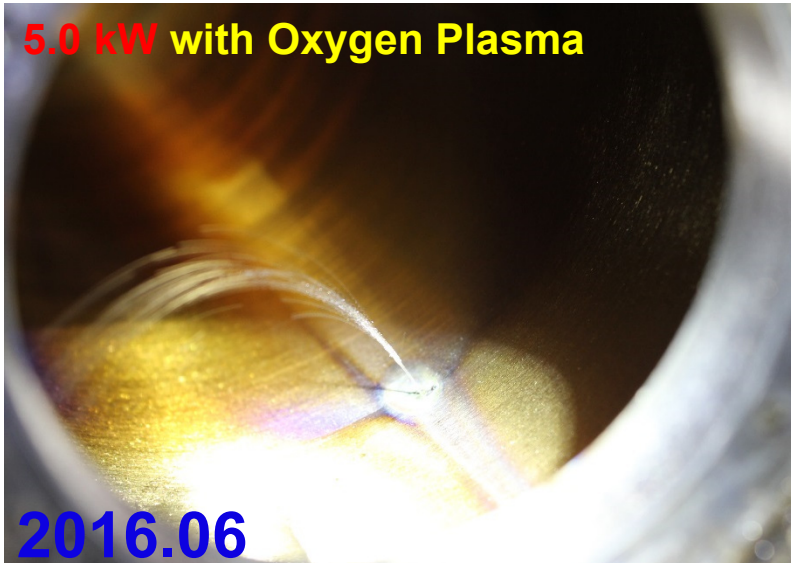
Beam Commissioning: Xenon

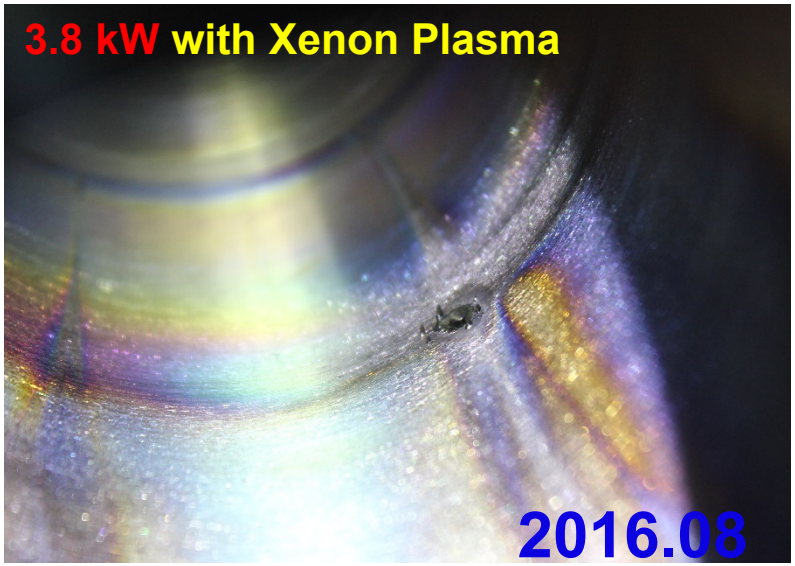




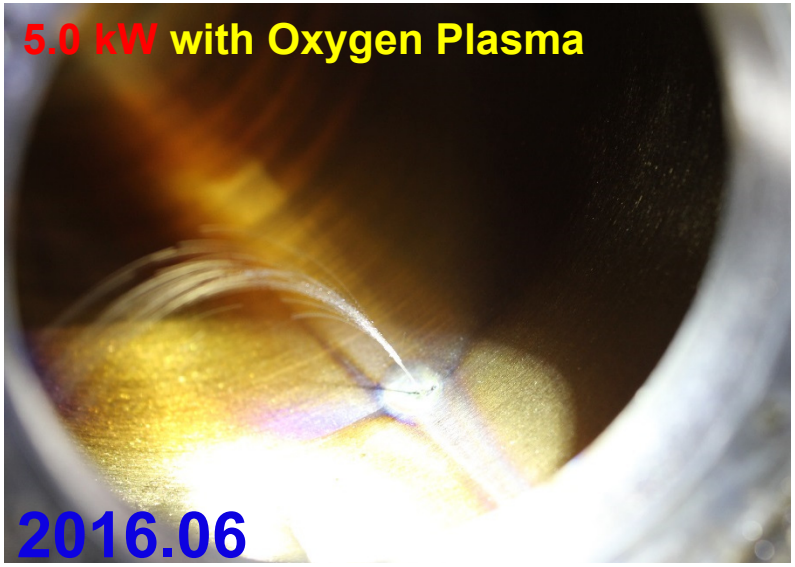
- ~10 days conditioning to produce 510 euA Xe^{27+}
- Total beam transmission efficiency is 86% (450 euA Xe^{27+}, 7.0 emA drain current)
- Obvious instability at high power

