Experiments of Pebble Divertor

US-Japan Workshop

Workshop Agenda

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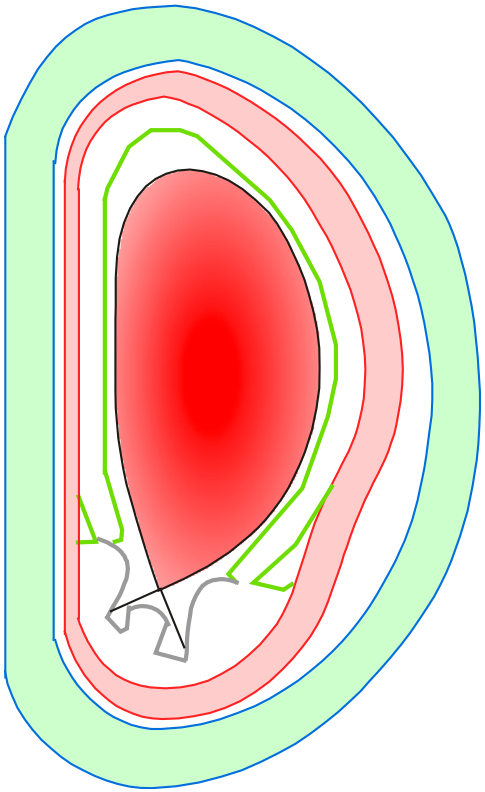
PWI on Steady- State Fusion Reactor



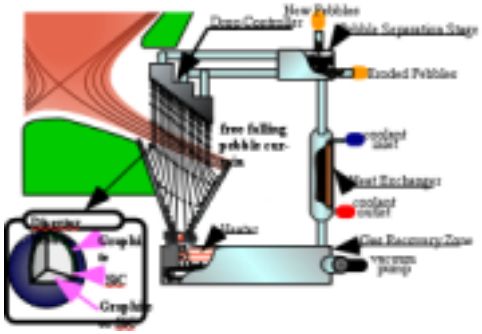
The cross section of ITER-FEAT

1: Intense erosion on divertor plate by particle load from core plasma.

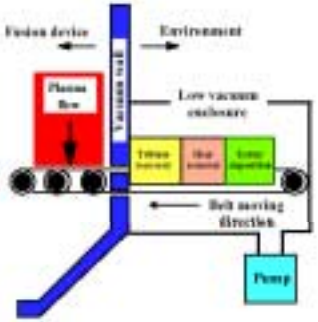
2: Reducing wall pumping effect by saturation with trapped particles.

The concept of moving-surface plasma -facing components

Solid

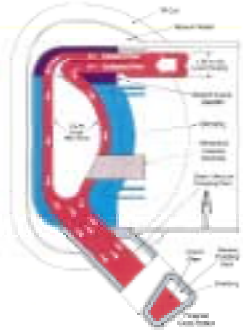


Pebble

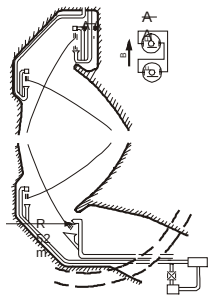


Belt

Liquid

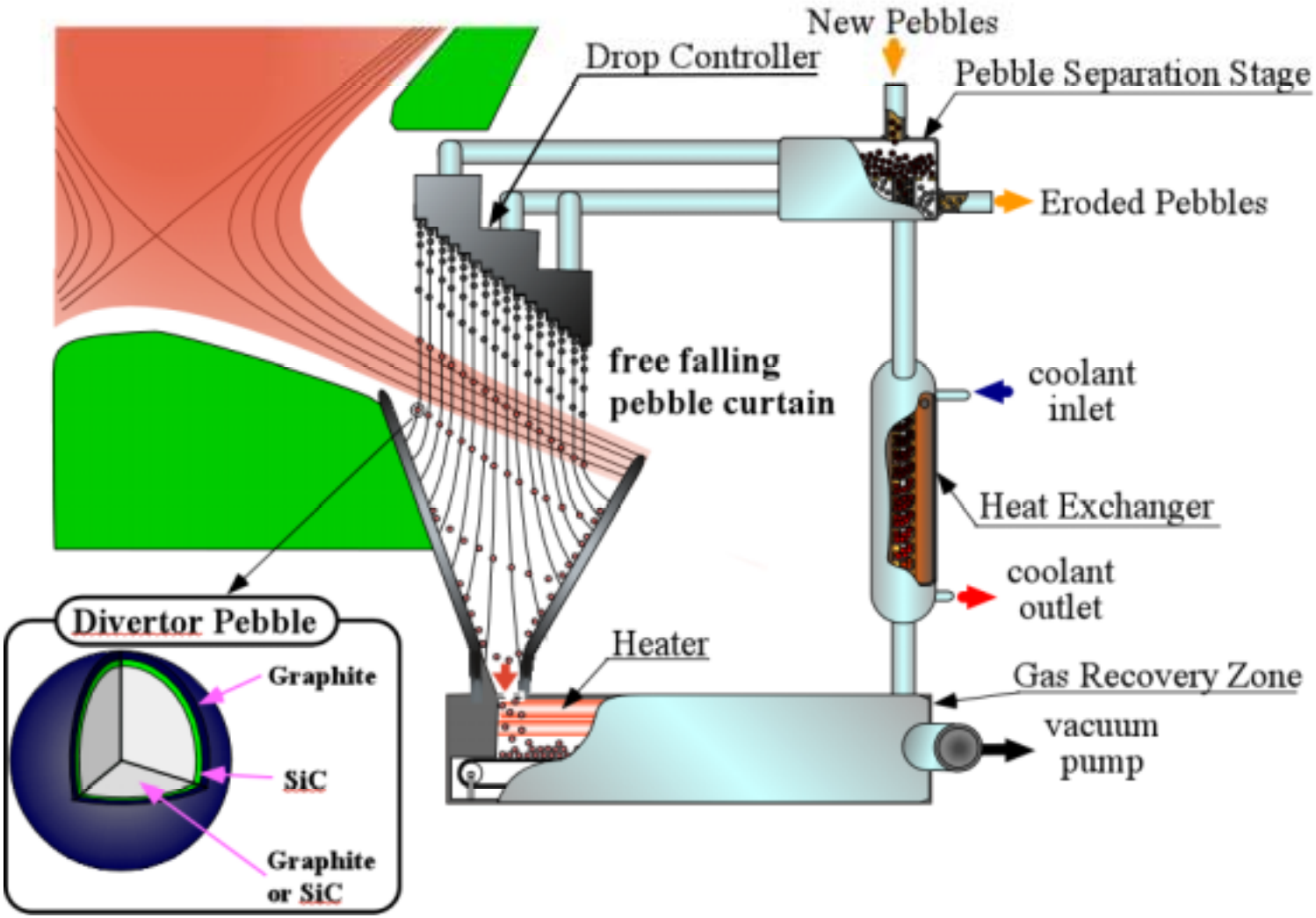


Film flow



Droplet

Pebble Divertor System



Features of Pebble Divertor

1. **Resistance to high particle load**

   Erosion of divertor pebble can be neglected.

