Double-Grid Inertial Electrostatic Confinement Fusion (IEC) for Recovery of Energy from Escaping Electron Beams

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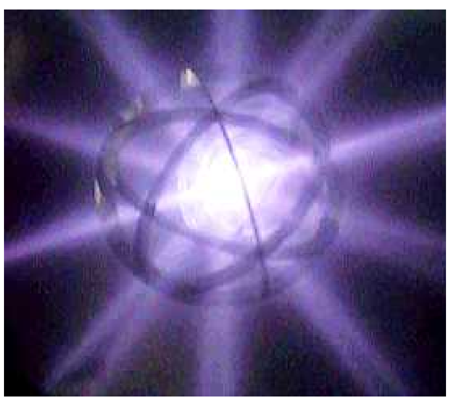
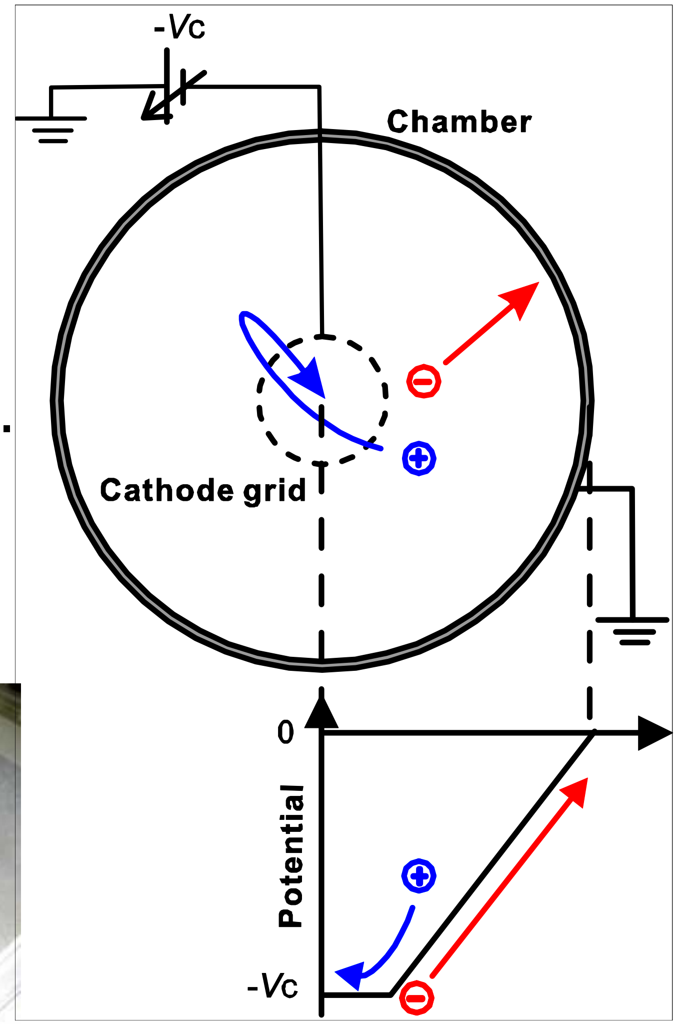
Glow discharge driven IEC

Ions are accelerated towards center.
→Fusion reaction.

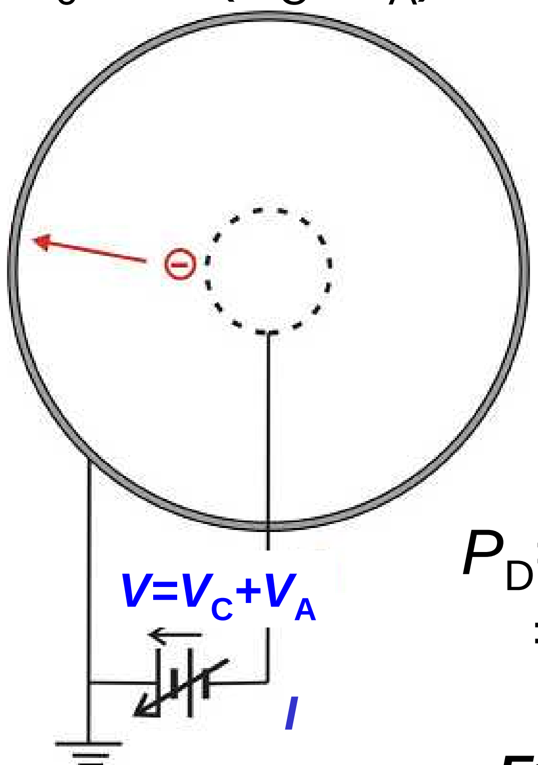
Escaping electrons get high energy.
→Waste of **most** input power
→**Low efficiency** of IEC





