핵융합로공학 선행연구센터
CARFRE
Center for Advance Research in Fusion Reactor Engineering

University Fusion Programs in Korea

Yong-Seok Hwang

Center for Advance Research in Fusion Reactor Engineering(CARFRE)

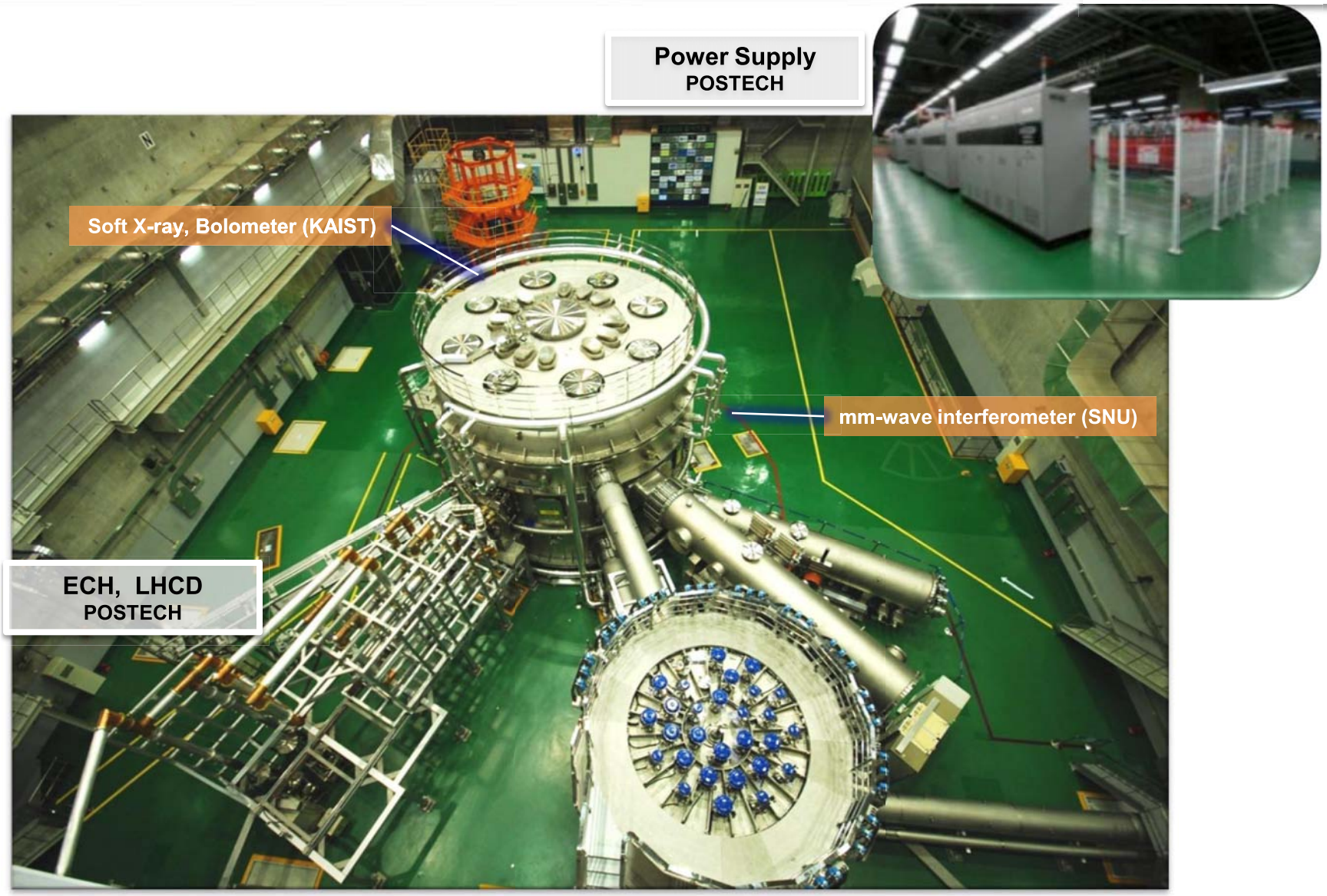
Seoul National University

Presented at 2009 US-KSTAR workshop at GA

OUTLINE

- University activities in KSTAR construction phase
- Major universities with fusion programs
  - Seoul National Univ.(SNU)
  - POSTECH
  - KAIST
  - Hanyang Uinv.(HYU)
- Outlook on University participations in KSTAR

University Participations in KSTAR Construction



Limited participation

SNU: Core and Edge Simulations

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CARFRE
Center for Advance Research in Fusion Reactor Engineering

Seoul National University
Department of Nuclear Engineering

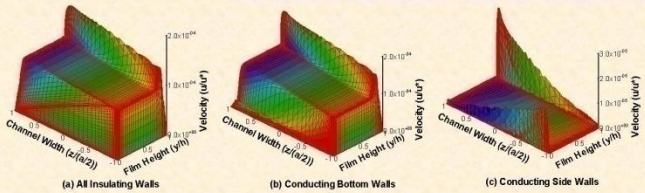
FUSMA
Fusion and Plasma Applicaiton Lab.

