Multi-Purpose Plasma (MP^2) Facility as a Steady State Divertor Simulator

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Abstract

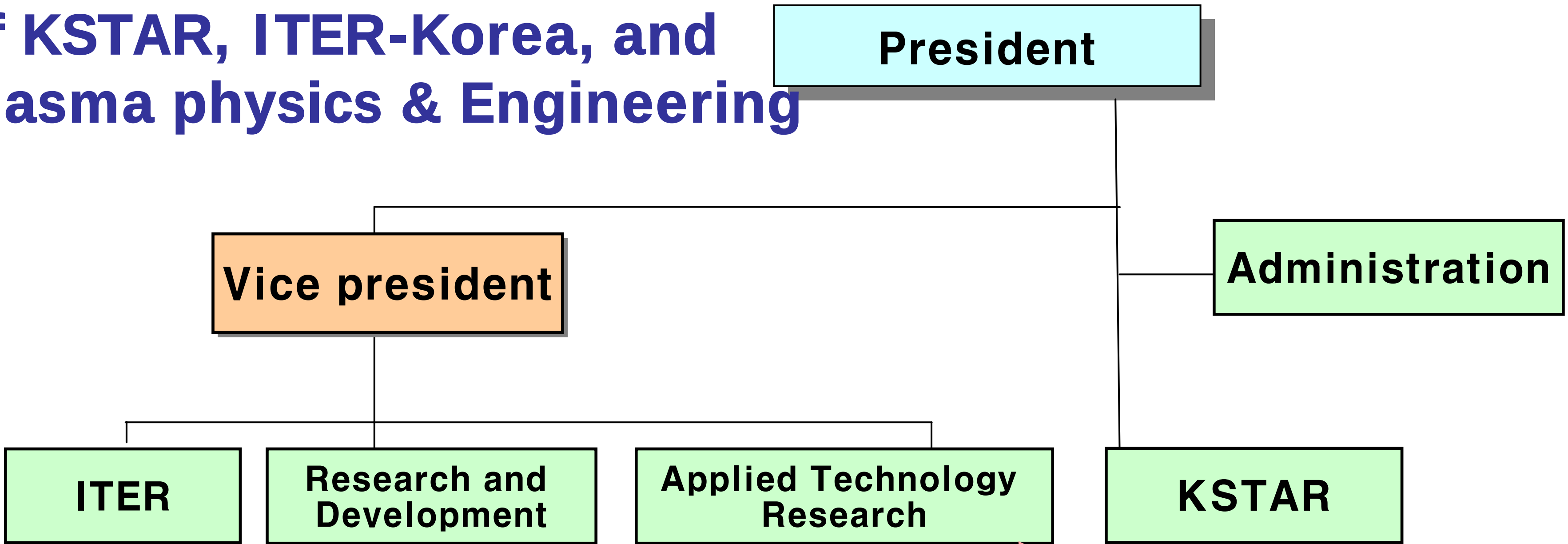
Half of mirror device, HANBIT at National Fusion research Center has been modified since last year aiming at increasing the usability and applicability of the device toward wider fields; wave physics in linear, quiescent plasmas, space simulation and plasma application as well as a mirror physics. Ideas and direction of the renovated facility, MP2 and the future experimental program will be presented. It is suggested that a program to study the use of flowing molten salts for a tokamak liquid divertor be undertaken on the multipurpose plasma (MP2) device. Two possible candidates, flibe (LiF-BeF2) and flinabe, (LiF-NaF-BeF2) are briefly described and the reasons for this choice over liquid metals are discussed. A simple preliminary experiment is described.

Outlines

- Renovation for HANBIT to MP^2(Multi-Purposed Plasma) Facility
- Assembly of MP^2
- LaB6 Source for MP^2
- Specification of MP^2
- Molten Salts Project
- Future Studies on the Molten Salts of MP^2

Structure of NFRC

- **NFRC is the host institution of KSTAR, ITER-Korea, and Plasma physics & Engineering**



- Plasma Physics related with Magnetic Fusion
  --- KSTAR and ITER
- ~ 40 persons (30 Ph.Ds, 7 Masters, ~3 supporters)
  + collaborators

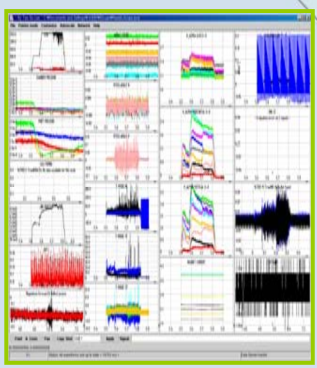
- Basic and Industry Applied Plasma Physics
  --- MP2 facility and many plasma sources
- ~ 40 persons (10 Ph.Ds, 15 Masters, ~15 Engineers)
  + collaborators (from industry)

Hanbit Magnetic Mirror Device

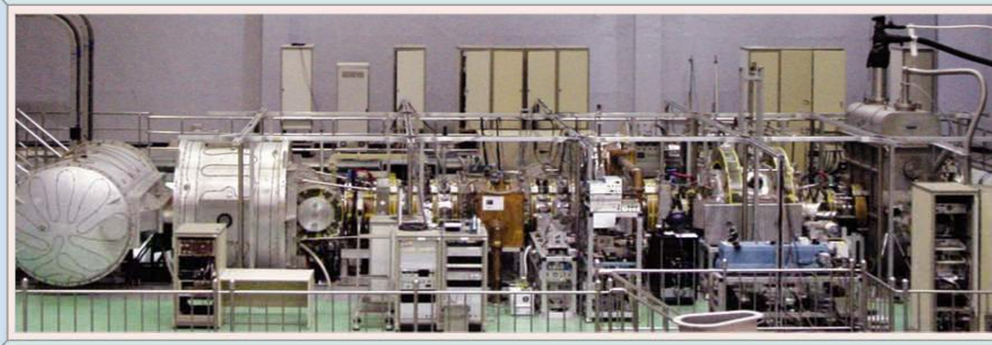
Plasma Diagnostic Systems

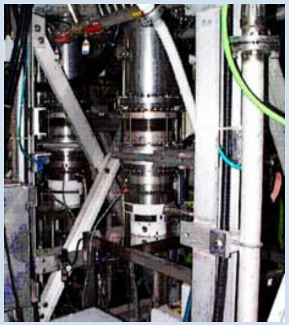
. H-alpha Monitor
. Visible Spectrometer
. VUV Spectrometer
. Fast CCD Camera
. Filter Scope
. Micrometer Interferometer
. Reflectometer