2. **Resistance to high heat load**

   Divertor pebble can be resisted up to 30 MW/m^2 .

3. **Particle control**

   Fuel particle, He particle and Impurities can be exhausted.

1. Resistance to high particle load

Irradiation period = 30 msec

Particle Flux : 1×10^{22} /m^{2}s[1]
Sputtering Yield : 0.1[2]

Erosion depth/ 1 shot = 10 pm

Circulation period = 200 sec

Erosion depth/day = 5nm

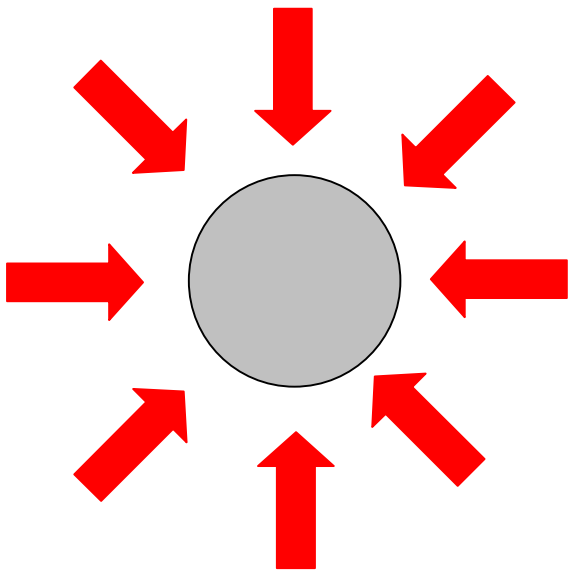
Thickness of plasma facing layer of Divertor pebble

= ～100μm

[1] F. C. Sze, et.al., J. Nucl. Mater. 246 (1997) 165

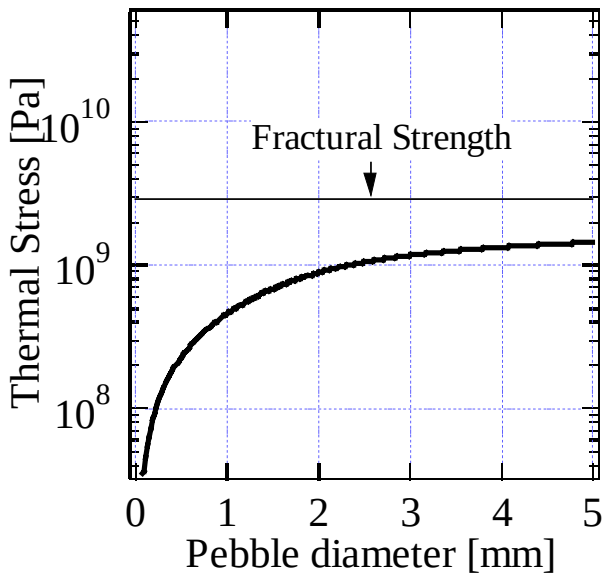
[2] W. O. Hofer, et.al., Physical Process of the interaction of fusion plasma with solid (1996) 118

2. Resistance to high heat load

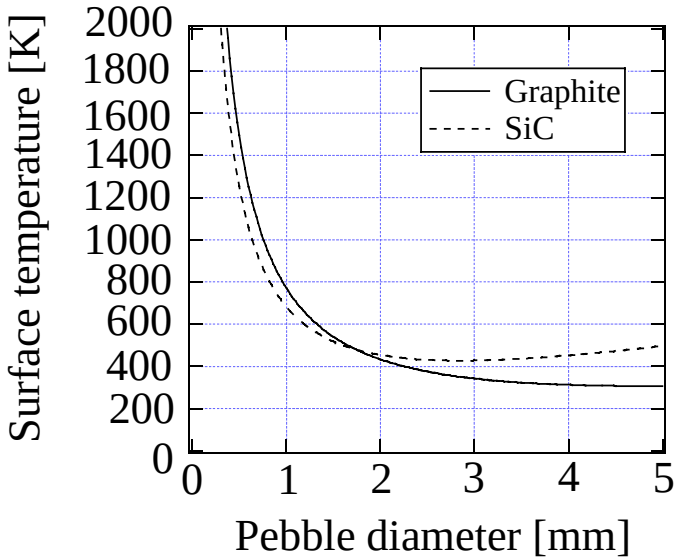


Isotropic irradiation
（30MW/m^{2}s）

Thermal stress(SiC)