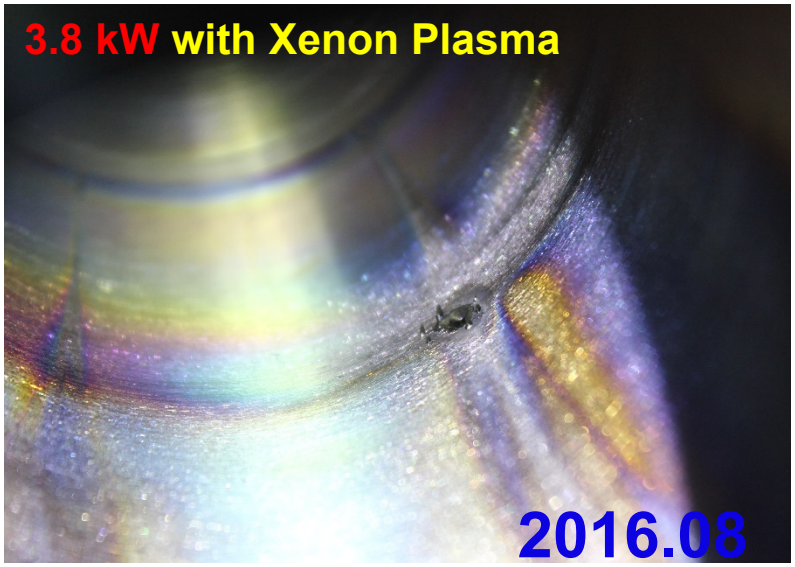
Beam Commissioning: High Power problem

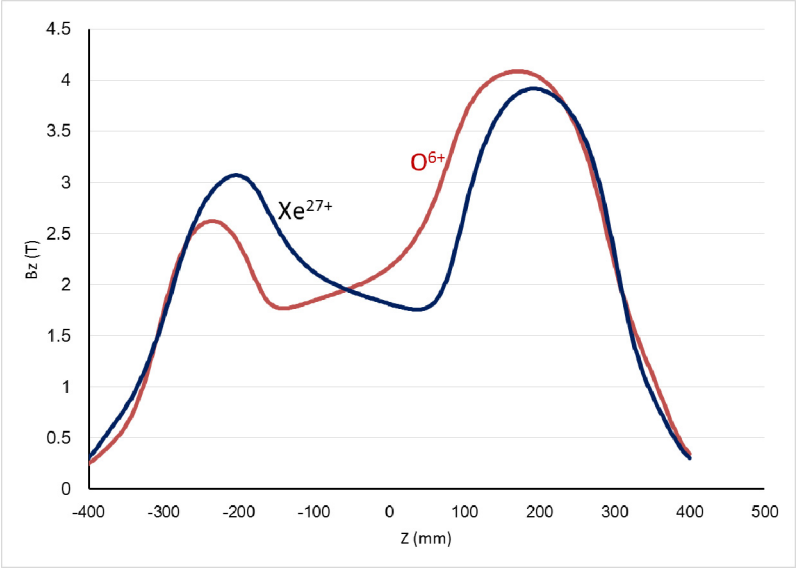




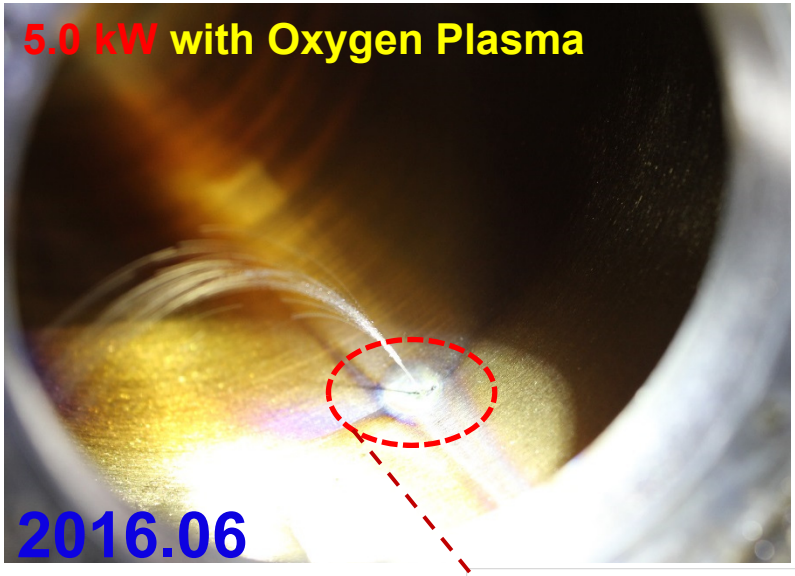
Beam Commissioning: High Power problem

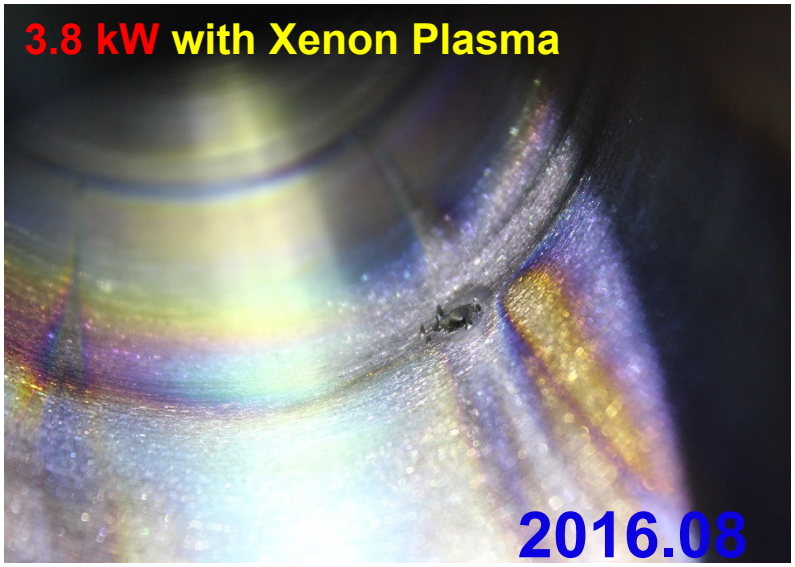


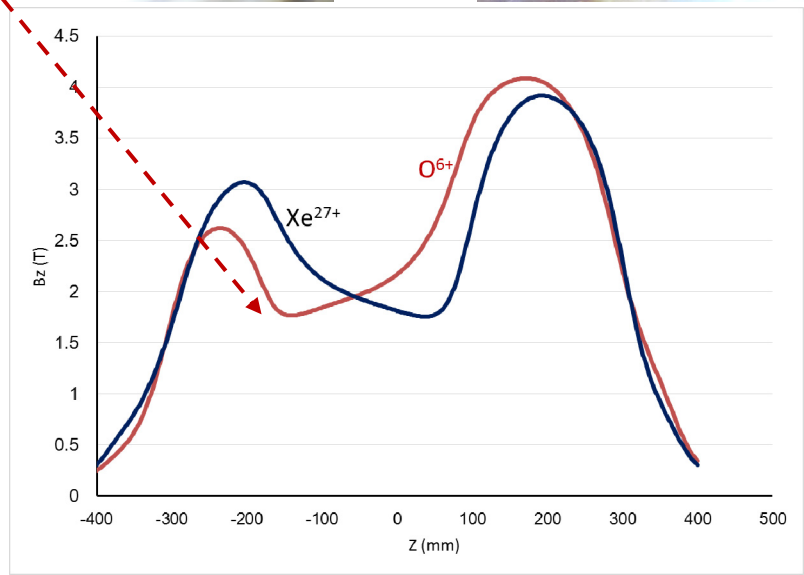