. Electrostatic Probes
. Magnetic Probes
. Diamagnetic Probes
. End Loss Analyzer
. CX-NPA
. Thomson Scattering System
. Laser Induced Fluorescence



Control System
Data Acquisition System





Magnet Power Supply
Vacuum Pumping System
Utility

Plasma Heating Systems

. 500 kW RF Power Amplifier
. 100 kW RF Power Amplifier
. 2 kW Klystron Amplifier(14.5 GHz)
. 1.5 kW Klystron Amplifier(7.87 GHz, 7.67 GHz)
. 5 kW Magnetron System(2.45 GHz)

Pre-ionization Devices

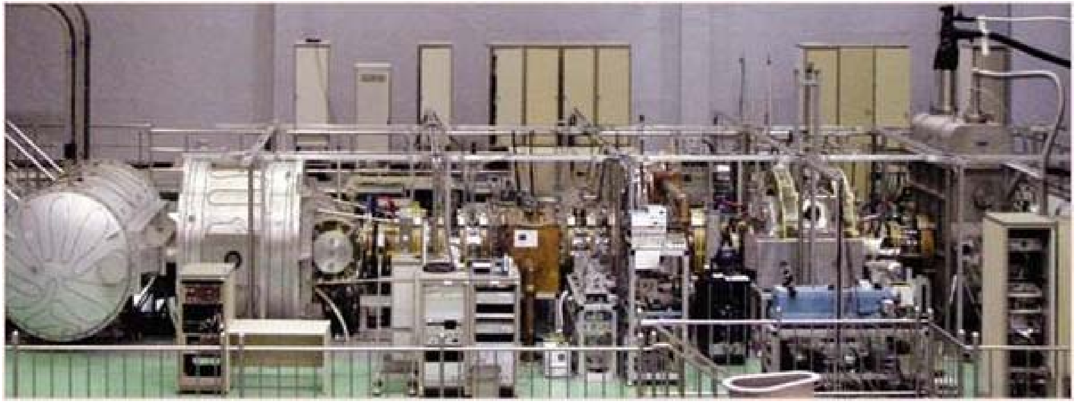
. MPD Gun
. Cathode Device

Brief history of Hanbit Device

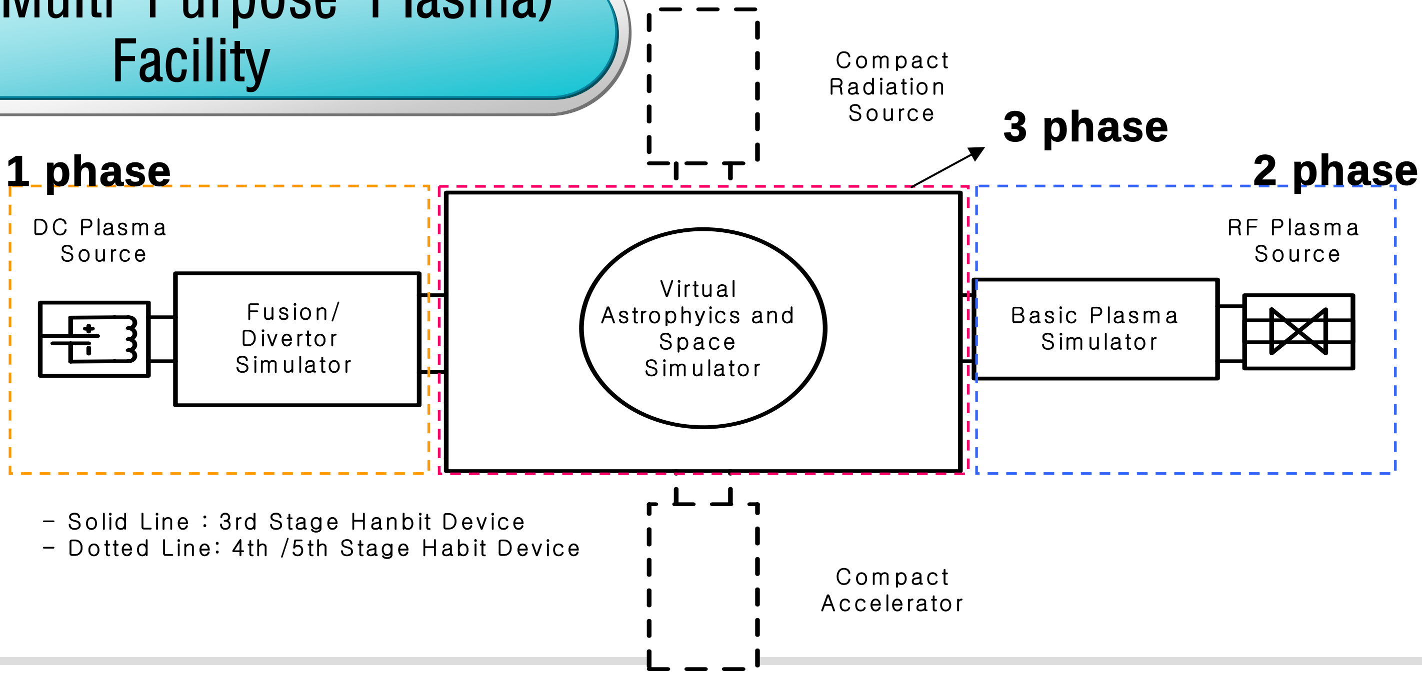
- 1993. 1 Refurbished from the Tara Machine of MIT
- 1995. 6 First plasma on the Hanbit Device
- ~2000.9 First campaign : basic system development
- ~2006.6 Second campaign : high temperature plasma confinement physics study
  - RF plasma heating
  - MHD stability
  - discharge characteristics, etc
- 2006. 12 First stage assembling of the MP^2 Facility (Cylindrical Plasma Generator)
- 2007. 1 First plasma on the MP^2 Facility