Computational Studies on Fusion Plasmas

Fusion and Plasma Application Laboratory
Department of Nuclear Engineering
Seoul National University

• MHD study on liquid metal divertors

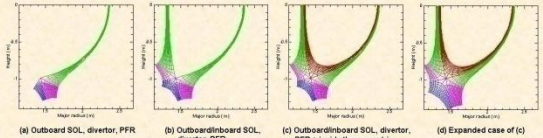
• Velocity profiles of liquid metal film flows in inclined magnetic fields



(a) All Insulating Walls (b) Conducting Bottom Walls (c) Conducting Side Walls

• Edge plasma transport
• Divertor operation regimes

• Various mesh configurations for edge transport modeling

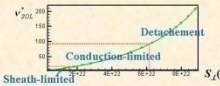


(a) Outboard SOL, divertor, PFR (b) Outboard/inboard SOL, divertor, PFR (c) Outboard/inboard SOL, divertor, PFR + inside the seperatrix (d) Expanded case of (c)

• Divertor operation regime identification

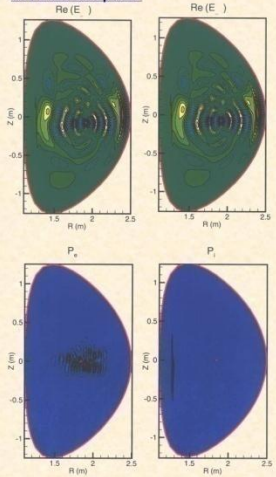
SOL (upstream) collisionality :

$$\nu^{*}_{zOL} \equiv L / \lambda^{u}_{ee} \approx 10^{-16} n_{eu} L / T^{2}_{eu}$$

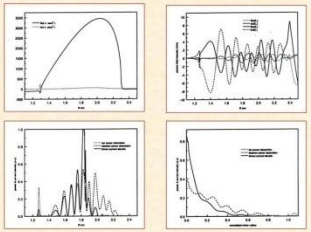


• Fast wave current drive (FWCD) in tokamaks

• Distribution of fast wave electric field and absorbed power

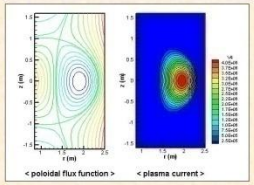


• Characteristics of fast wave propagation, absorption and current drive

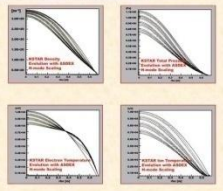


• Plasma equilibrium
• Core plasma transport

• MHD equilibrium with free boundary conditions

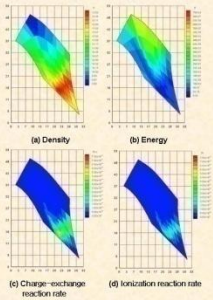


• 1D core plasma transport



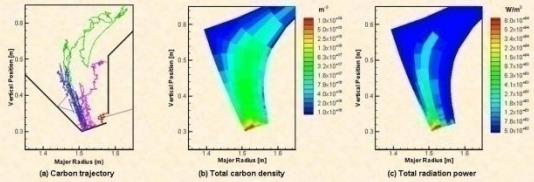
• Recycling neutral transport

• Monte Carlo simulation in detached divertor plasmas

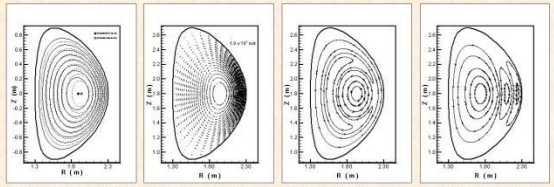


• Impurity transport

• Self-consistent Monte Carlo simulation for carbon impurities



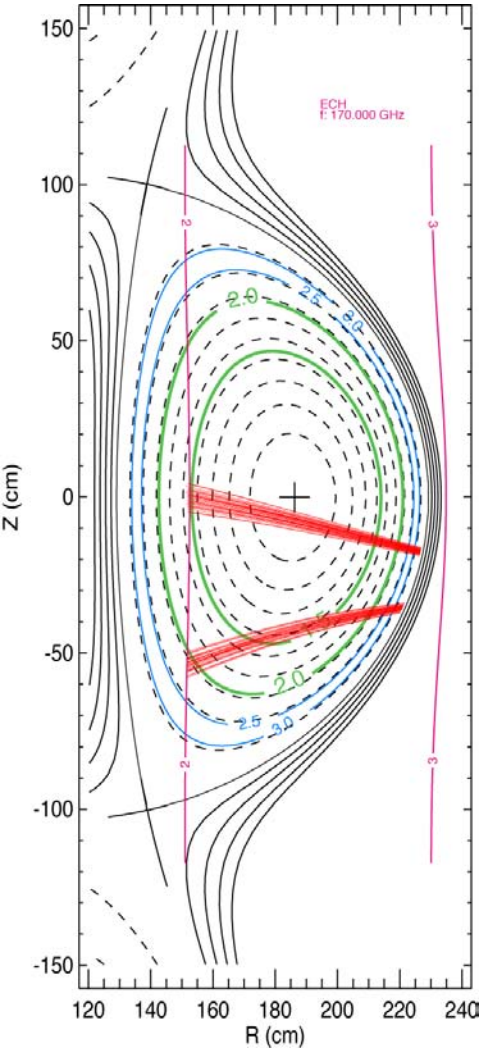
• MHD equilibrium with toroidal and poloidal rotations



(a) Displacement of isobaric surfaces from magnetic flux surfaces with a toroidal rotation in existence (b) Poloidal flow with toroidal and supersonic poloidal rotations in existence (c) Poloidal plasma current with toroidal and subsonic poloidal rotations in existence (d) Poloidal plasma current with toroidal and supersonic poloidal rotations in existence

http://fusma.snu.ac.kr

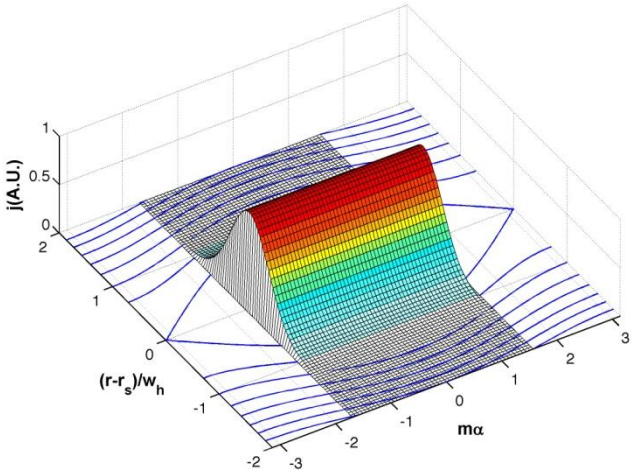
SNU: Conceptual Design of KSTAR NTM Control