Surface temperature



Pumping Process of Pebble Divertor

T_M **The maximum temperature in the irradiation**

⇩

R_t **The amount of transient retained gas**

↑

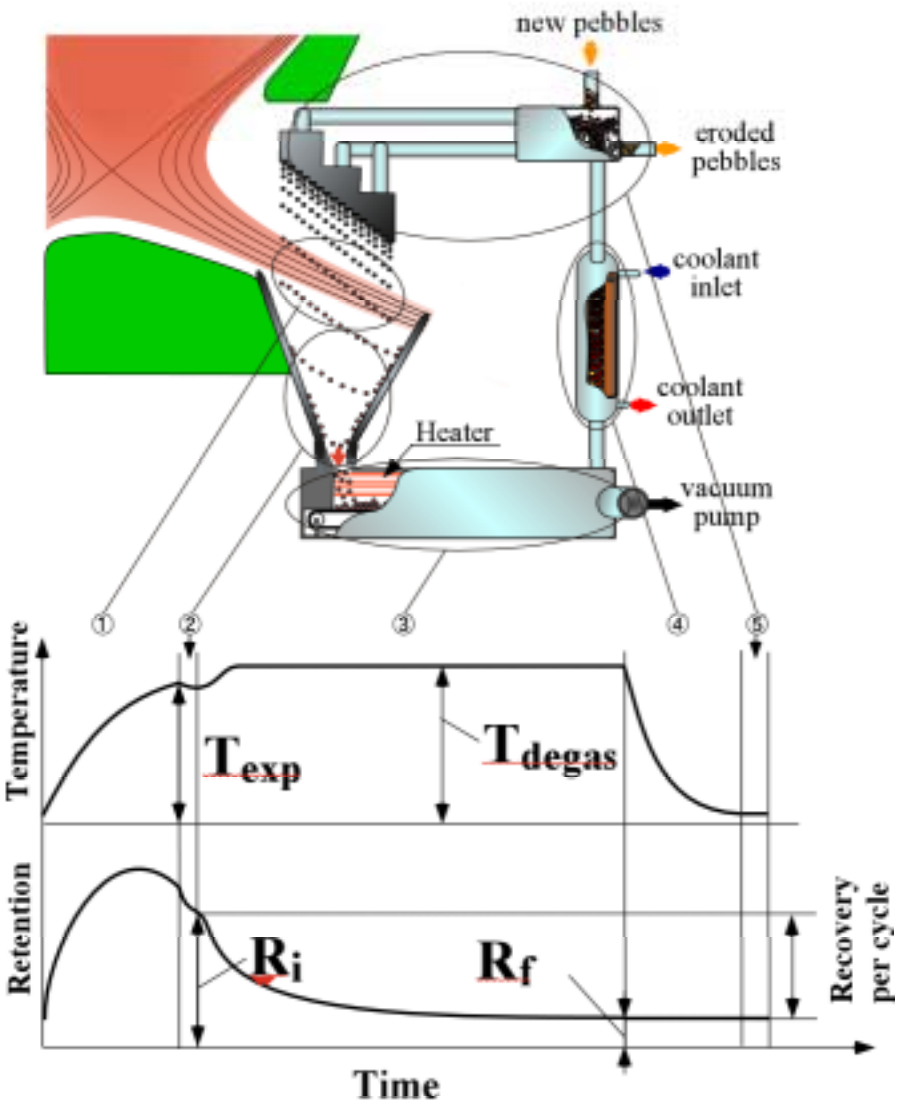
Pumping Capacity

↓

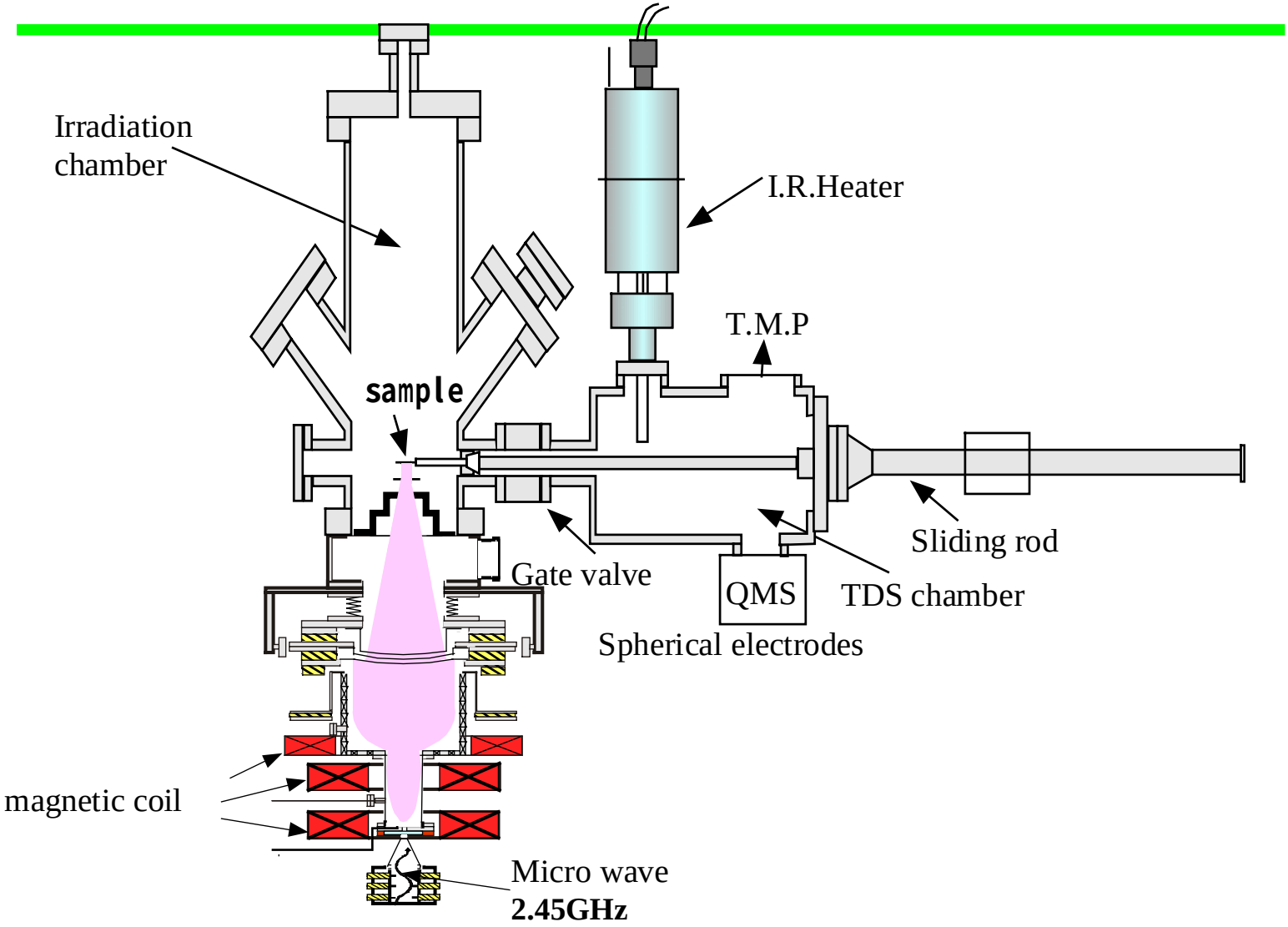
R_r **The residual amount of retained gas**