Facility for basic plasma physics research

Hanbit Device



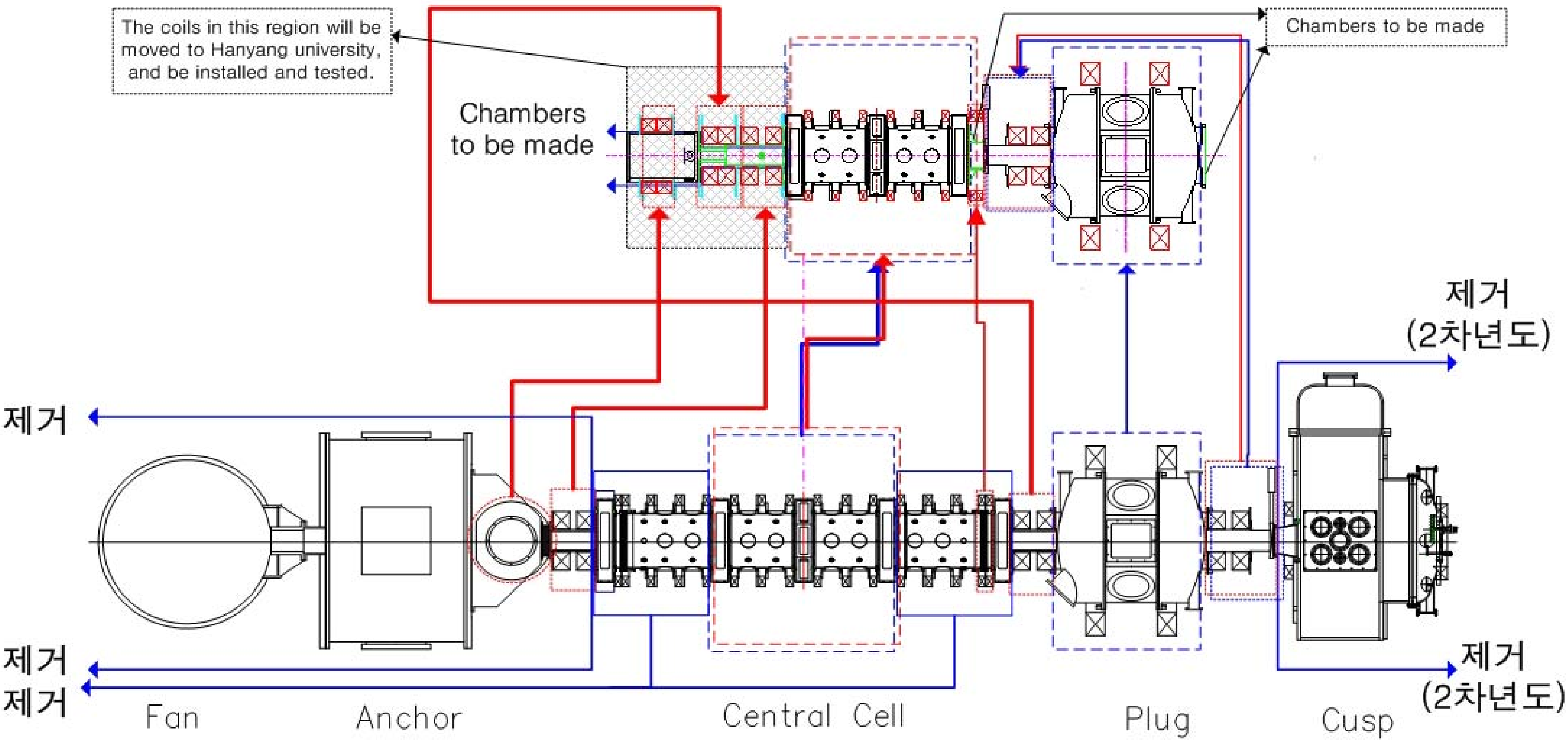
MP² (Multi Purpose Plasma) Facility



Assembly of MP²

First stage assembling of MP²

