論文 / 著書情報
Article / Book Information

Title	Study on IEC with magnetic field at Tokyo Institute of Technology
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Journal/Book name	CD, , ,
Issue date	2010, 10
DOI	
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HOTTA LAB

12th US-Japan Workshop on Inertial Electrostatic Confinement Fusion, Osaka, Japan, Oct. 20-21,2010

Study on IEC with magnetic field at Tokyo Institute of Technology

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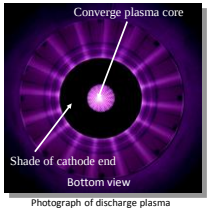
Cylindrical IEC device with **axial cusp magnetic field**

To reduce pressure

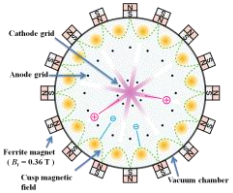
The axial cusp magnetic field confined electrons near the chamber wall and ions were produced and accelerated efficiency in a low pressure operation.

To increase cathode current

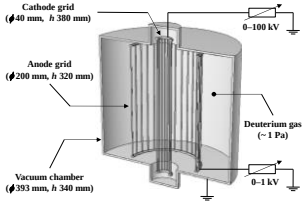
The high current pulsed operation was attempted.



Photograph of discharge plasma



Cross section of the cylindrical IEC device

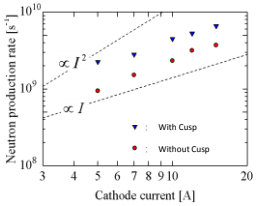


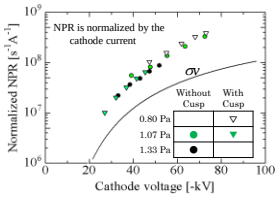
*Pulse width 20 μs, Repetition frequency 4 Hz

Schematic of the cylindrical IEC device

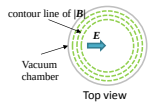
External appearance of the cylindrical IEC device

✓ The pressure , cathode voltage and current can not be controlled independently.





- Beam-cathode, beam-background reaction were dominant.
- The cusp magnetic field and the anode biasing were effective to enhance the NPR.
- The maximum NPR was 7.4 × 10^9 s^{-1} (V_c = –80 kV, I_c =15 A)
- As the pressure decreased, the normalized NPR became high.



The confinement effect of the axial cusp magnetic field was **not** sufficient, because electrons moved in the axial direction by **E** x **B** drift motion.

The ways to improve NPR

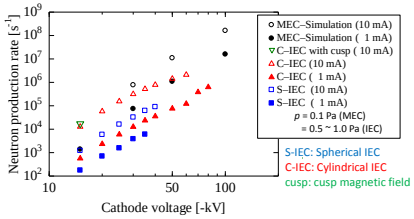
◆**To increase ion density**

- To increase cathode current — with cusp
- To improve ion confinement — MEC

◆**To increase ion energy**

- To reduce pressure — with cusp, MEC
- To increase cathode voltage

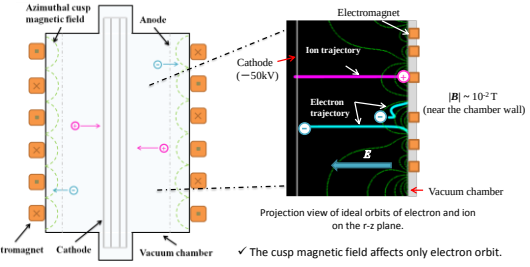
Comparison of NPR



- The MEC device has similar performance to that of the cylindrical IEC device with axial cusp magnetic field.
- The expected NPR of the MEC device : 1.6 x 10^8 s^{-1} (V_c = –100 kV, I_c = 10 mA, B_z = 240 mT)

New trial **Azimuthal cusp** magnetic field

Azimuthal cusp magnetic field is expected to confine electrons and produce ions more effectively at low pressure, because electrons move in the azimuthal direction by **E** x **B**.



Projection view of ideal orbits of electron and ion on the r-z plane.

✓ The cusp magnetic field affects only electron orbit.

References

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K. Tomiyasu et al., "EFFECTS OF CUSP MAGNETIC FIELD IN A CYLINDRICAL RADIALLY CONVERGENT BEAM FUSION DEVICE, Fusion Science and Technology," Vol. 56, pp. 967-971 (2009).

K. Yamauchi et al., "Performance of Neutron/Proton Source Based on Ion-Source-Assisted Cylindrical Radially Convergent Beam Fusion," IEEJ Trans. FM, Vol. 126, No. 11, pp.1177-1182 (2006).

MEC (Magnetic-assisted Electrostatic Confinement)

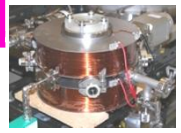
To increase ion density in a low pressure and low current operation

To improve ion confinement

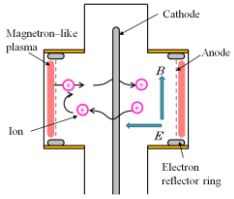
An axial uniform magnetic field was applied to prevent ions from hitting the central cathode rod.

Ion source-assisted operation

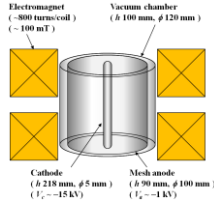
The magnetron motion and electron reflector rings confined electrons near the anode and enhanced ion generation was expected at low pressure. Production of a localized plasma was suppressed near the cathode.



External appearance of the MEC device

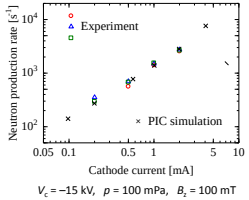


Ideal operation of the MEC device

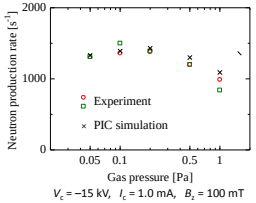


Schematic of the MEC device

✓The pressure , voltage and current can be controlled independently.

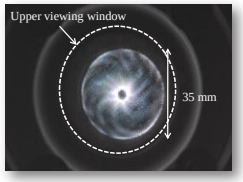


V_c = –15 kV, p = 100 mPa, B_z = 100 mT

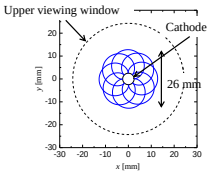


V_c = –15 kV, I_c = 1.0 mA, B_z = 100 mT

- The maximum NPR was 2.6 x 10^3 s^{-1} (V_c = –15 kV, I_c = 2 mA)
- The cathode current was limited by the space charge limitation. (V_c = –15 kV ⇒ I_c < 4 mA)
- Beam-cathode reaction was a dominant fusion type, assuming the deuterium density in the electrodes 3x10^{28} m^{-3} in the PIC simulation.



Luminescent region at the upper viewing window (V_c = -15kV, I_c = 1 mA, p = 100 mPa, B_z= 50 mT)



Orbit of secondary electron from cathode

Ion generation occurred near the cathode, because a lot of secondary electrons were trapped around the cathode by the uniform magnetic field.