⇧

T_D **Temperature for degassing**



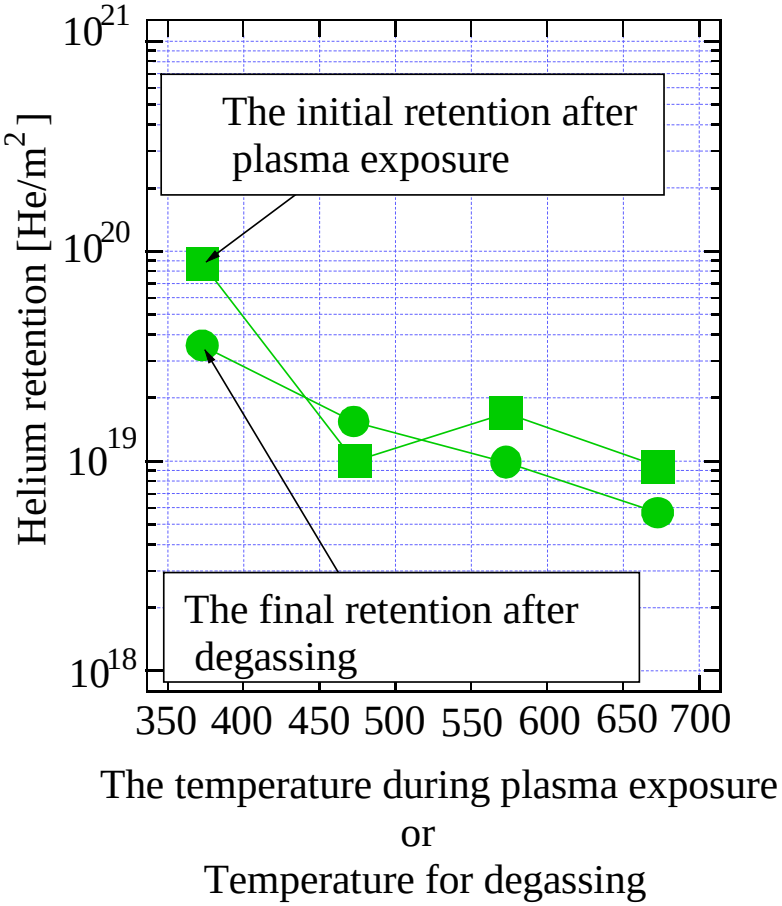
Experimental Facility: (HiFIT)