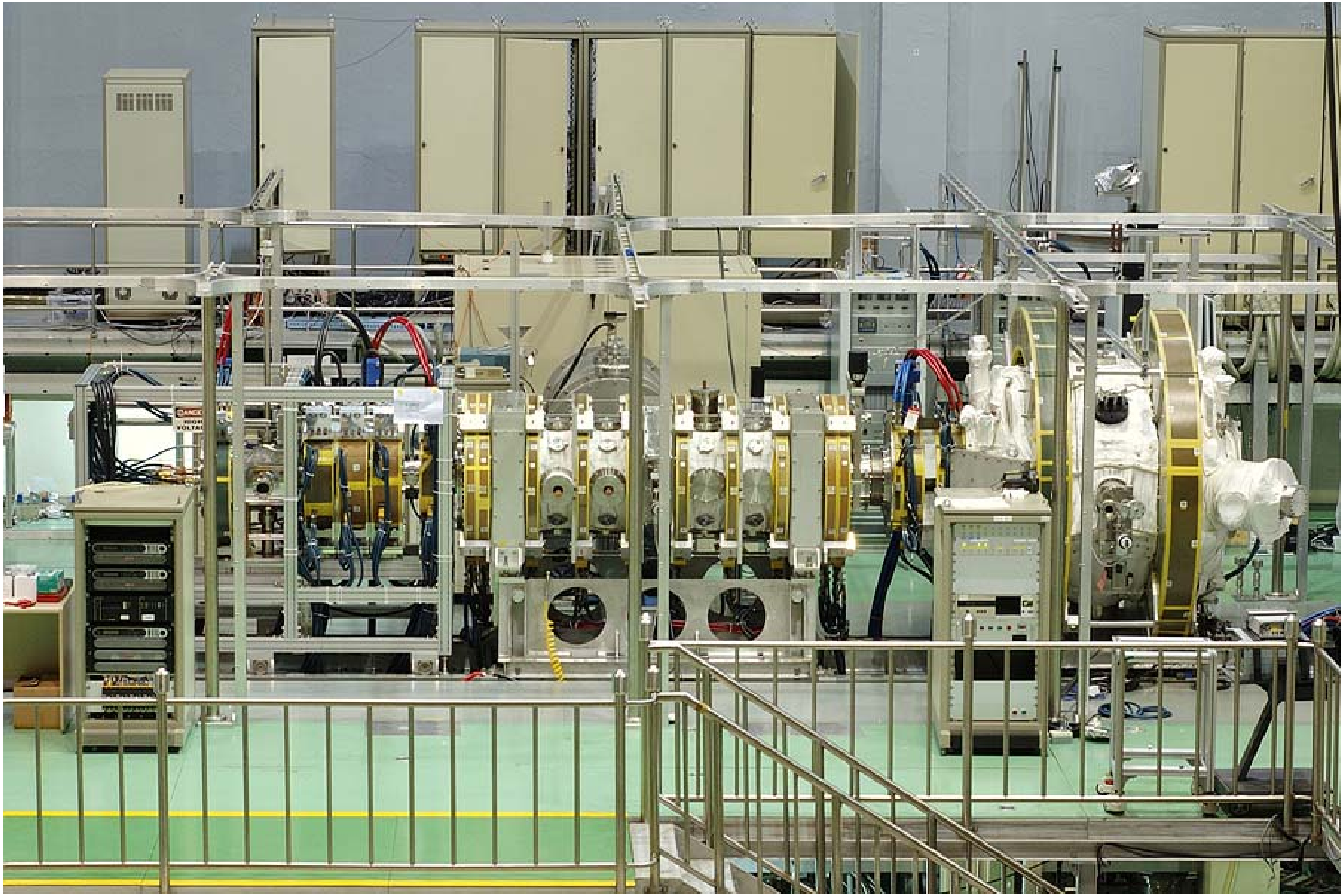
(rev: 28-Aug-2006)



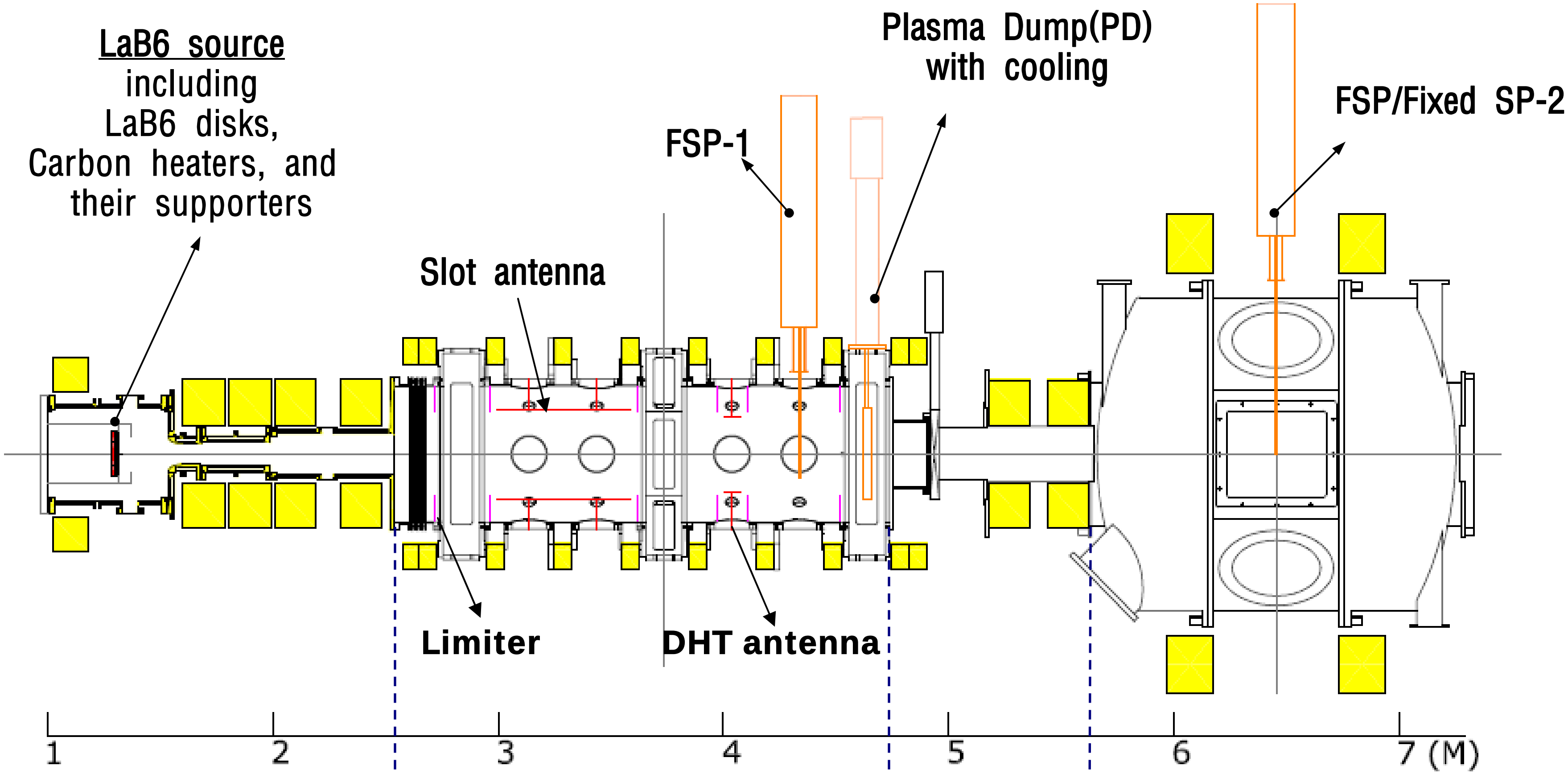
NOTE) → 챔버 이동 경로. → 자기장 코일 이동 경로. — Chamber to be made.