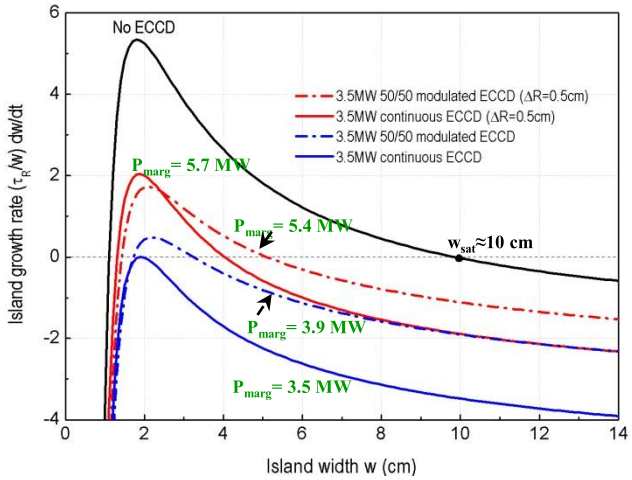
- Optimized ECCD injection for the 3/2 & 2/1 NTMs

- **Active suppression of NTMs by localized ECCD is a key issue of KSTAR aiming high confinement, steady-state advanced operations.**

- **To realize successful NTM suppression by the planned 170GHz ECCD system, SNU has performed NTM-relevant studies as following.**
  - **Optimization of ECCD injection for efficient NTM suppression**
  - **Development of fast NTM identification method by using ECE measurement**
  - **Analysis of NTM stability & development of dynamic NTM control simulation**
  - **Development of model-based advanced NTM control method**



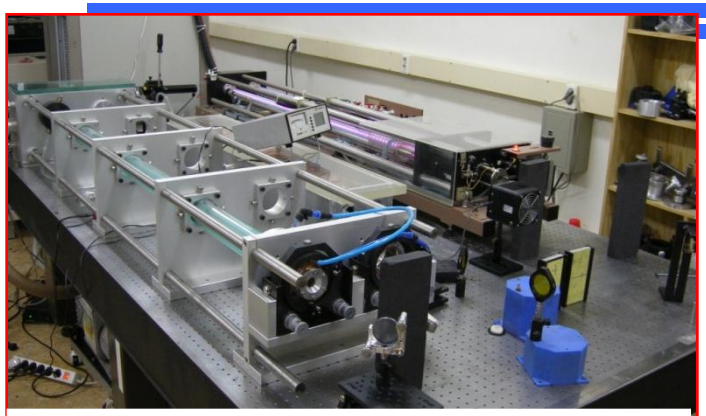
- Analysis of ECCD modulation effect on island



- Stability of the 2/1 NTM in the KSTAR plasma

SNU: FIR Interferometer/Polarimeter for KSTAR

Conceptual Design of KSTAR Interferometer/Polarimeter[1)]



FIR laser: 90mW/90W achieved

1) M.S. Cheon, et al., Rev. of Sci. Inst., 2004

POSTECH: ECH and LHCD Development

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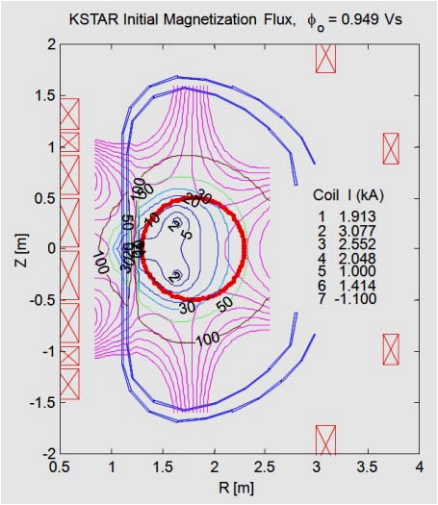
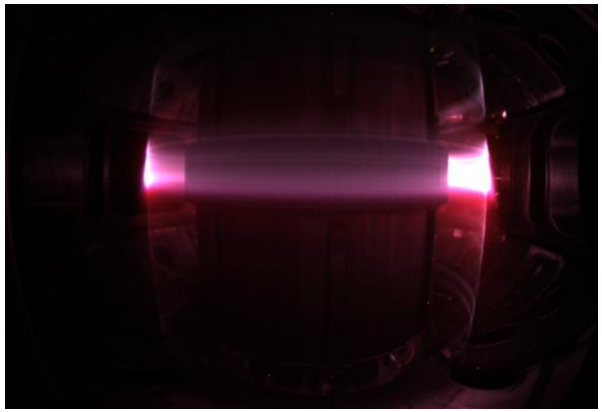
84GHz ECH System