Principle of Recovery of energy using a Double-Grid IEC

$P_0 = VI = (V_C + V_A)I$



Glow driven IEC

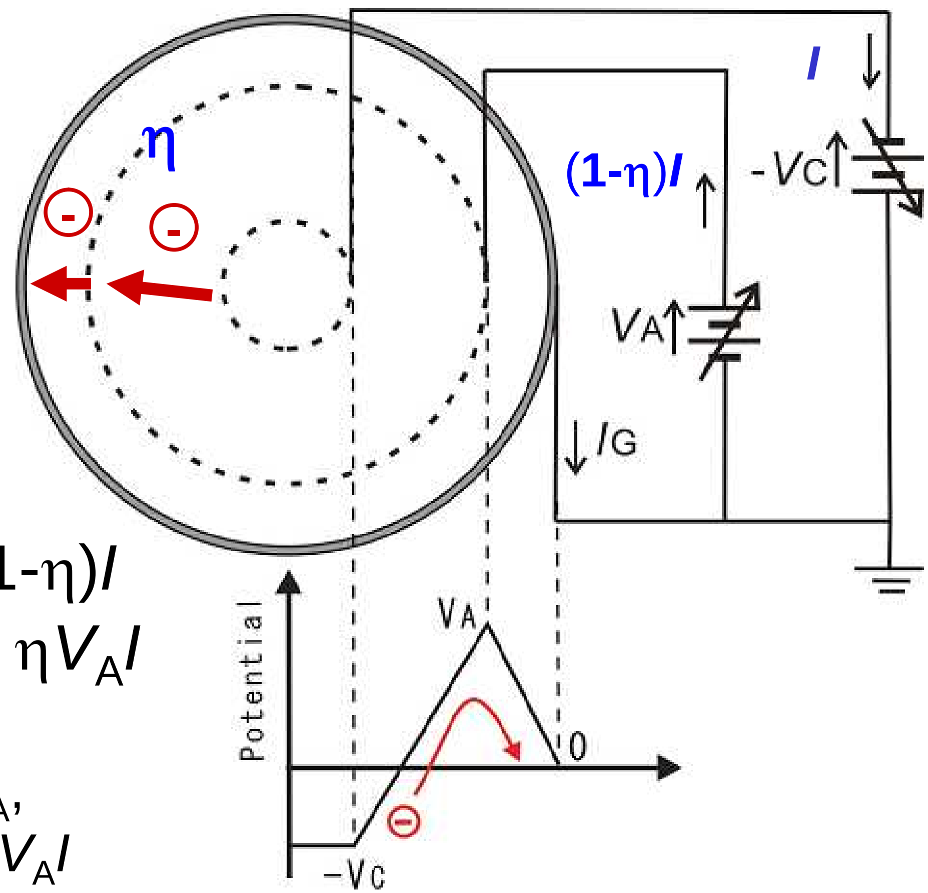
$$P_D = V_C I + V_A(1-\eta)I$$
$$= (V_C + V_A)I - \eta V_A I$$