Total view of MP^2 Facility

Linear Machine Part in MP^2 Facility



Linear Machine Part in MP² Facility



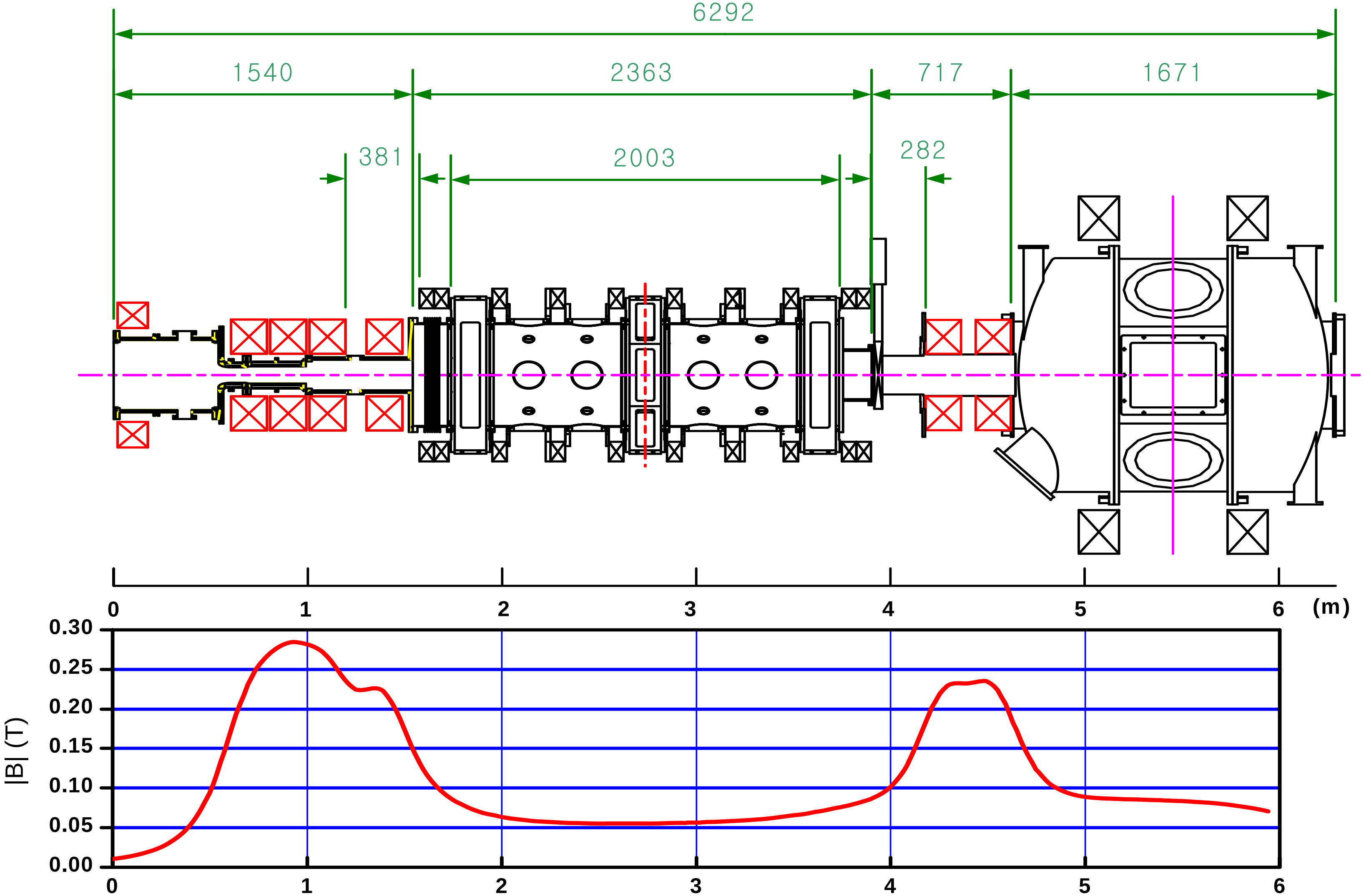
LaB6 Plasma Source Region

Divertor Simulation / Mirror Region

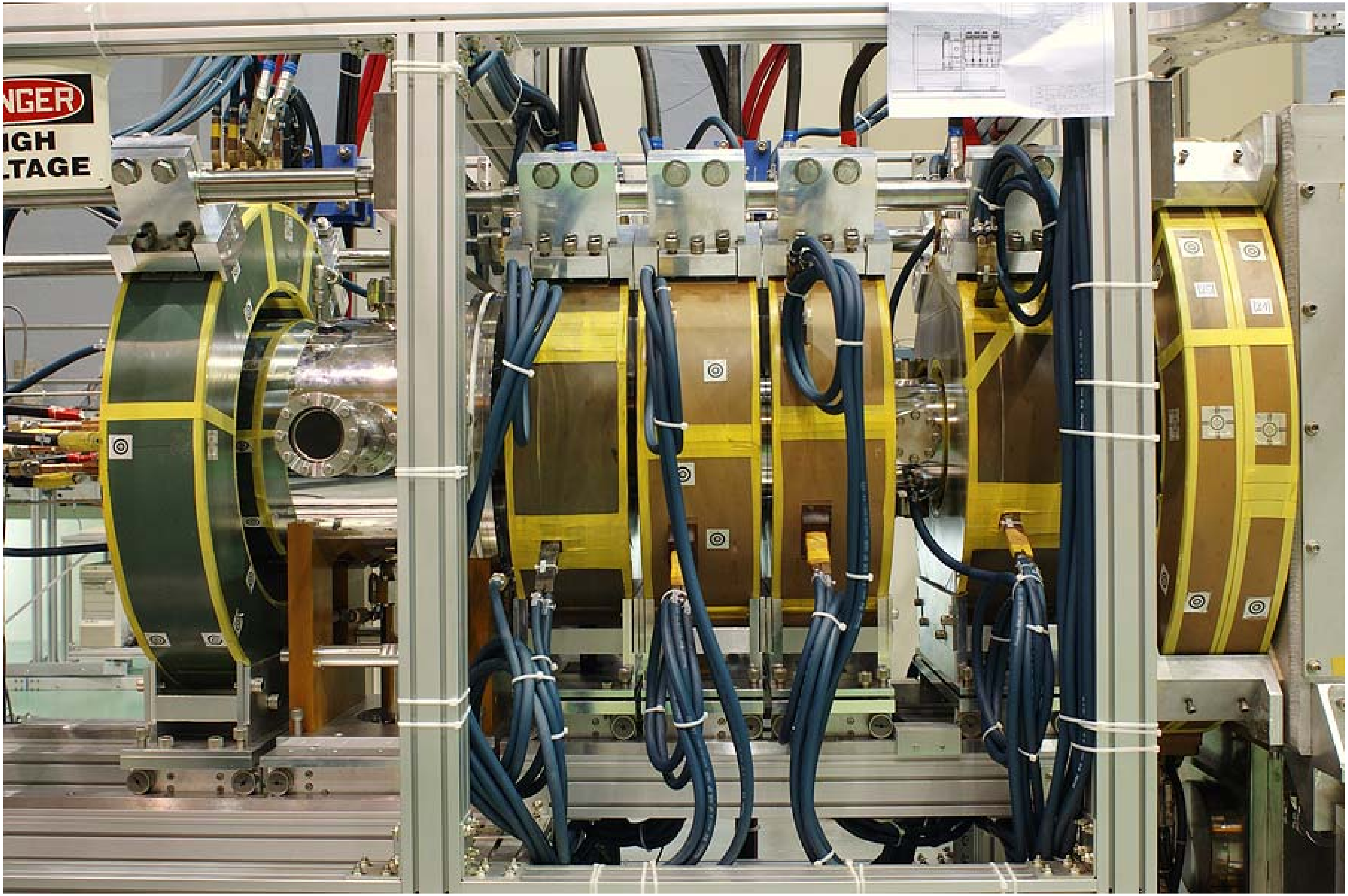
Space / Buffer / Divertor Simulation Region

Linear plasma device of MP² Facility

B-field profile for steady state operation



Source for Linear Machine Part in MP² Facility