5GHz Klystron Test for LHCD

Startup scenario

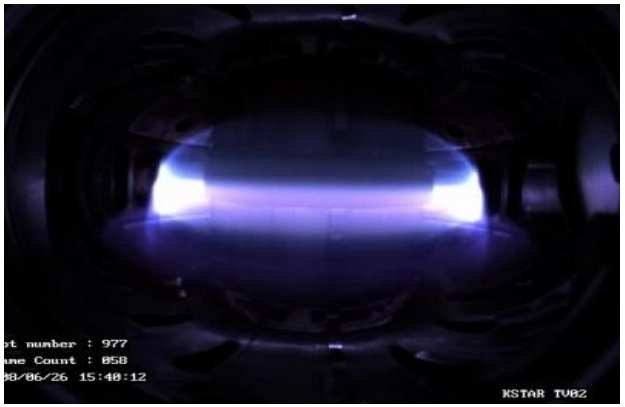


ECH pre-ionization test under TF field only



Shot 558
TF = 13.3kA (1.5 T @ 1.6 m)
ECH = 84 GHz, 500kW, 50ms,

ECH pre-ionization test at dipole-like field configuration

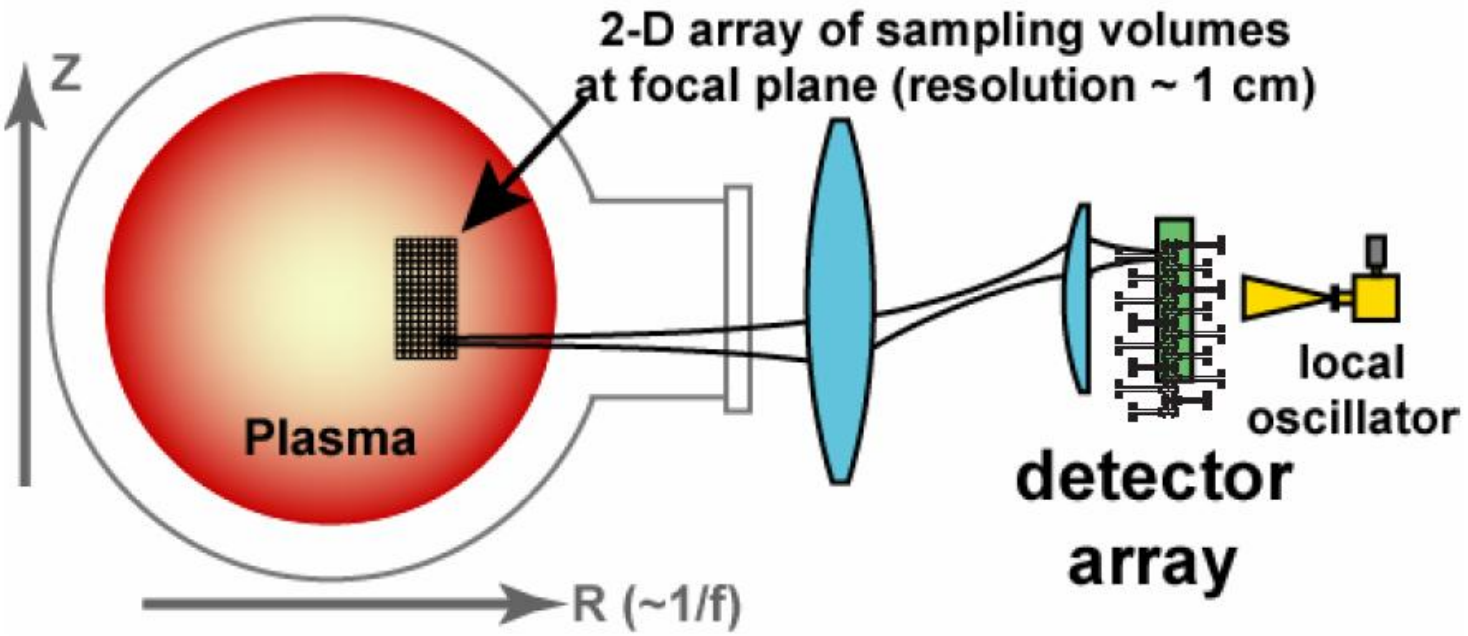


Shot 977
TF = 14 kA (1.5 T @ 1.7 m)
ECH : perpendicular launch

POSTECH: Fusion Science Research Center(Planned)

Advanced diagnostic development and core MHD physics

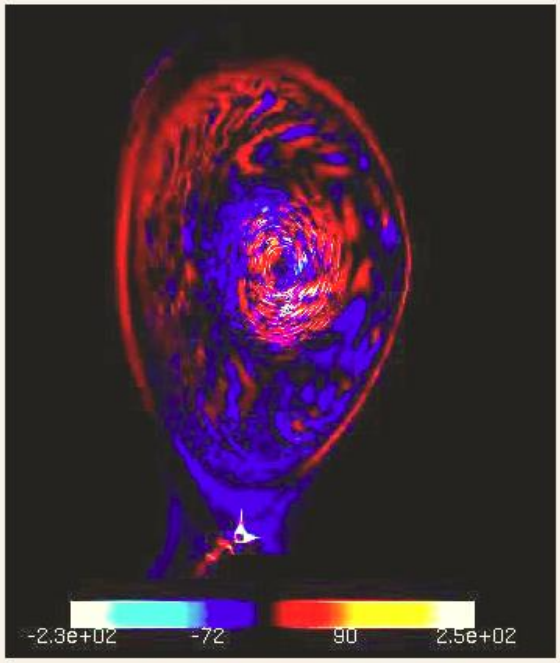
Thomson scattering, VUV spectrometer *for KSTAR*.
Advanced diagnostics: ECEI and multi-frequency MIR system.



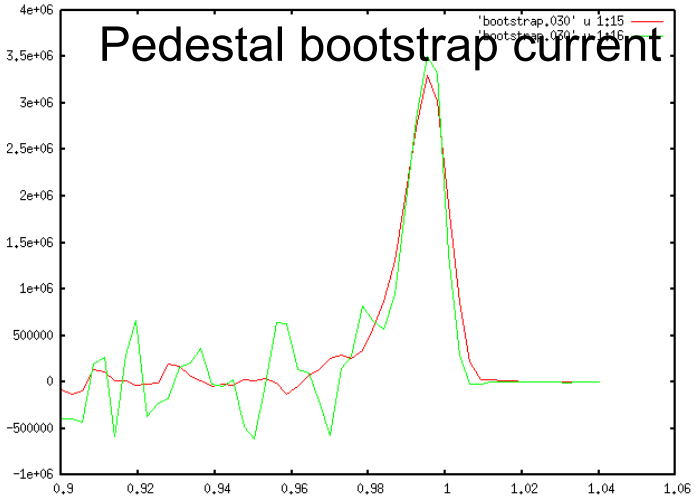
2-D ECE imaging system

KAIST: Fusion Theory and Simulation

- Imported reduced full-f particle code **XGC0** and full-f gyrokinetic particle code **XGC1** from US CPES (Prof. C.S. Chang is on joint position with KAIST).
- Graduate students
  - ❖ added one impurity species to XGC0.
  - ❖ studied bootstrap current dynamics in edge pedestal.
  - ❖ are finishing up converting XGC1 into circular geometry to fit it into local cluster (120 cores).
  - ❖ are studying verification method for turbulence solutions of gyrokinetic equations (method of manufactured solution).