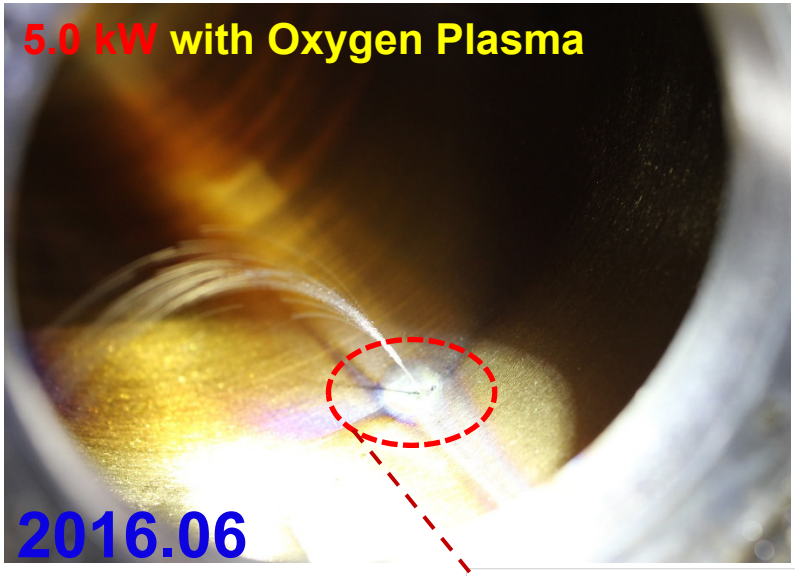
Beam Commissioning: High Power problem

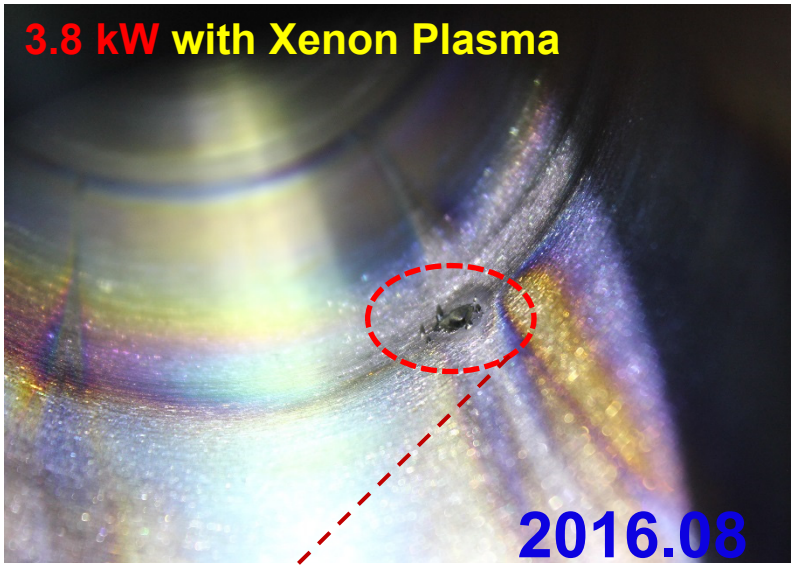


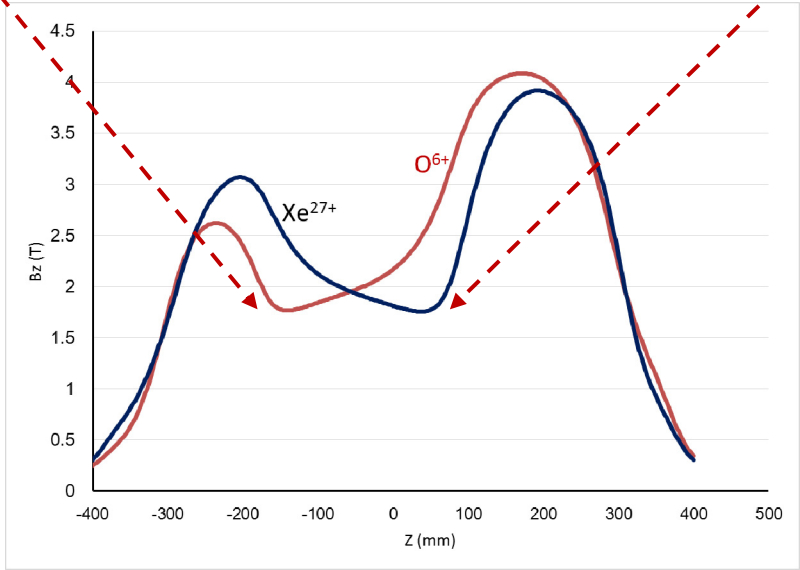




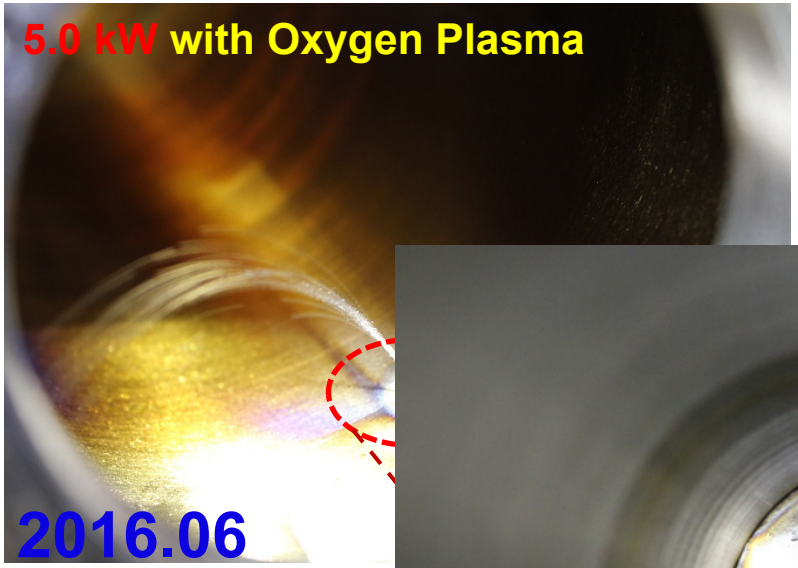
Beam Commissioning: High Power problem

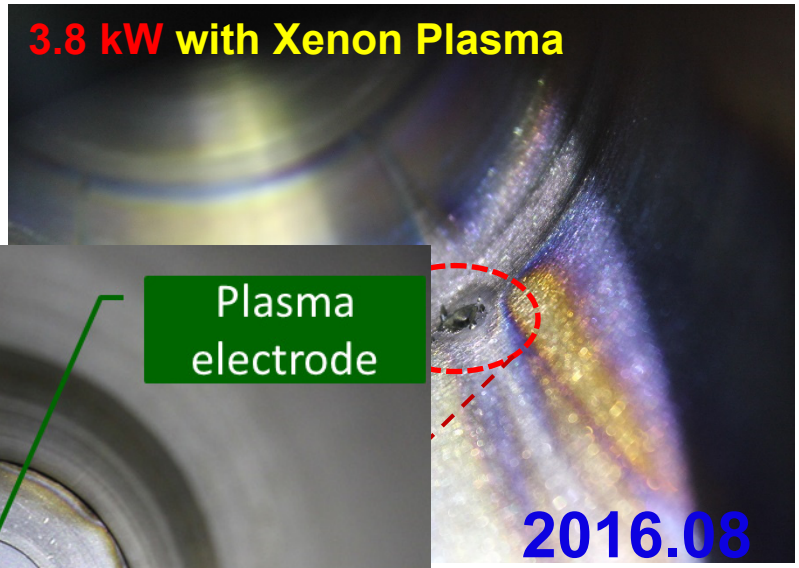


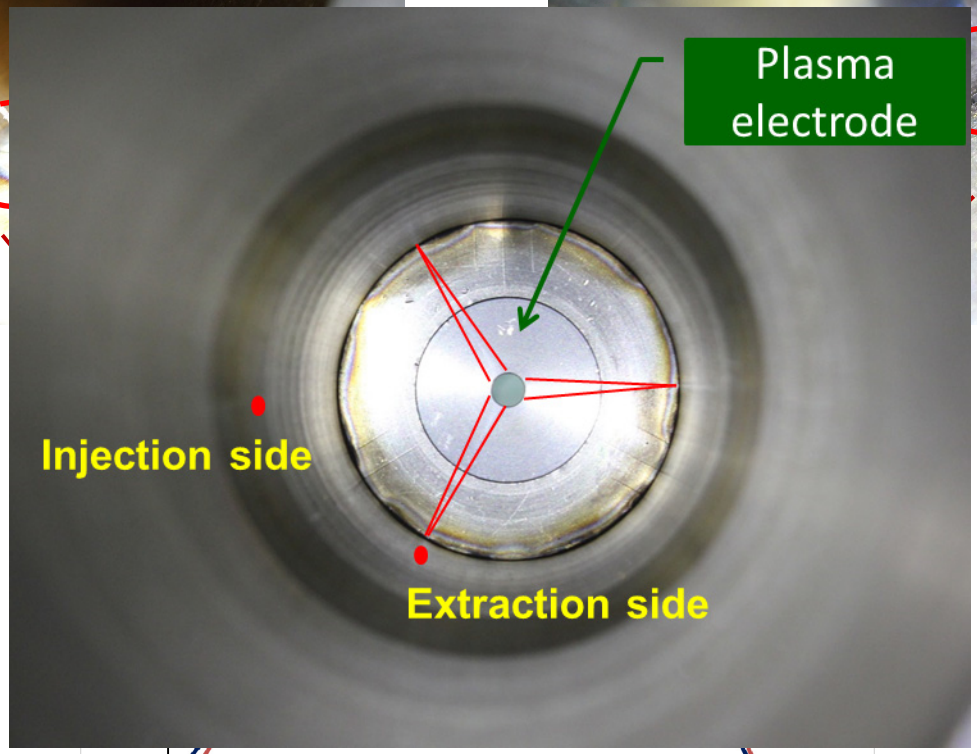