Placement of LaB6 discs & Needed P/S's

The center LaB6 disc and the peripheral discs need to be independently heated to adjust plasma column size.

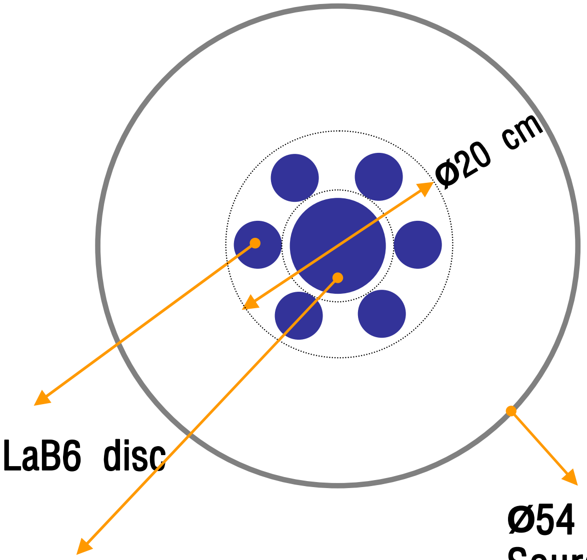
1. Heater Power Supply (P/S)

<u>One</u> P/S for carbon heater
to heat LaB6 Center disc
: DC P/S (30 V / 330 A)

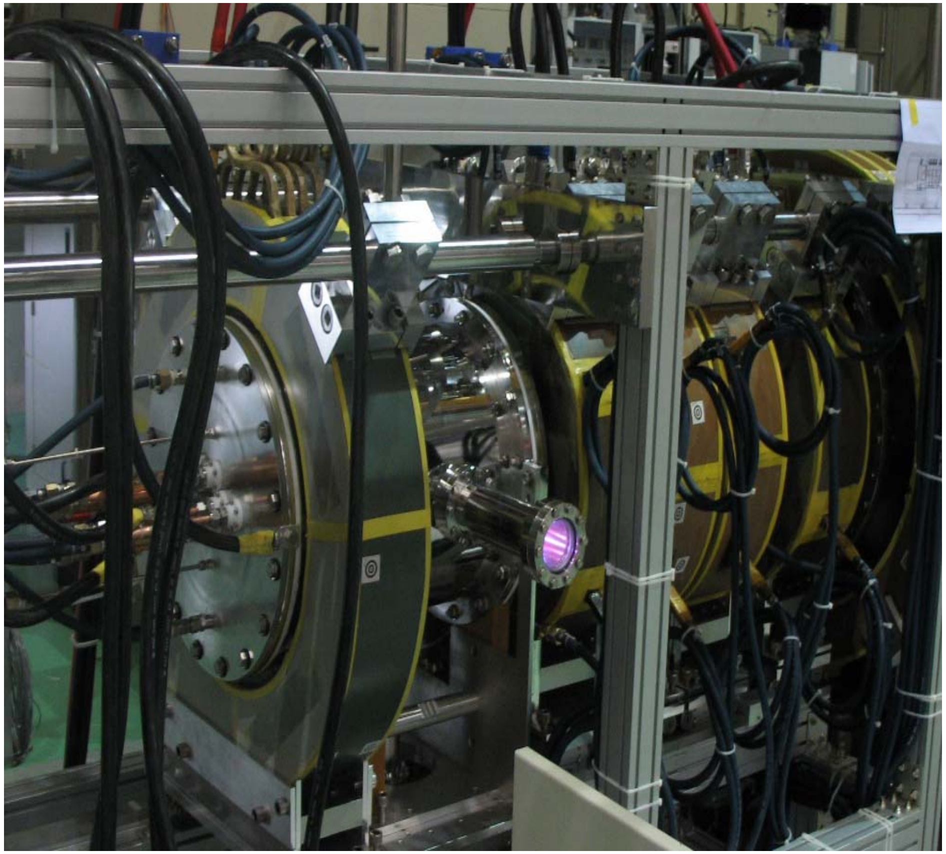
<u>Four</u> P/S's for carbon (tungsten) heater
to heat LaB6 Peripheral discs
: DC P/S (40 V / 330 A) x 4EA