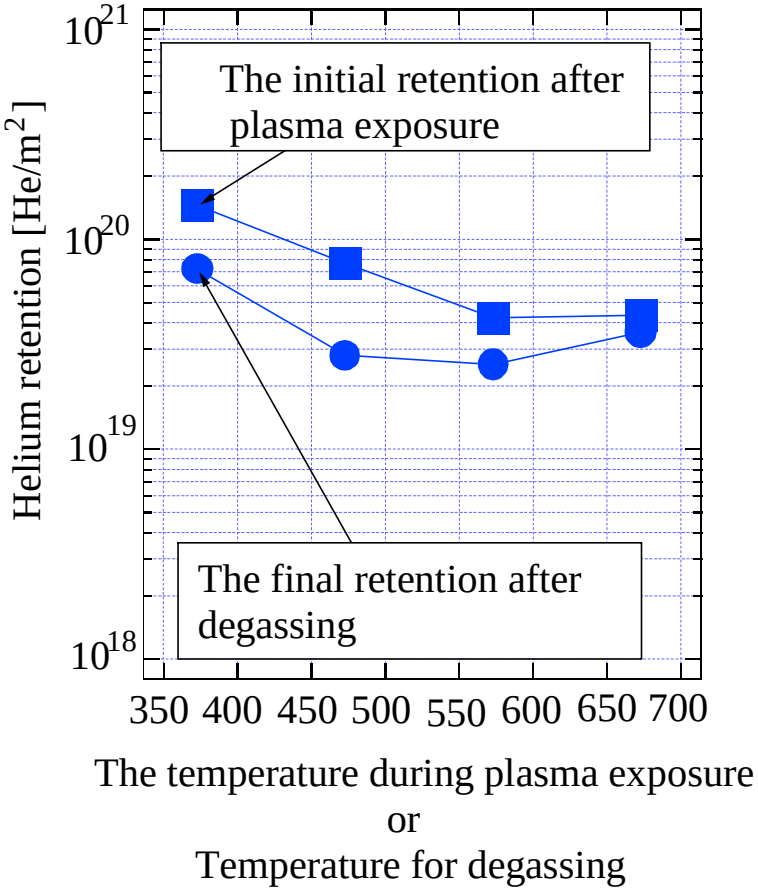
The fluence = 5 x 10^{21} /m^2

Temperature Dependence of He Retention

Beam energy=0.3keV

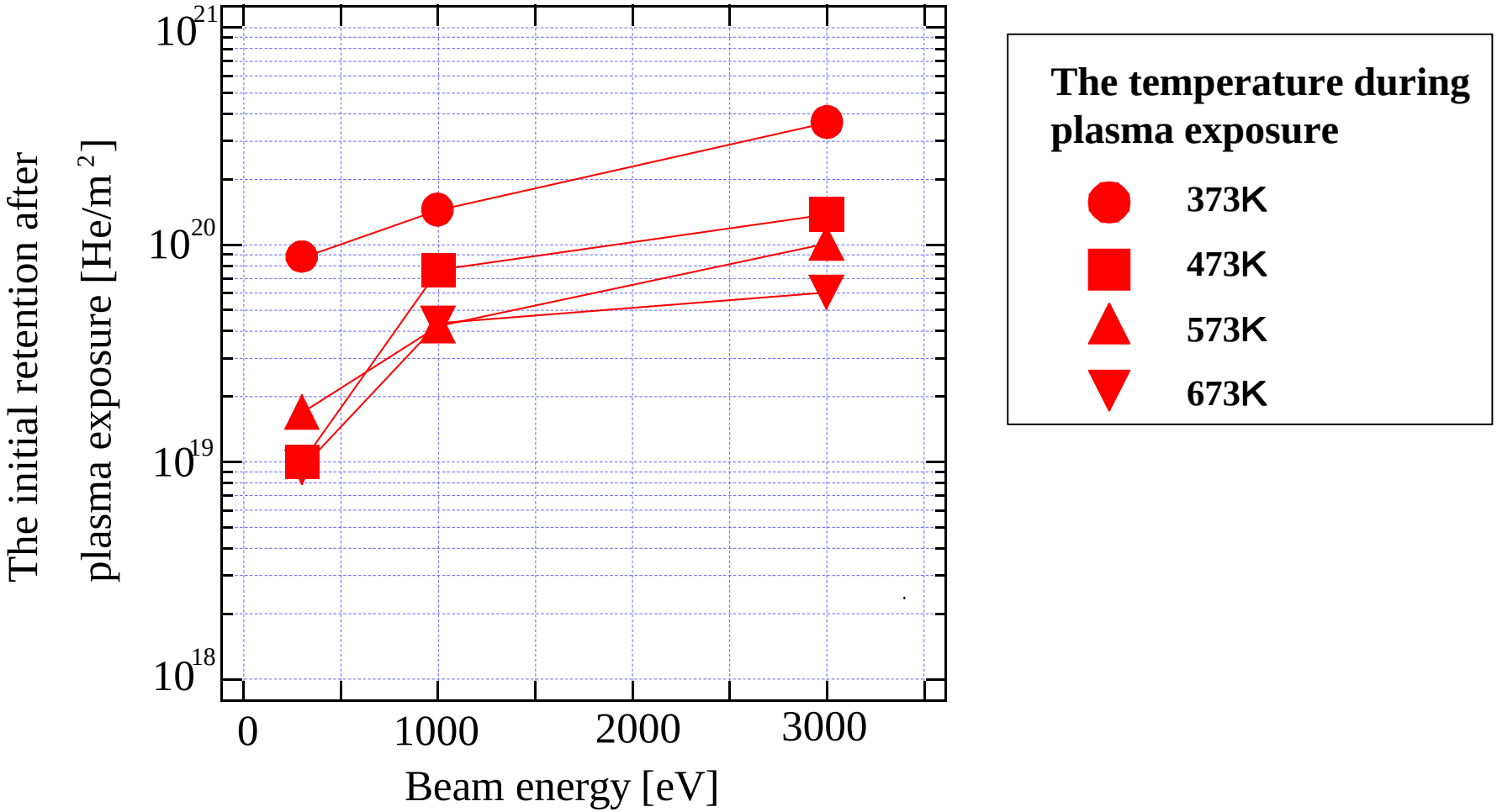


Beam energy=1keV

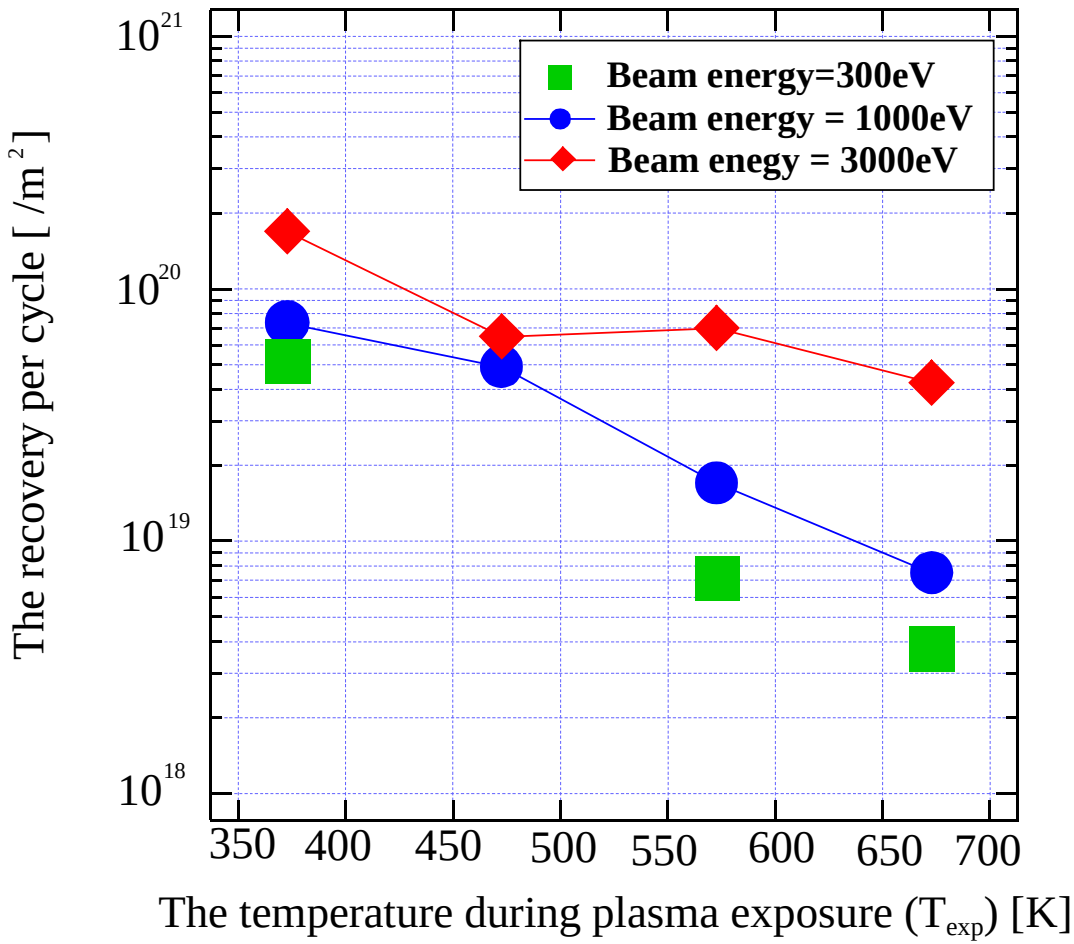


The fluence = 5 x 10^{21} /m^2

Energy dependence of Helium retention