Ex. $\eta = 1$, $V_C = V_A$,

$P_D = (V_C + V_A)I - V_A I$

$= V_C I = 0.5VI$

$= \mathbf{0.5}\boldsymbol{P_0}$



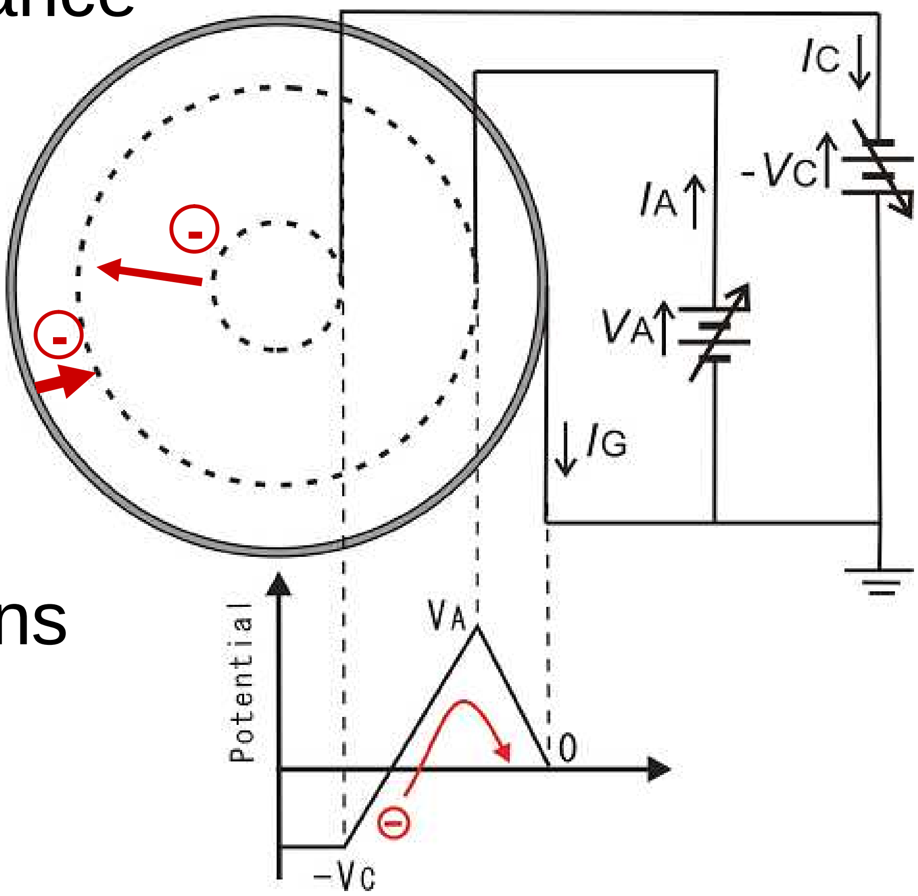
Double-Grid IEC

Requirements for Recovery of Energy

1. High anode transmittance
   for electrons

2. No ionization
   outside the anode

3. Suppression
   of secondary electrons
   from the chamber



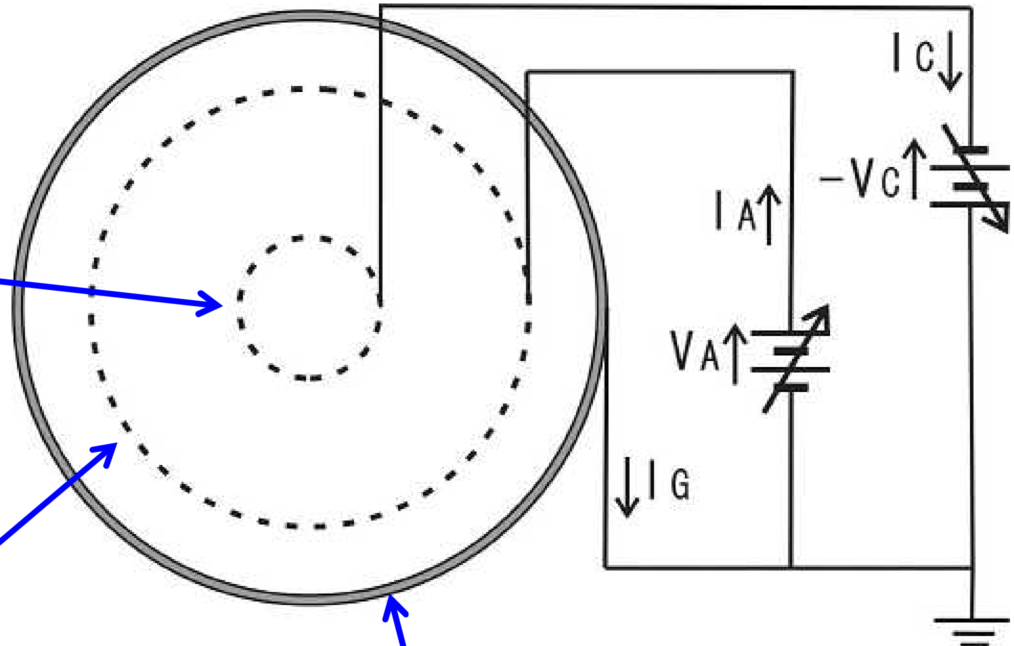
Experimental Setup