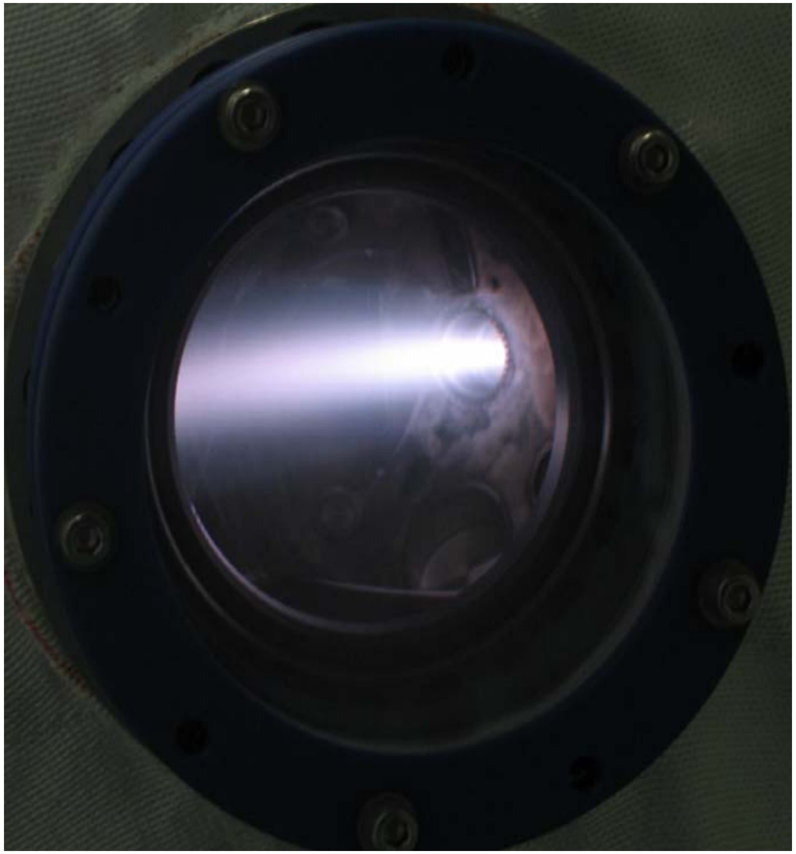
2. Discharge Power Supply

: DC P/S (250 V / 150 A) or
DC P/S (250 V / 80 A) x 2EA

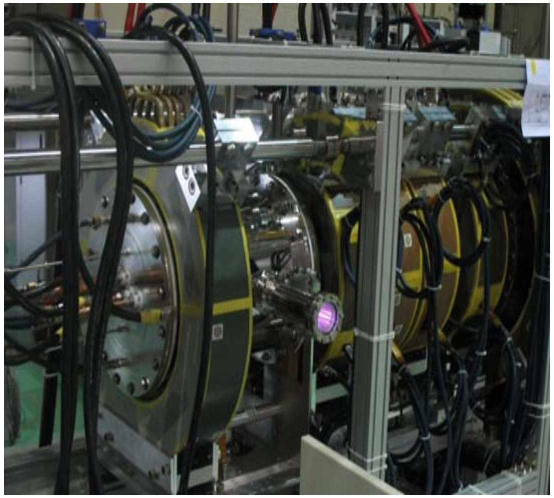


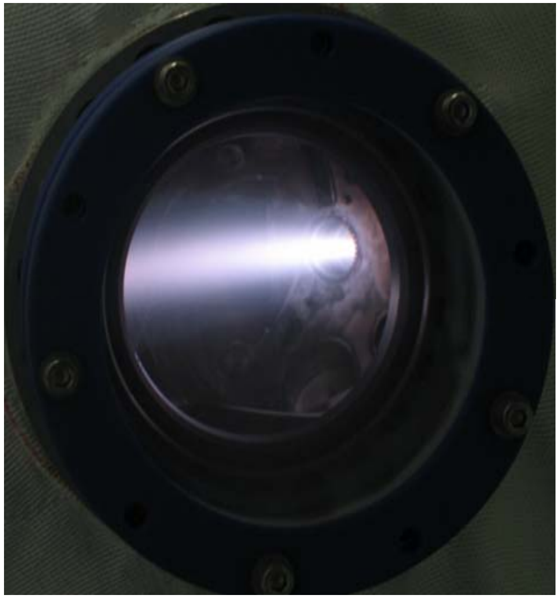
First plasma on the MP² Facility





Specifications of MP²





Plasma Size (cm)	3.5
Chamber Diameter (m)	0.6(small) 1(large)
Chamber Length (m)	10
Magnetic Field (kG)	~ 1 kG
Plasma Source	Honeycomb-like LaB6 Cathode
Cathode Size (cm)	25
Discharge Type	Steady state DC discharge
Cathode Heating Power (kW)	up to 36kW
Discharge Power	250V - (1-100A)
Operating Gas	H2, He, Ar
Operating Pressure (mTorr)	0.1-10
Plasma Density (cm^{-3})	up to 10^{12}
Electron Temperature (eV)	1-20 eV
Ion Temperature (eV)	0.1 Te
Location	Daejeon, Korea

Molten Salt experiments instead of liquid metals

- Molten salts have not yet been experimentally investigated in a divertor, the first wall, or blanket programs with plasma