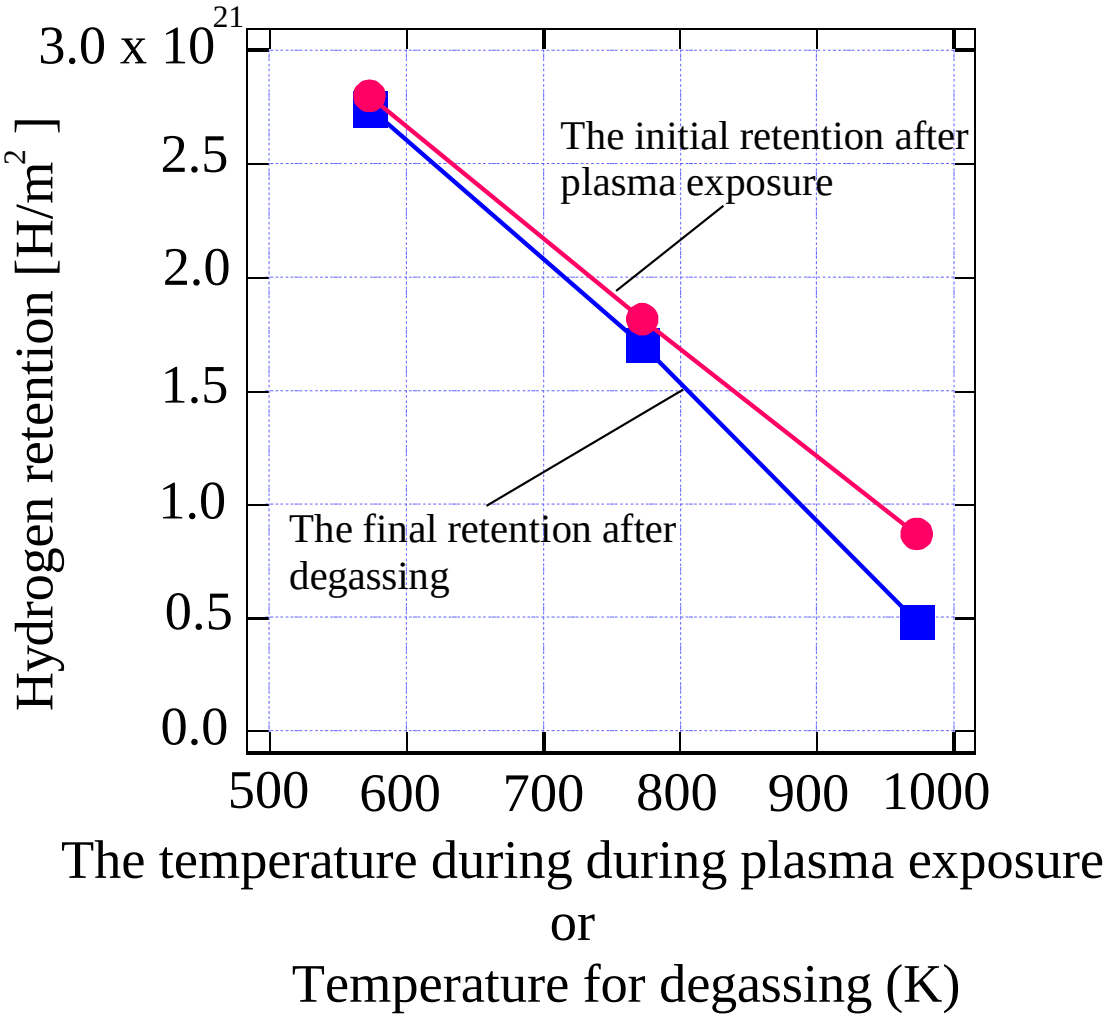


Helium recovery per cycle



$$T_{exp} = T_{degas}$$

Temperature dependence of Hydrogen retention



<u>Experimental state</u>

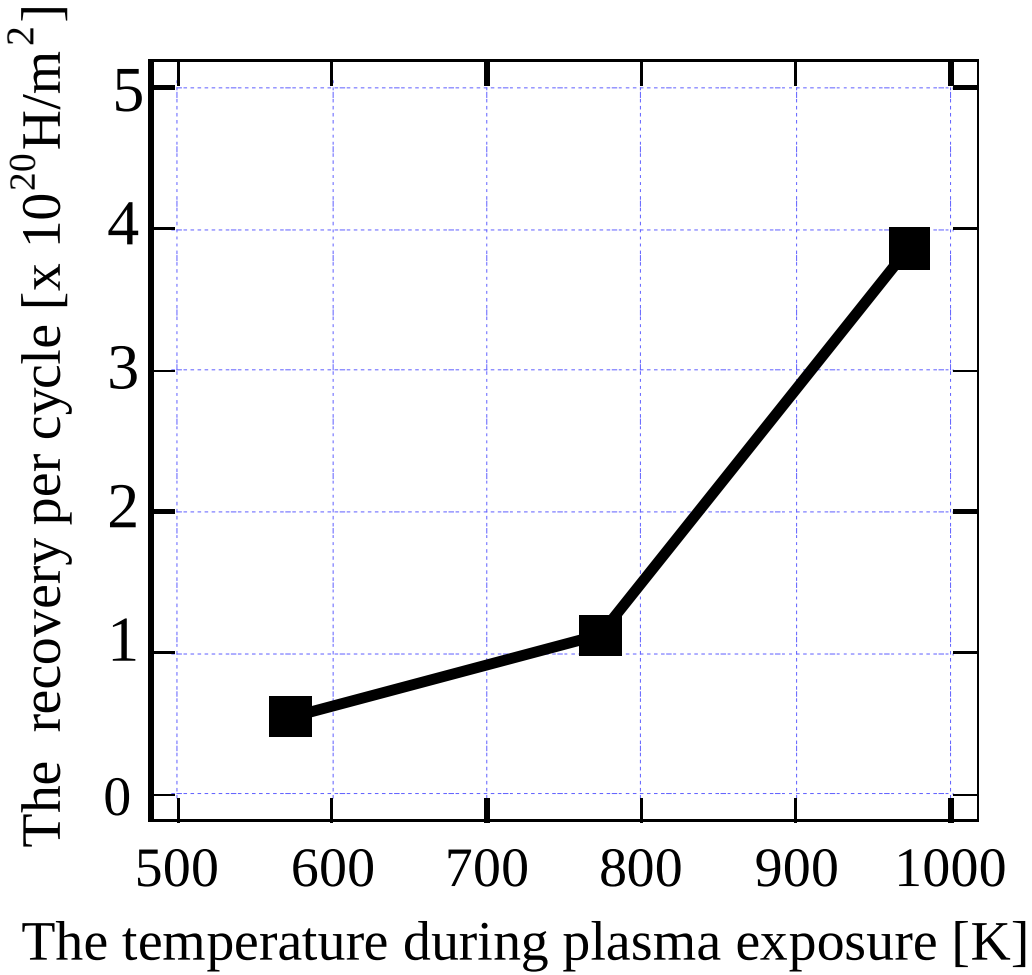
Beam energy : 1.7KeV

Fluence :2.6x10^{22}(H/m^2)

The temperature during plasma exposure:

575,773,973(K)