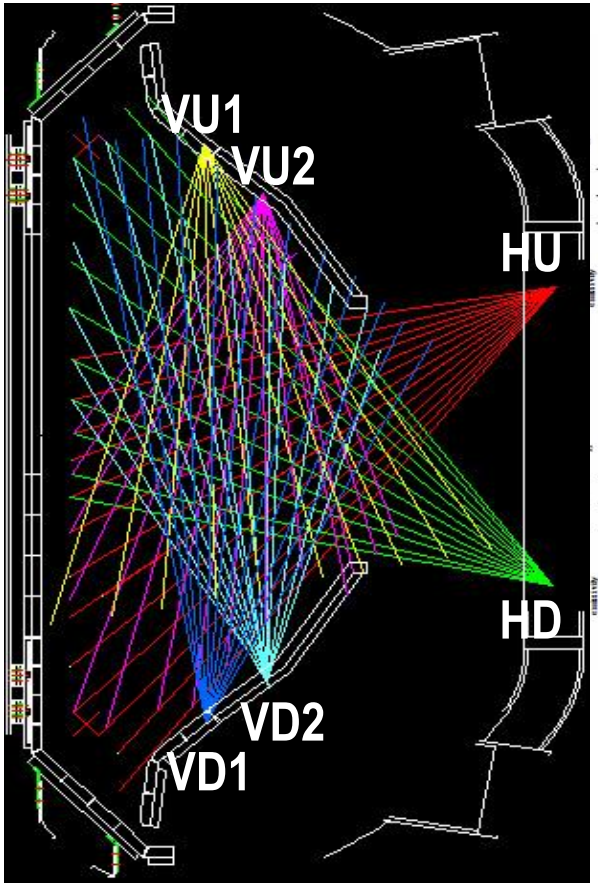


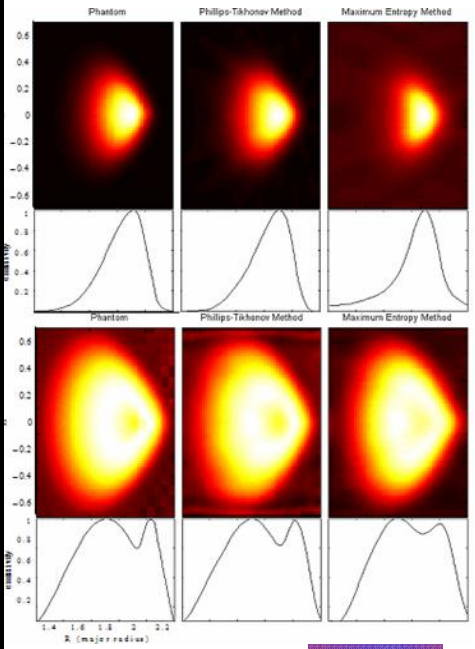
Full-f ITG turbulence



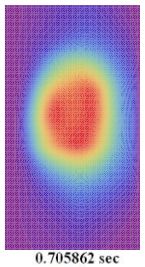
KAIST: Imaging Diagnostics Development

SXR array diagnostics





Sawtooth



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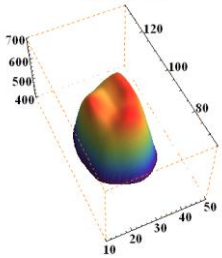
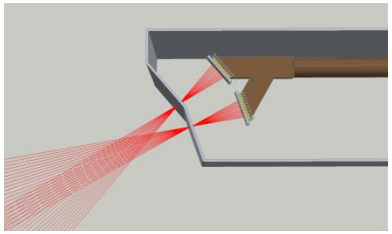
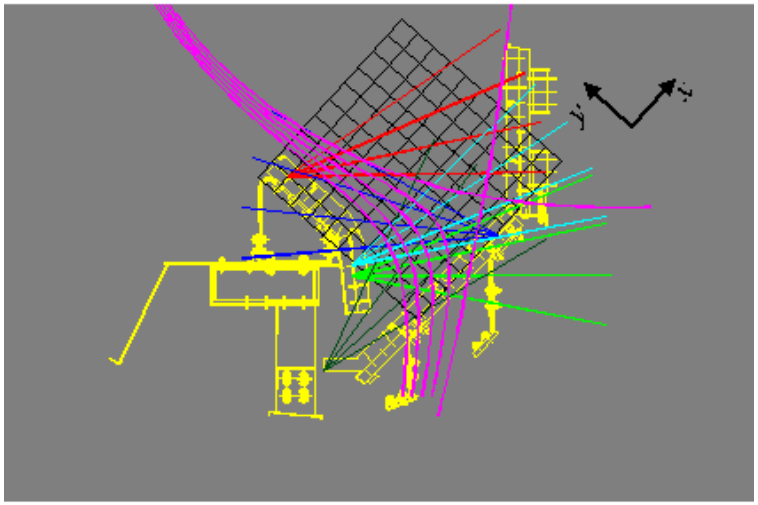