1.0~1.6Pa

Cathode

outer:65mm
inner:55mm

-5~ -20kV DC



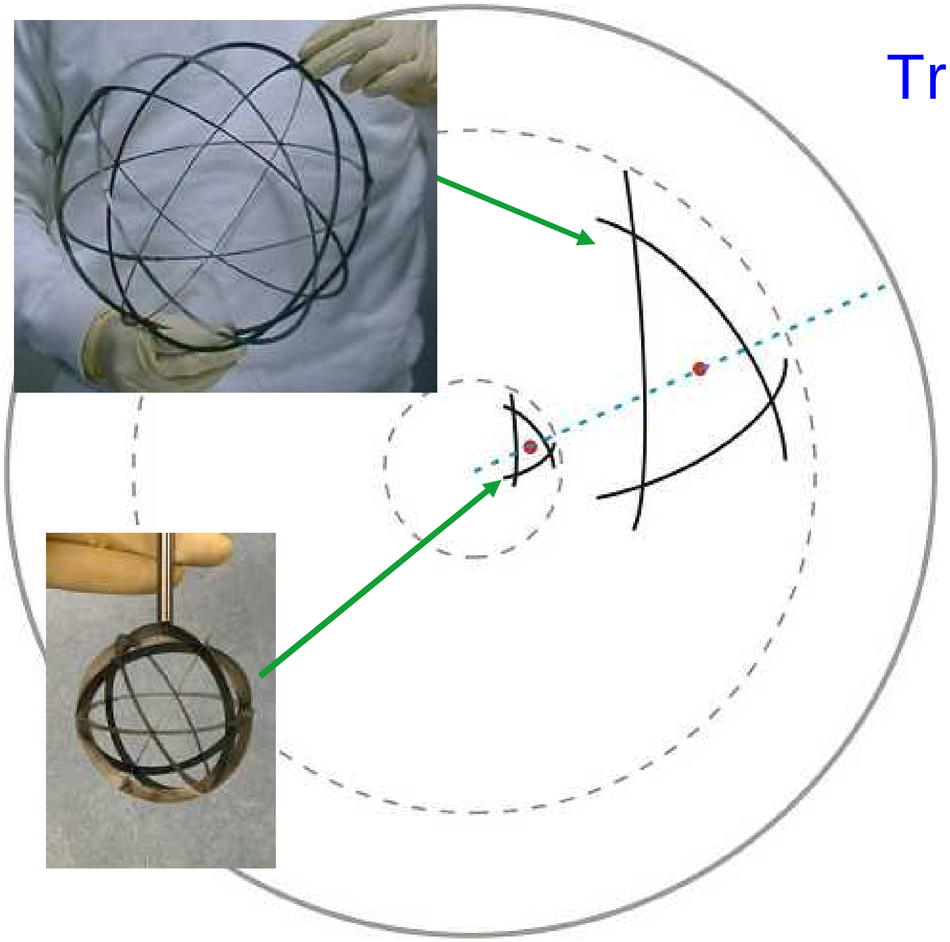
Anode
outer:250mm
inner:240mm
~99%

18~33kV DC

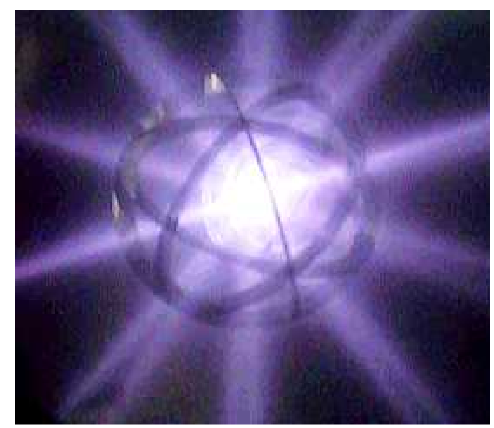
Chamber

inner:340mm

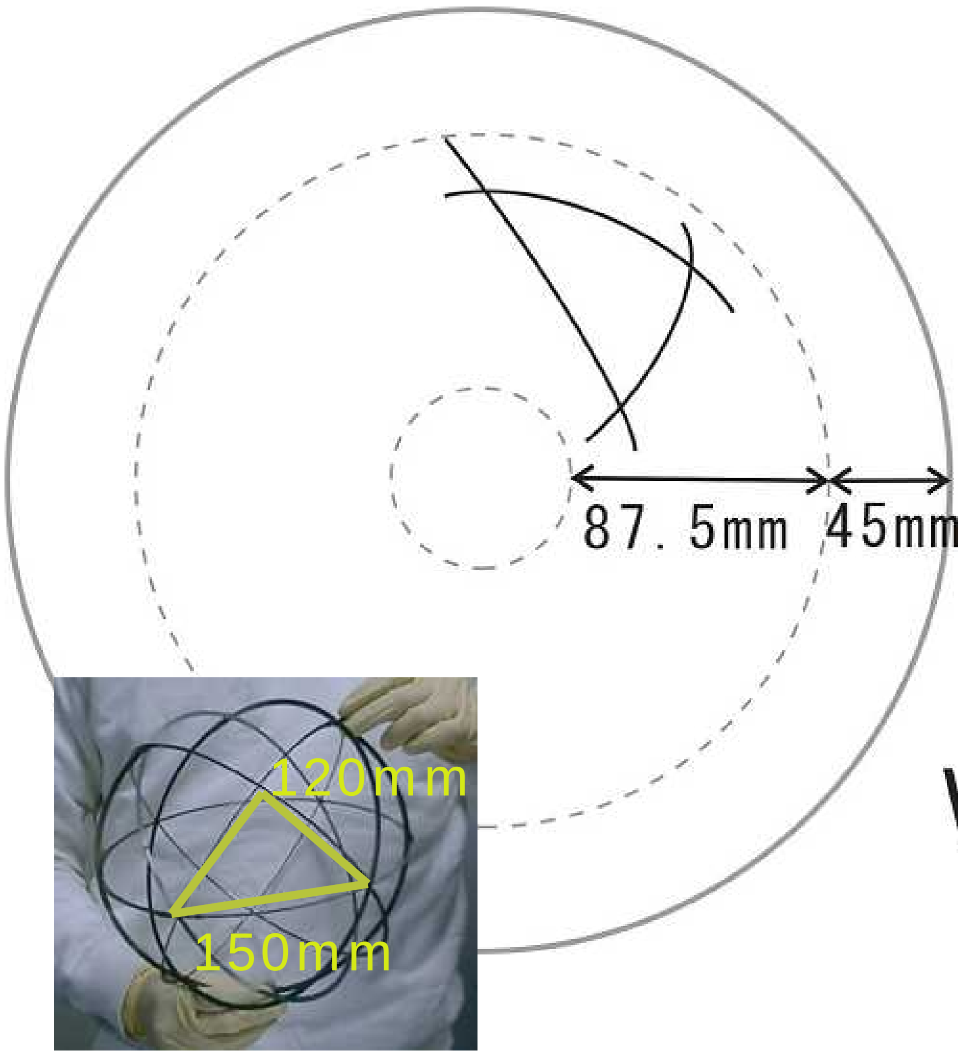
Arrangement of Electrodes to Maximize the Anode transmittance



Triangle spaces of the cathode and the anode were located on **the same direction**.