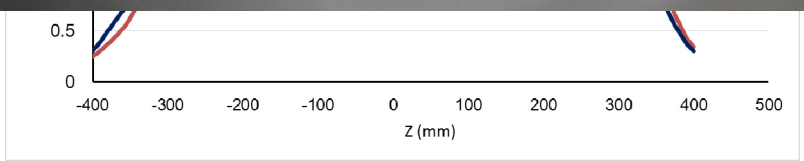


Beam Commissioning: High Power problem

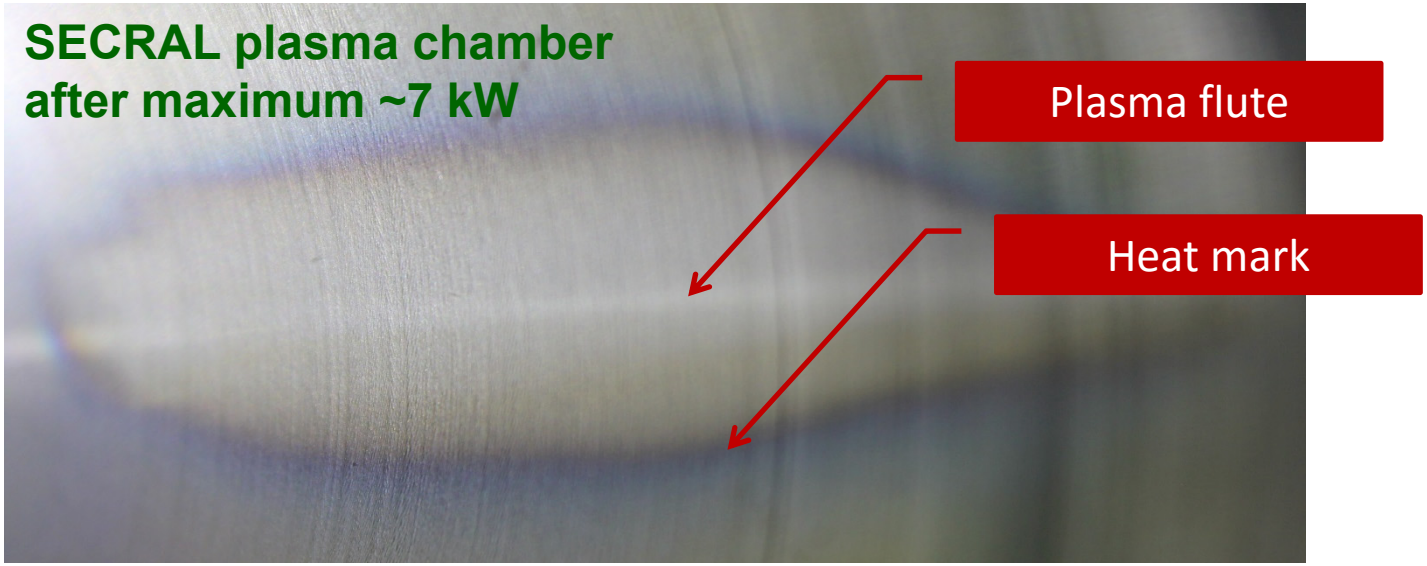




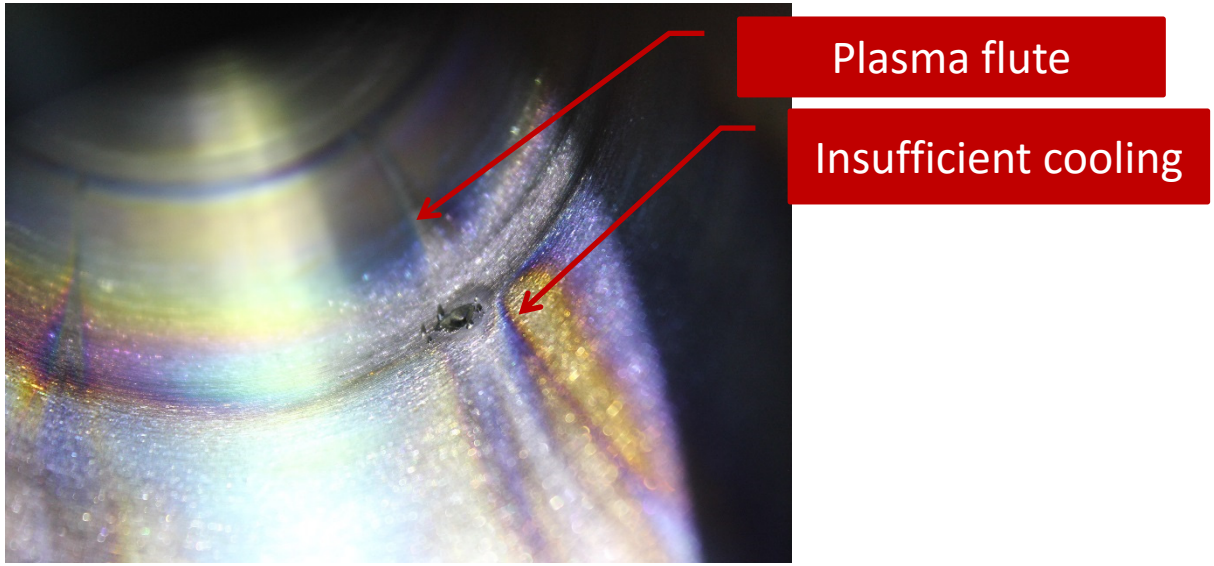




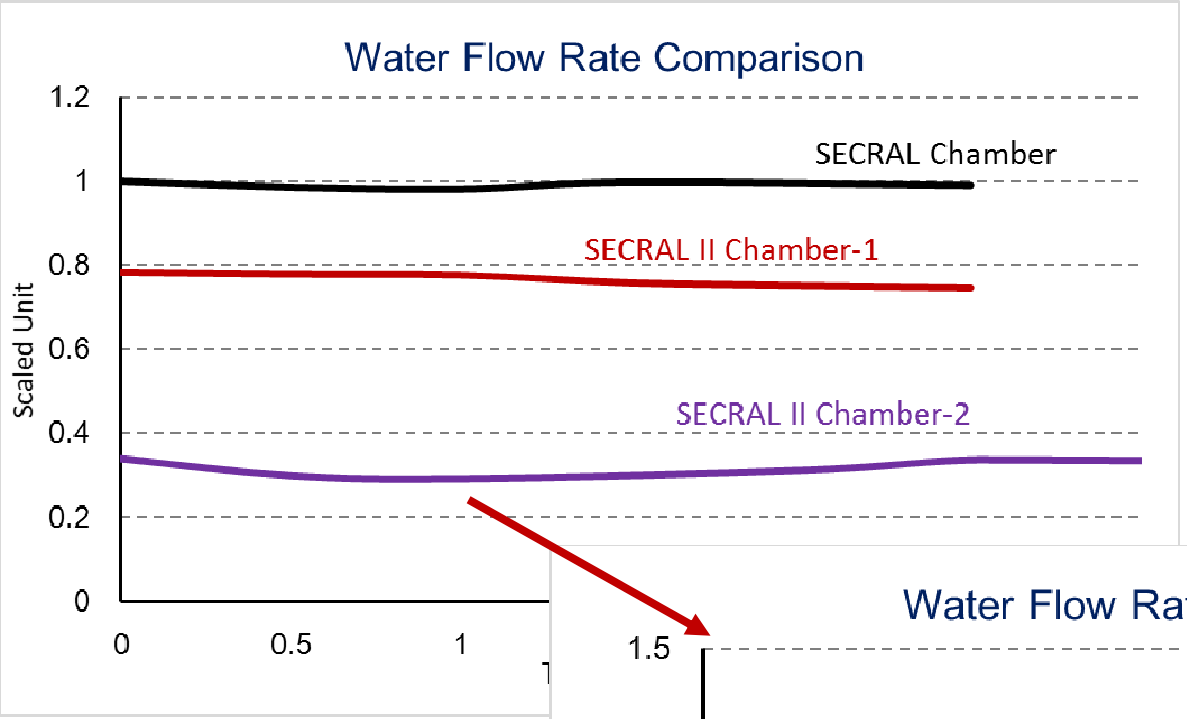
Beam Commissioning: Trouble Shooting

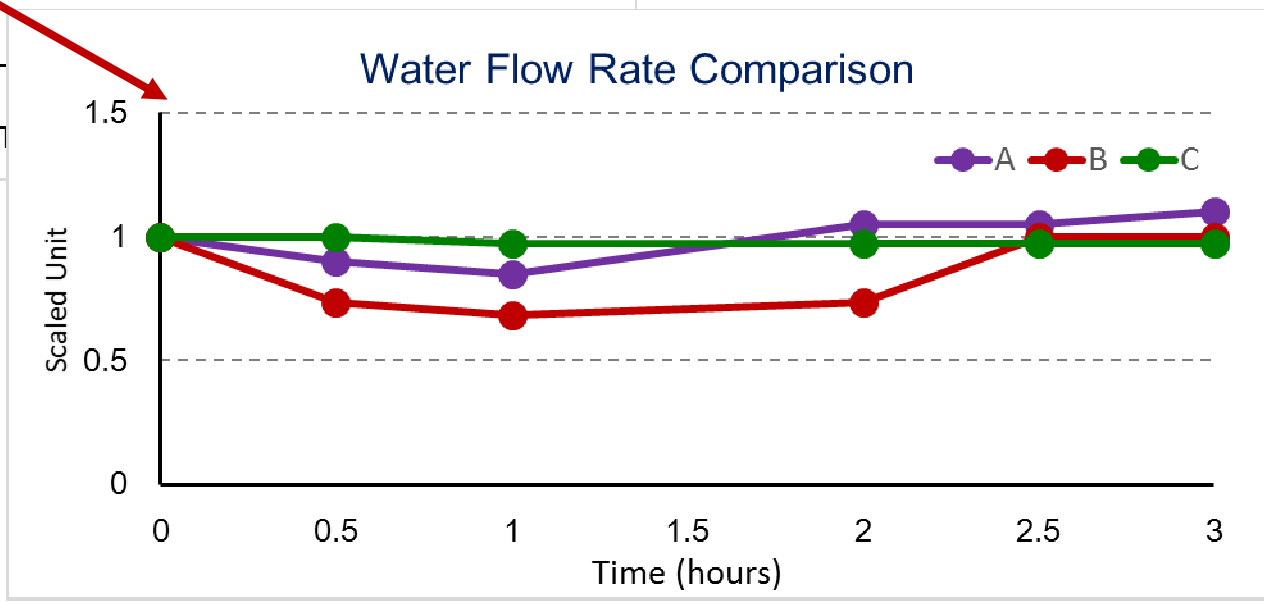