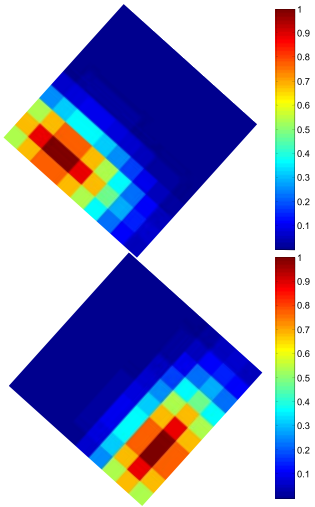


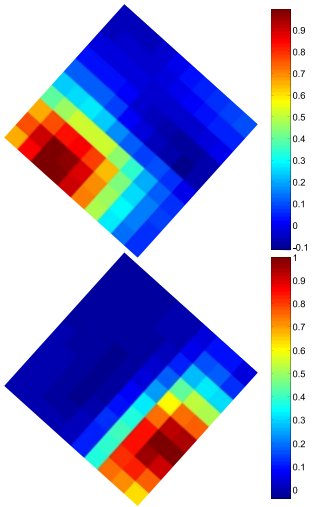
Divertor bolometer tomography



Phantom

Recontruction

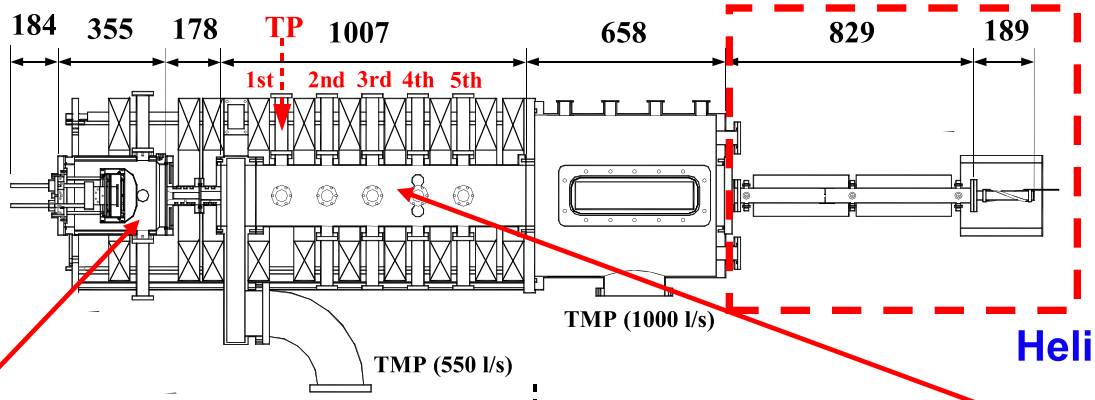




HYU: Divertor Plasma Simulator

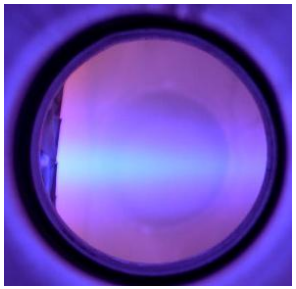
- **DiPS (Diversified Plasma Simulator):**
  Divertor Plasma Simulator (DiPS)
  + Space Propulsion Experiment (SPEX)

Old Version Helicon Source
: Now it is renovated

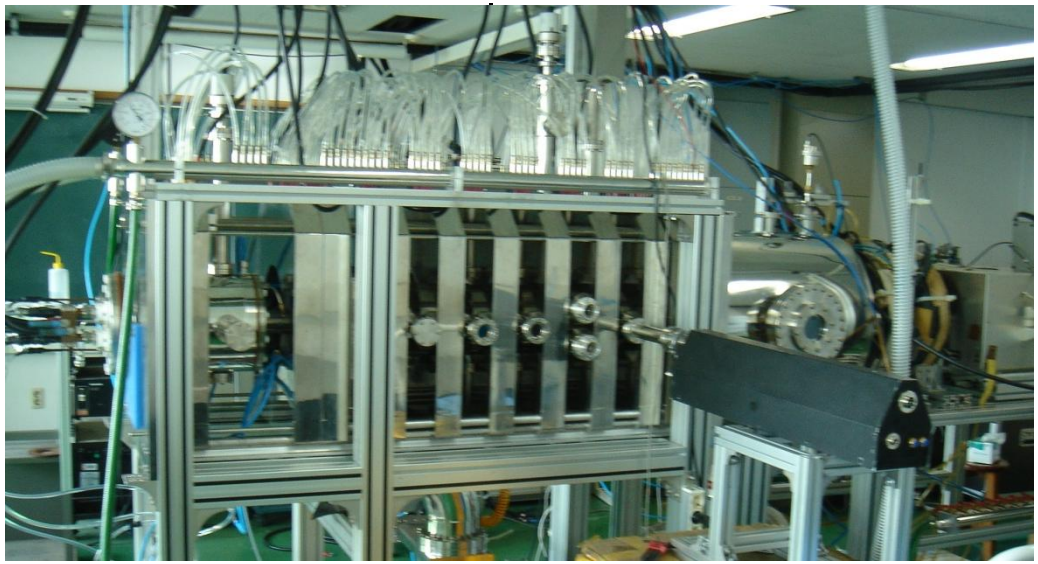


Helicon RF Plasma

LaB_6 DC Plasma



Source region



Diagnostic region
Probes
OES, LIF
Thomson, etc

HYU: Center for Edge Plasma Sciences(Proposed)

1. Electric Probes

Fast Scanning & Fixed Probe Design → Test in DiPS → Analysis program for KSTAR

Test in DiPS: Thermal and Life time

- FSP – Probe Tip Design for KSTAR (vertical FSP for divertor in KSTAR)
- Flush-Mout, Dome, Slanted Type Probe Experiment → Fixed Probe for KSTAR & Divertor Design
- Negative ions/Dust diagnostics
- Edge fluctuations/ Flows in SOLs

2. Optical Diagnostics– OES, LIF, LTS

Probe Calibration
OES – Ha (Wall Conditioning), He CR (KSTAR Edge : Radiation Cooling Effect)
Divertor LTS (ne, Te, Dust)
Edge LIF : feasibility study for the KSTAR

3. Wall Conditioning, Boronization & Material Test

- Boronization – Life Time Test in DiPS (High Heat Flux)
- Material Test – Graphite, CFC, W, Mo, diamond coated Target
  with ion(50~60 keV), electron(~1MeV), and neutron beams