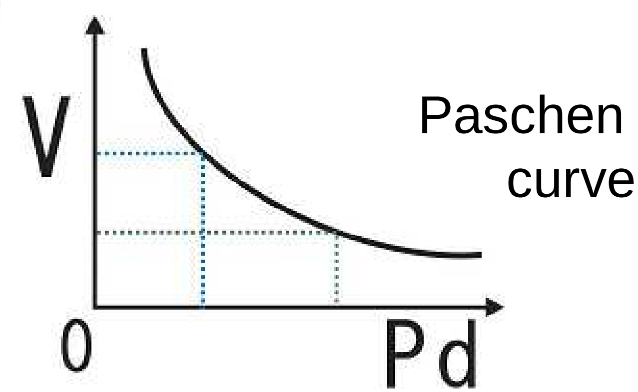


Effect of Arrangement of electrodes on Glow discharge

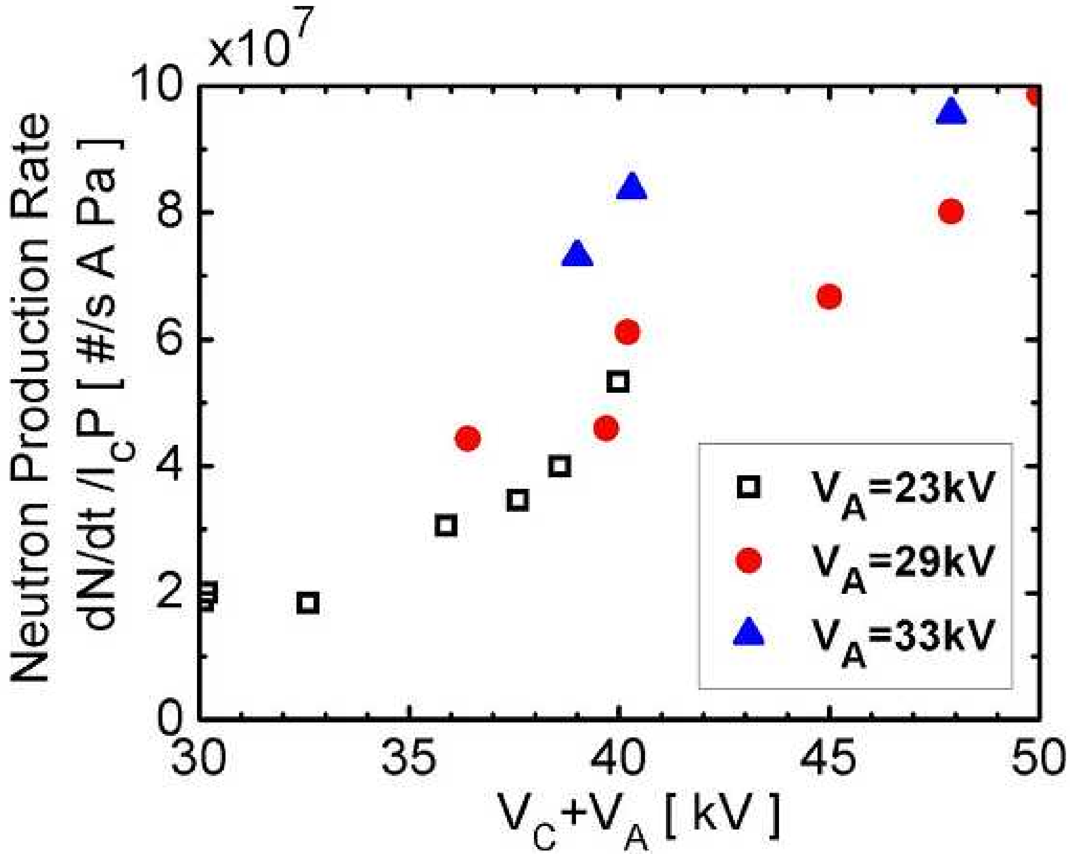


Cathode and Anode
..**87.5mm**
Anode and Chamber
..**45mm**

→If the anode were solid, no discharge would occur outside the anode.

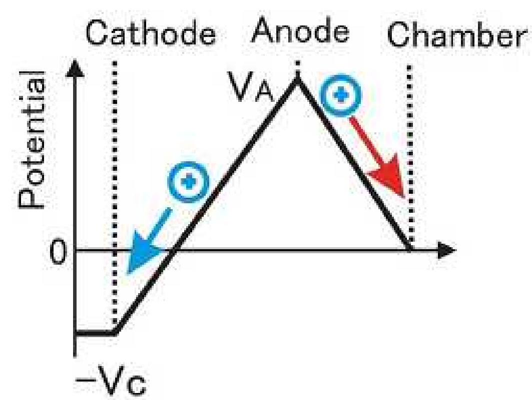


Neutron Production Rate (NPR)



A slight dependence of NPR on the anode potential V_A.

→Undesirable ionization outside the anode.