SECRAL II plasma chamber after maximum 5.0 kW



Beam Commissioning: Trouble Shooting





SECRAL II Milestones

2013.01—2013.03: Contract and sextupole coil prototyping

2013.03—2014.06: Cold mass fabrication

2014.07: Cold mass successfully tested

2013.05—2015.08: Cryostat and magnet integration

2015.09: Factory test and acceptance

2015.12: User's site acceptance test

2016.01: 1st plasma at 18 GHz

2016.03—2016.05: Instrumentation and control test

2016.06: First oxygen plasma at 28 GHz and plasma burnt hole at 5 kW

2016.08: First xenon plasma at 28 GHz and plasma burnt hole at 3.8 kW

Summary

- A 28 GHz superconducting ECRIS has been successfully built at IMP
- Total ion source developing time is around 3 years
- 5.4 emA O^{6+}, 1.57 emA O^{7+} and 510 euA Xe^{27+} have been produced within short conditioning time
- Plasma chamber cooling is essential for high power high performance test and operation
- More R&D is needed to make SECRAL II performing better

Acknowledgement

ECR Team:
J. W. Guo, W. H. Zhang, X. Fang, Y. C. Feng, X. Z. Zhang, H. Y. Ma, Y. Yang, H. W. Zhao

Magnet Team:
W. Wu, B. Zhao, Y. M. Ma, D. S. Ni, T. J. Yang, L. Z. Ma

The Company: XSMT inc.

Thanks for your attention

谢谢！