4. Edge Plasma Issues

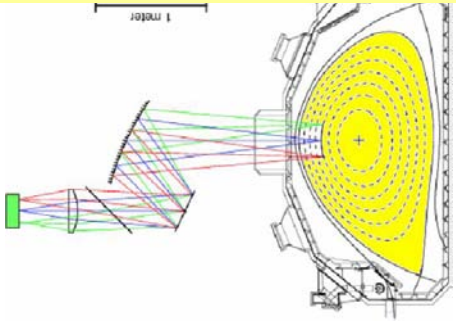
- ELM Simulation with Laser Pulse or Biased Target (IGBT)
- Liquid divertor concept

Core Research Centers in University

~4M US$ assigned for
University-leading research

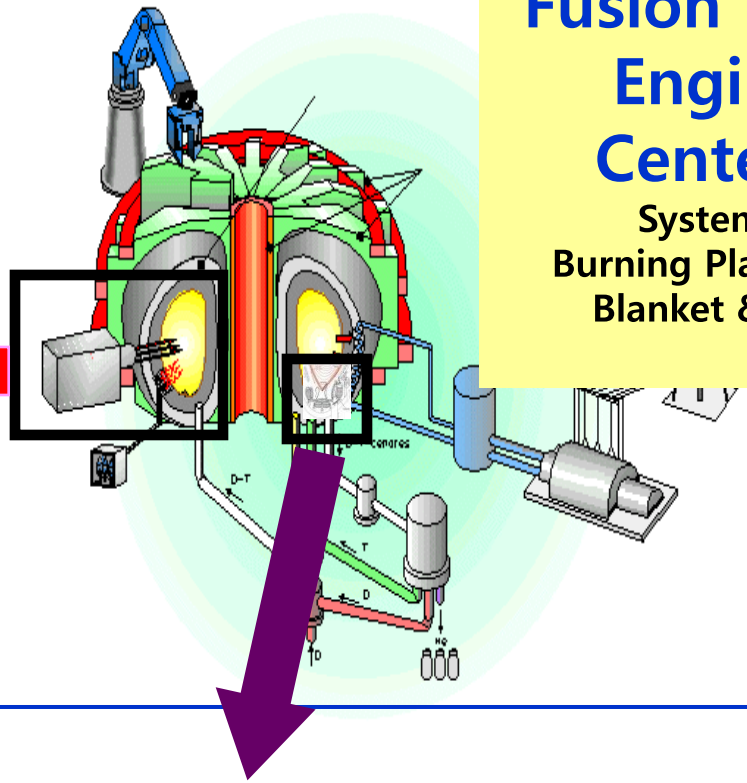
Plasma Core Research Center

Diagnostics
Control
Heating & CD



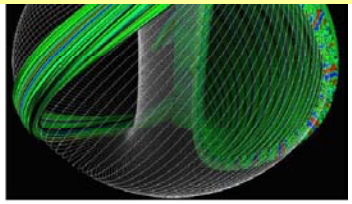
Fusion Reactor Engineering Center(SNU)

System Integration
Burning Plasma Control
Blanket & Neutronics
Material



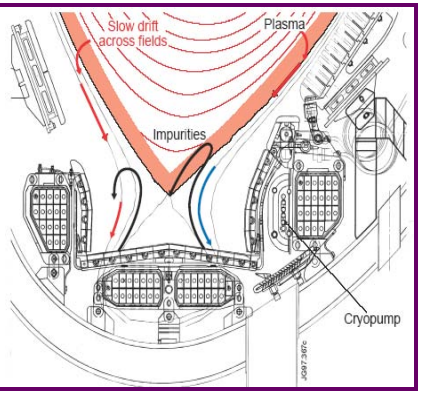
Fusion Simulation Center

Transport
MHD



Plasma Edge Research Center

Divertor
PFC
Edge Diagnostics



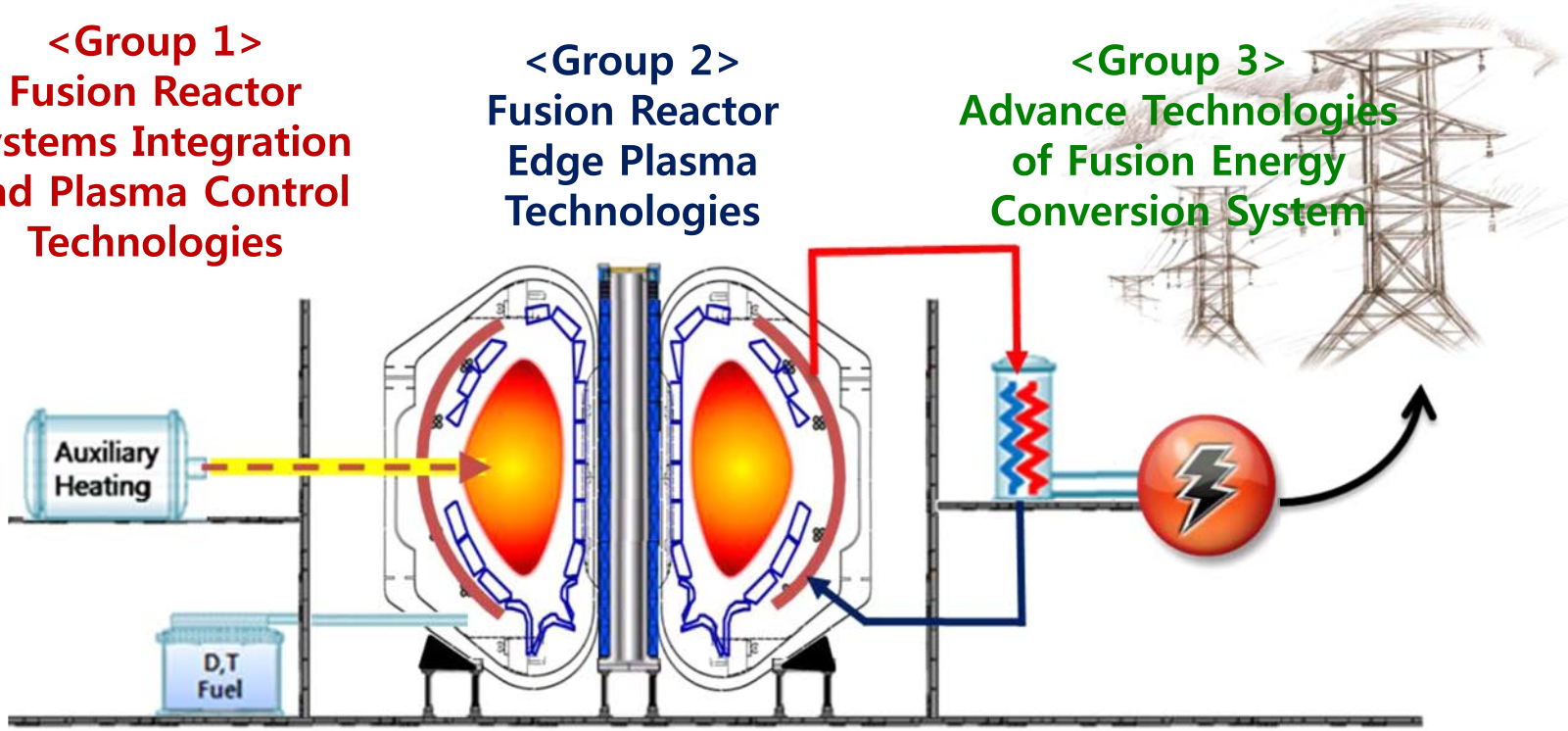
Center for Advance Research in Fusion Reactor Engineering