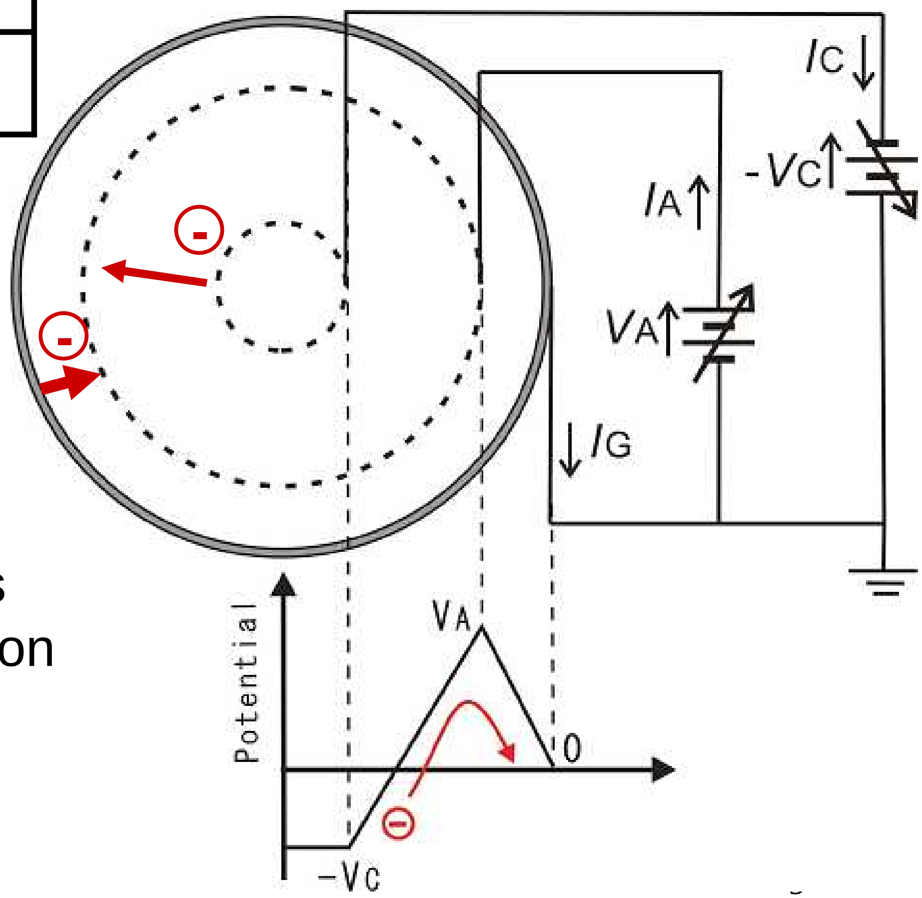


Typical conditions of Experiments

1.0Pa

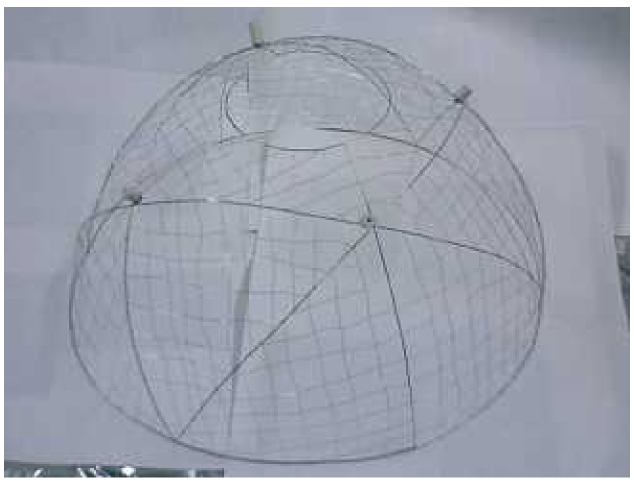
$-V_C$ [kV]	I_C [mA]	V_A [kV]	I_A [mA]
-15	2.3	23	4.4