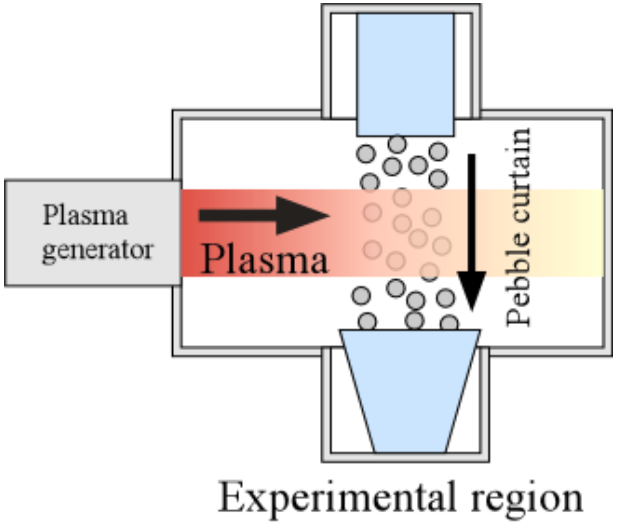
Hydrogen recovery per cycle



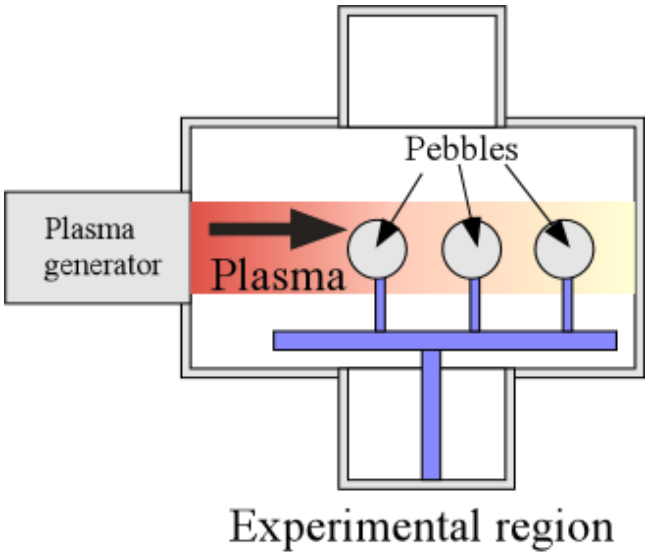
Development of ECR plasma device

Motivation

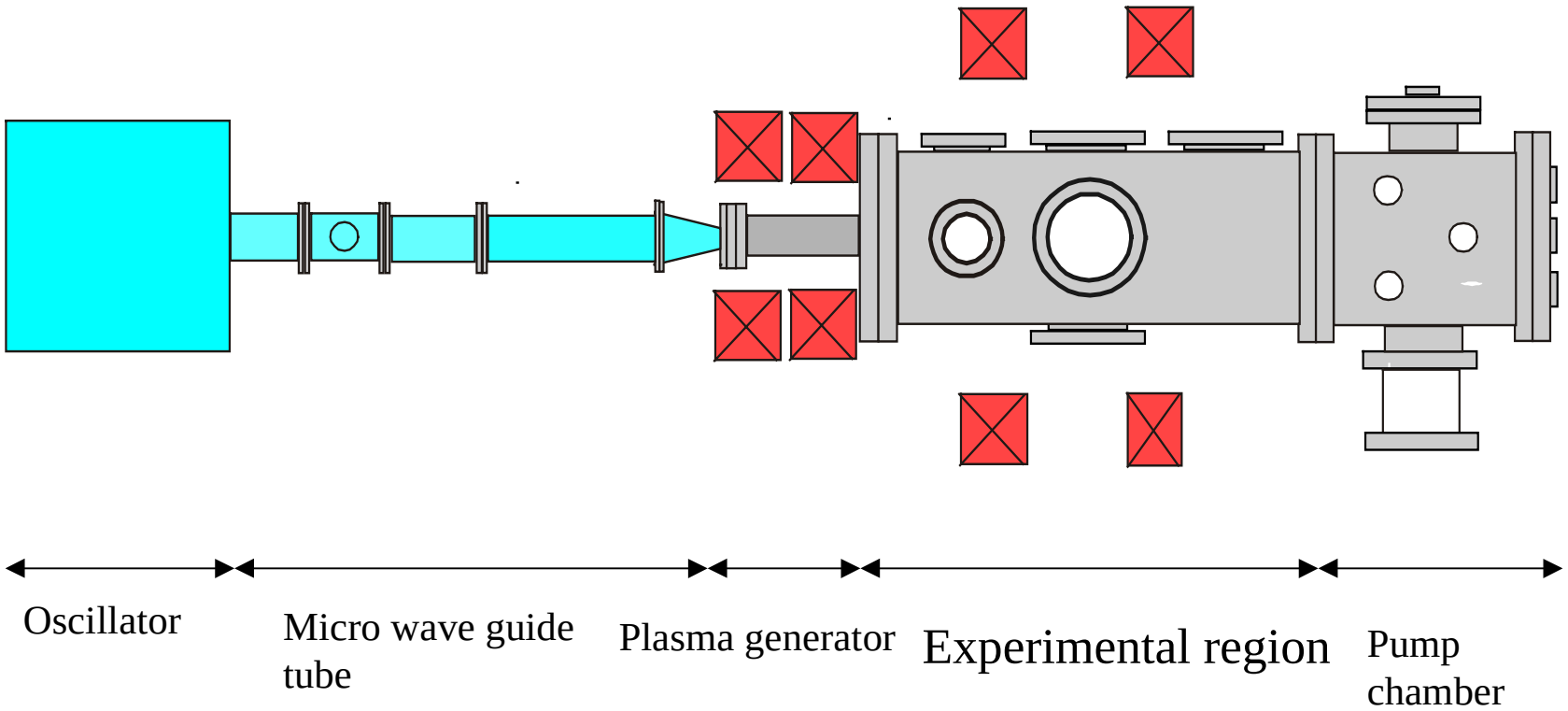
The estimation of the shielding effect of the pebble curtain against the plasma by dropping pebbles across the plasma flow in the ECR plasma device.



The observation of the influence of the electric field around the pebbles upon the incident particle flux to the pebbles by setting up the pebbles in the plasma flow of the ECR plasma device.