- Lead the development of key technologies crucial for continuous and stable operation of fusion reactors
- Develop analysis tools and compile experimental database for fusion reactor design and systems integration
- Foster well-trained fusion research personnel
- Promote international collaborations in fusion research

<Group 1>
Fusion Reactor Systems Integration and Plasma Control Technologies

<Group 2>
Fusion Reactor Edge Plasma Technologies

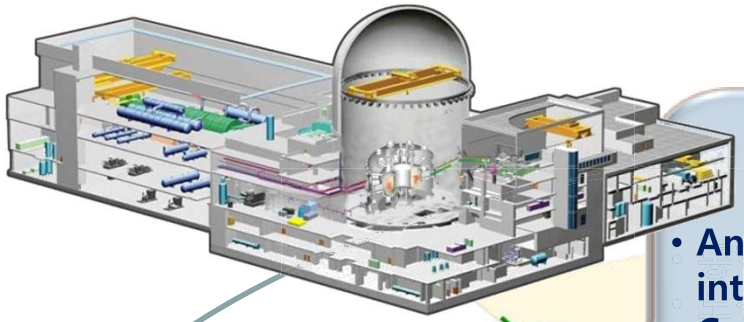
<Group 3>
Advance Technologies of Fusion Energy Conversion System



Organization: 10 Projects with 16 Principal Researchers from 5 Major Universities and 2 National Institutes

Funding: ~1M US$/yr for 6.5years(+ 3 years optional)

Phase 1 (Sep 2008- Feb 2012): Development of Key Technologies with Research Infrastructure

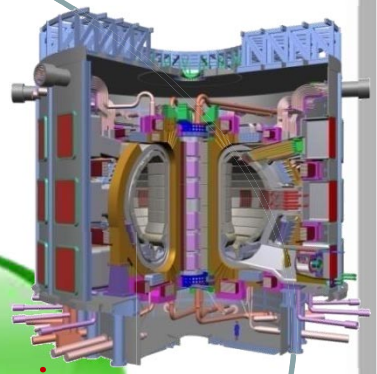


Group 1
Fusion Reactor Systems Integration and Plasma Control Technologies

- Analysis tool for the integrated system
- Core plasma models

Heat and particle flux, System integration data

Neutron flux, System integration data



Group 2
Fusion Reactor Edge Plasma Technologies

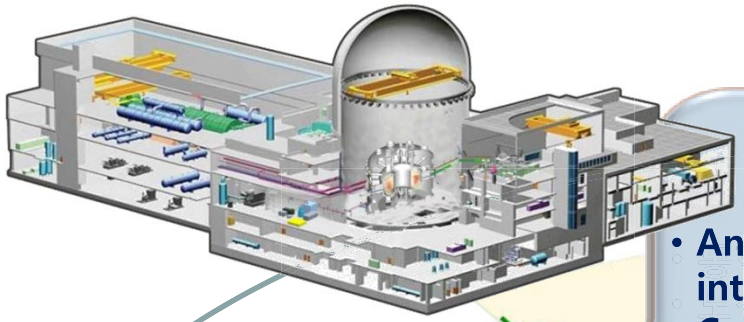
- Edge plasma models
- PFCs property tests

PFCs, Blanket
High temp/
Low activation material

Group 3
Advance Technologies of Fusion Energy Conversion System

- Blanket analysis model
- Tritium behavior analysis

Phase 2 (Sep 2013- Feb 2015): Integration of Key Technologies for Applications

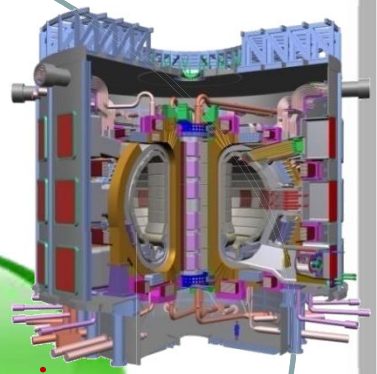


Group 1
Fusion Reactor Systems Integration and Plasma Control Technologies

- Analysis tool for the integrated system
- Core plasma models
- Fusion reactor conceptual study
- Tokamak control tech

Heat and particle flux, System integration data

Neutron flux, System integration data



Group 2
Fusion Reactor Edge Plasma Technologies

- Edge plasma models
- PFCs property tests
- Edge plasma operation conditions
- PFC material development

PFCs, Blanket
High temp/
Low activation material

Group 3
Advance Technologies of Fusion Energy Conversion System

- Blanket analysis model
- Tritium behavior analysis
- Blanket design concept
- Power conversion system model

Thank You !