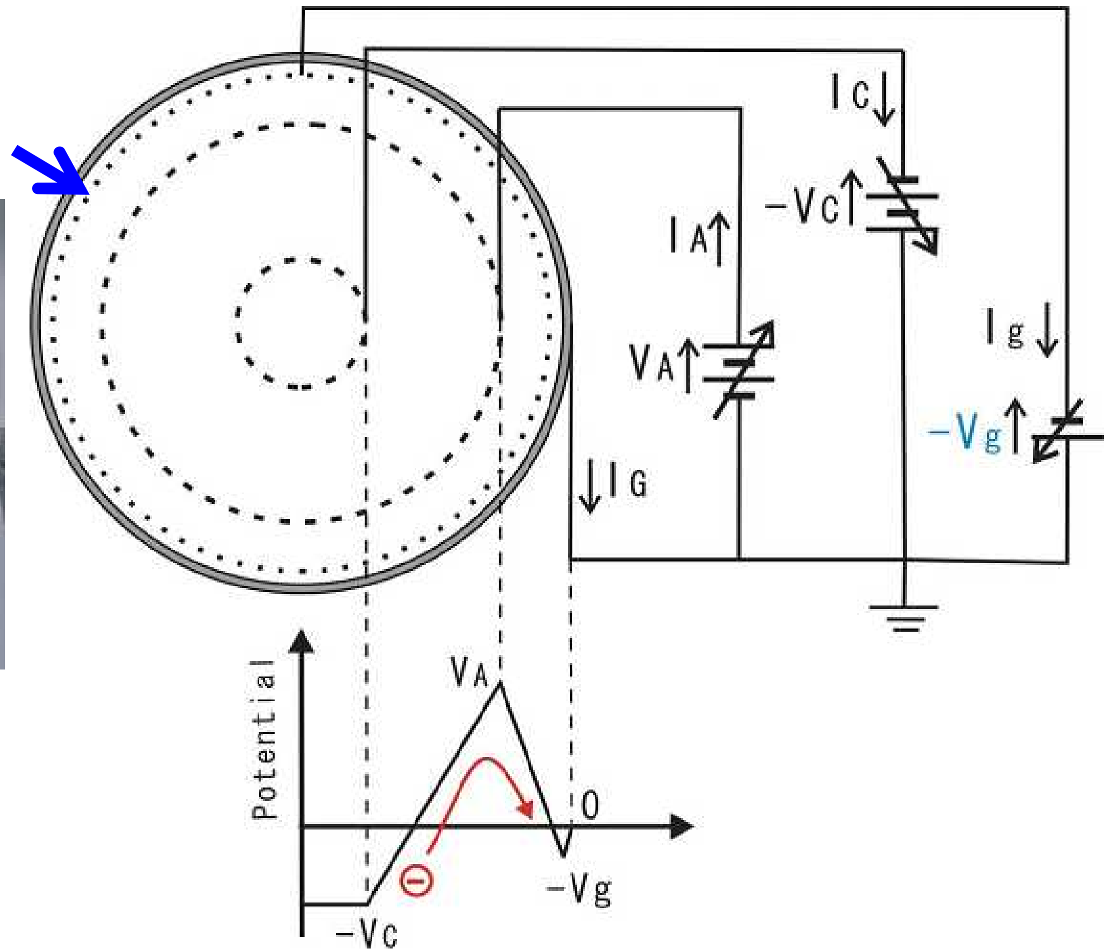
double



Considerable amount of electrons
into the anode ← outside ionization

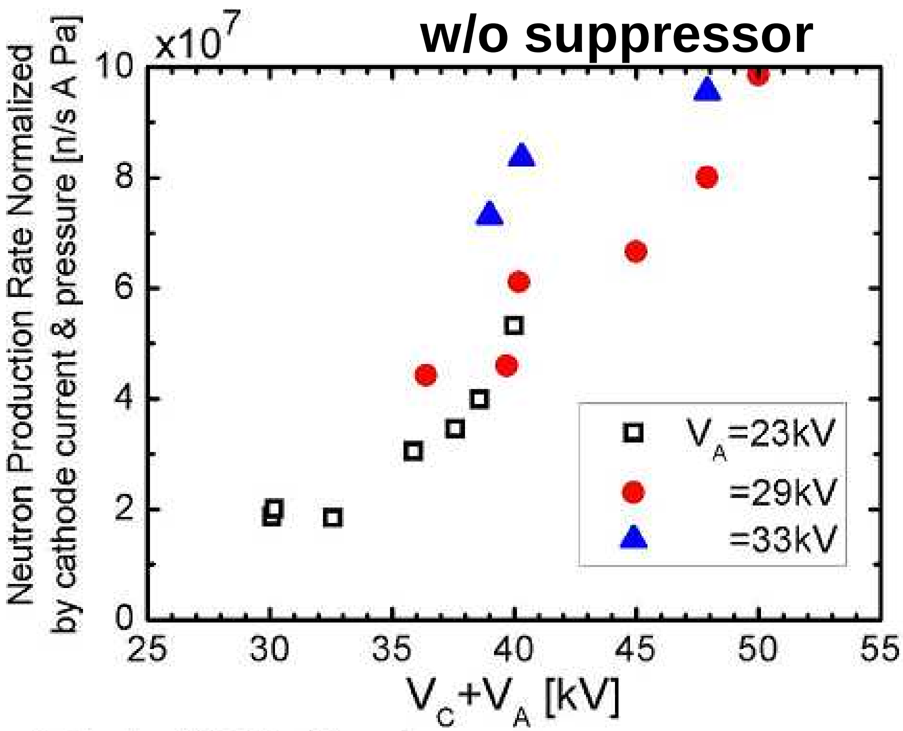
Secondary Electron Suppressing Grid

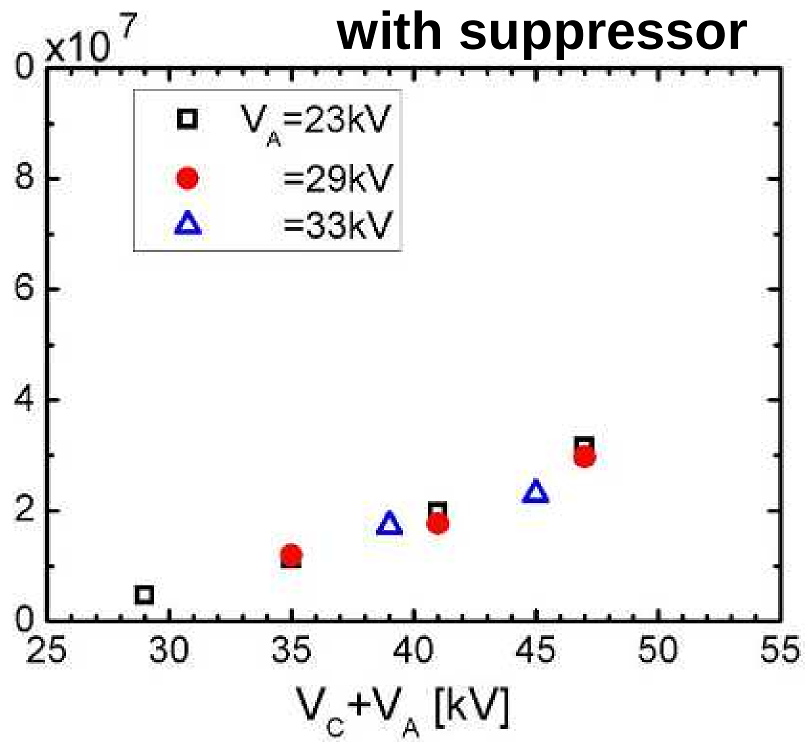


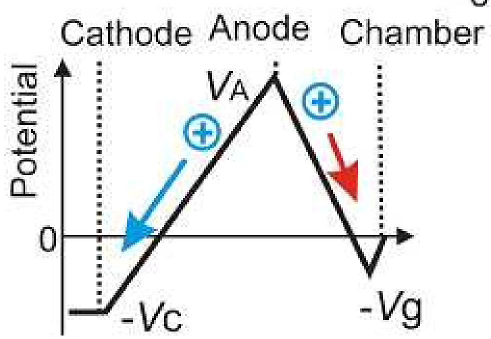


320mm ~90%
-1kV