- Molten salts have been experimentally investigated in two molten salt reactors at ORNL in the 1950's and 1960's

- Two possible molten salts as liquid wall materials study, FLiBe ($LiF-BeF_2$) and FLiNaBe($LiF-NaF-BeF_2$)

- Two molten salts have similar physical properties except for melting point, The melting temperature of FLiBe is about 459℃ and 380℃ for FLiNaBe

Properties of Molten Salts

Typical Liquid Metal and Molten Salt Thermophysical Parameters

Properties	Units	FLiBe	Lithium
Composition	Mole %	66% LiF + 34% BeF_2	100% Li
Melting Point	K	733	459
Operating Point	K	773	673
Density	kg/m^3	2036	490
Dynamic Viscosity	kg/m/s	0.015	4.02×10^{-4}
Kinematic Viscosity	m^2/s	7.37×10^{-6}	8.19×10^{-7}
Electrical Conductivity	S/m	155	3.19×10^{6}
Thermal Conductivity	W/m/K	1.06	50.4
Heat Capacity	J/kg/K	2380	4209
Surface Tension	N/m	0.2	0.366

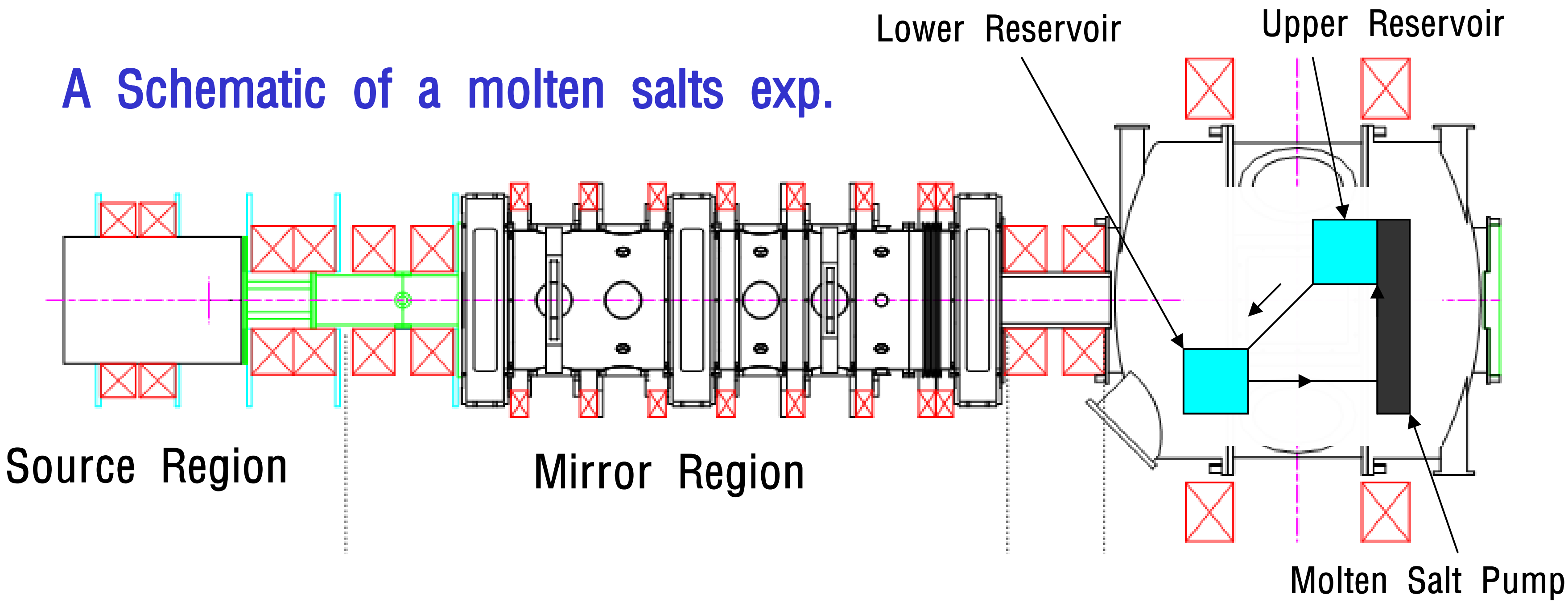
ABDOU et al.,NUCLEAR ENGINEERING AND TECHNOLOGY, VOL.37 NO.5 OCTOBER 2005

- Low thermal Conductivity
  - Low heat transfer to limit the peak surface temperature
  - For high heat transfer turbulence necessary
  - The turbulence potentially affected by the strong magnetic field

Properties of Molten Salts

- Low Electrical Conductivity (~10^2 Ω^{-1} m^{-1})
  - 4 order of magnitude smaller than typical liquid metals(~10^6 Ω^{-1} m^{-1})
  - No Strong MHD effects on surface flow.
  - Possibility of turbulent flow on the divertor surface.
  - But no vanishing of the electrical conductivity which is 30 times greater than sea water
- High Viscosity
  - about 10 times that of water.
- No Corrosive on Stainless Steel
  - Control of corrosion coming from fluorine and hydrogen-fluoride generation by plasma interaction.
- Low vapor Pressure, Less Evaporation

Use of Molten Salts in MP²



- Study the Plasma-Molten salts interaction
- Concern on the possibility that the magnetic field might alter the flow
- Depression of the Fluorine generation
  - ➢ Study on the 'Redox' Agent, for example Be.
- Study the effects of turbulence on the heat transfer and flow.

Discussion

- A linear steady-state plasma device, which is a part of MP^2 facility, has been assembled as a divertor simulator
- As the name implies, the MP^2 will have various research scopes of plasma
- At the first stage of the research experiments on linear plasma device of MP^2 will be done for the dust plasma phenomena, mirror plasma physics, and PMI
- Research on the plasma-molten salts interaction will be the main topic in MP^2 once the device for it will be built
- The Reynold, Froude, Rayleigh and Nusselt numbers of molten salts will be varied to study the effects of turbulence on the heat transfer and turbulence flow on the divertor surface.