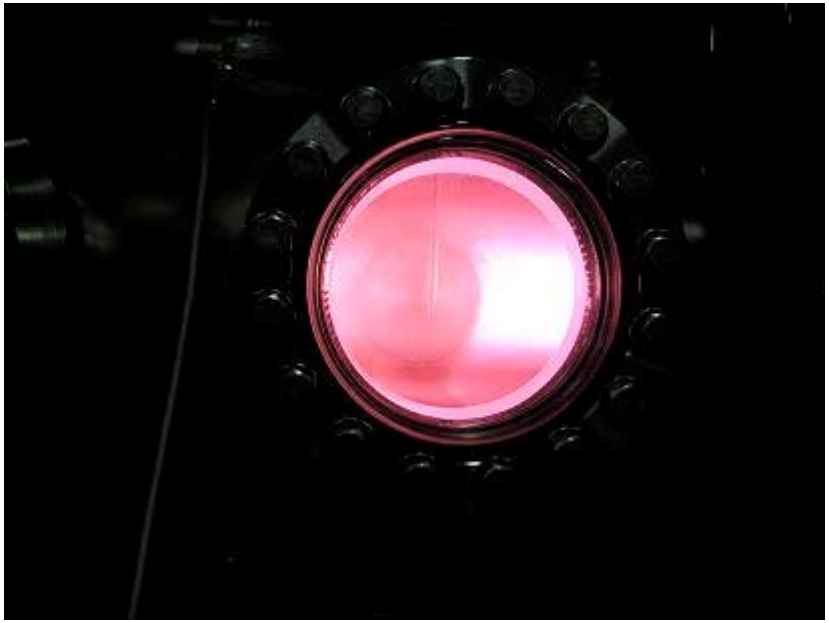


ECR plasma device



Top view of the ECR plasma device

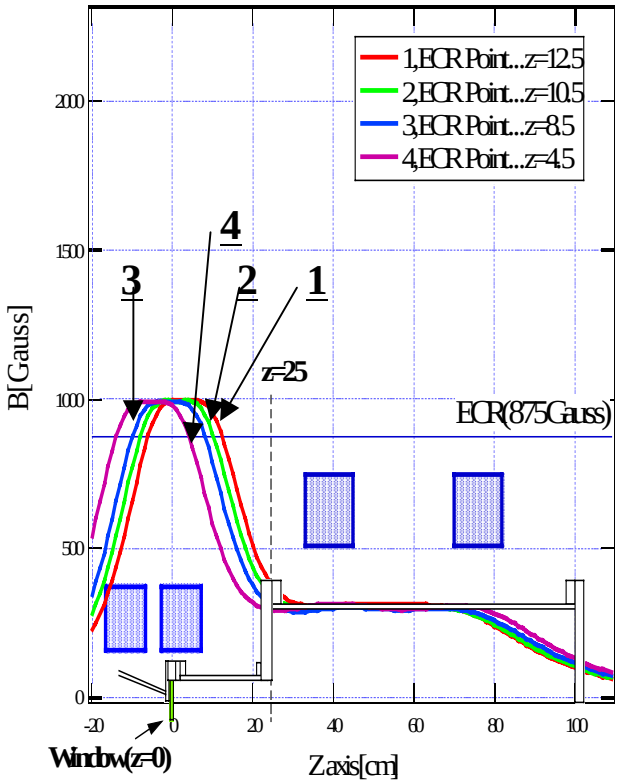
ECR plasma device



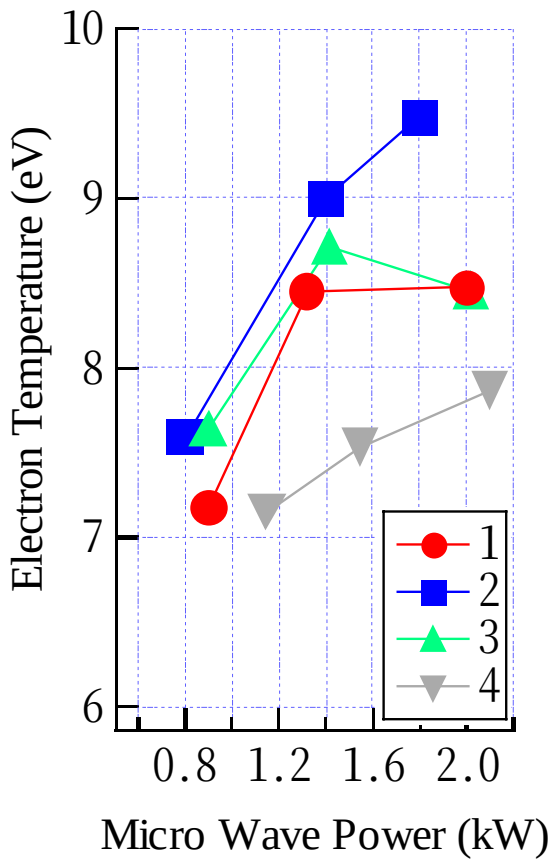
He Plasma

Plasma Parameters

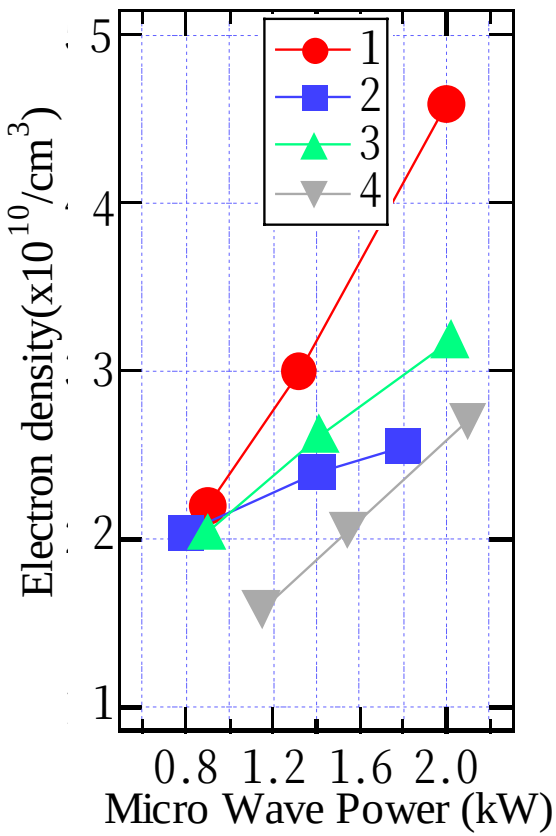
Magnetic field configuration



Te



Ne



Summary and Future Plan

The characteristics of He retention and hydrogen retention in graphite, which is candidate material of the pebble surface, have been estimated experimentally in order to ensure the possibility of the particle control by pebble divertor.

From the experiments for Helium and Hydrogen retention, Helium and Hydrogen can be recovered even though the temperature for degassing is equal to the temperature during plasma exposure. The low energy consumption for the degassing can be achieved by using this characteristic.

The additional experiments for Helium and Hydrogen retention at the low beam energy conditions have to be conducted in order to estimate the performance of the retention in the future fusion reactors.

The ECR plasma device has been developed in order to estimate the shielding effect of the pebble curtain against the plasma and the influence of the electric field around the pebbles upon the incident particle flux to the pebble.