Comparison of NPR dependence on the Cathode and Anode Voltage



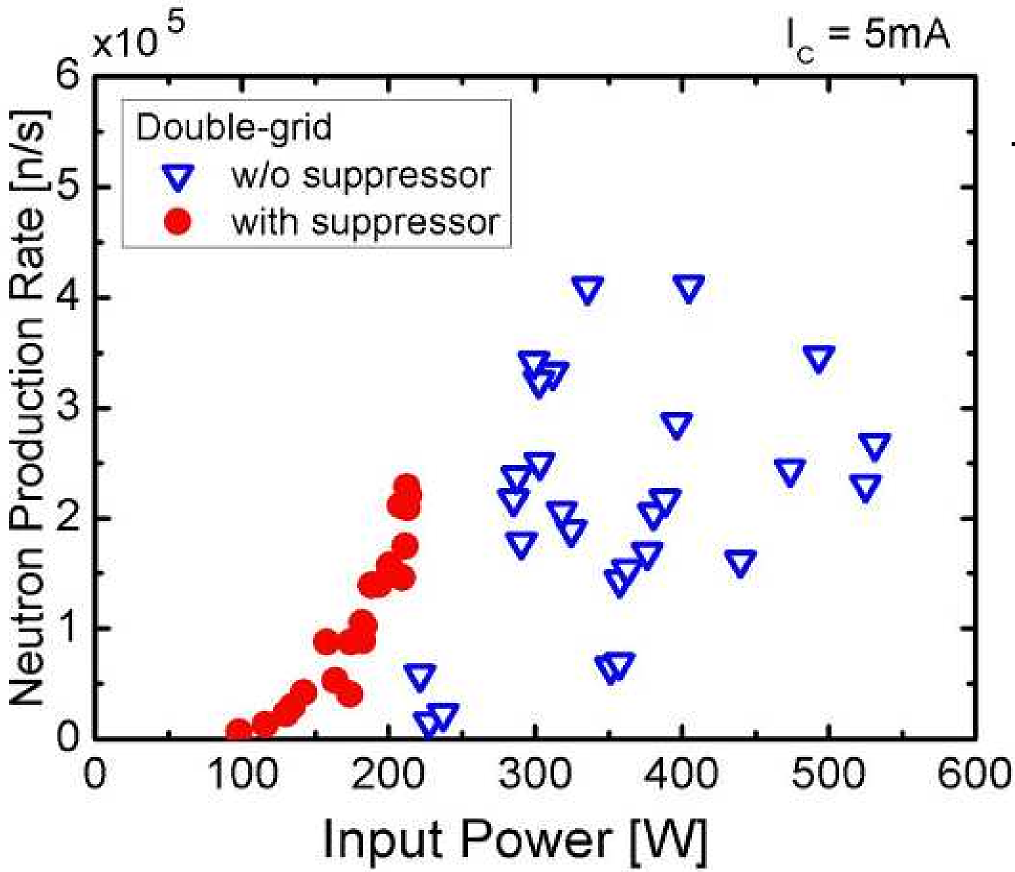




Much less NPR dependence on anode potential with the suppressing grid.

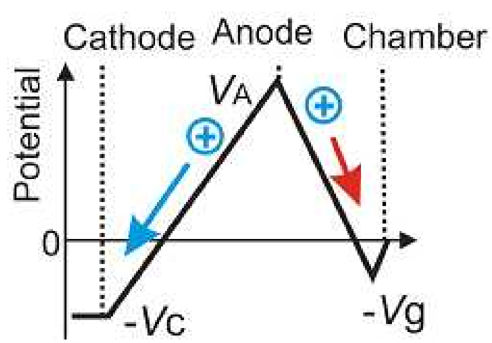
…Reduction of outside ionization!

Comparison of Efficiency w/o and with suppressor

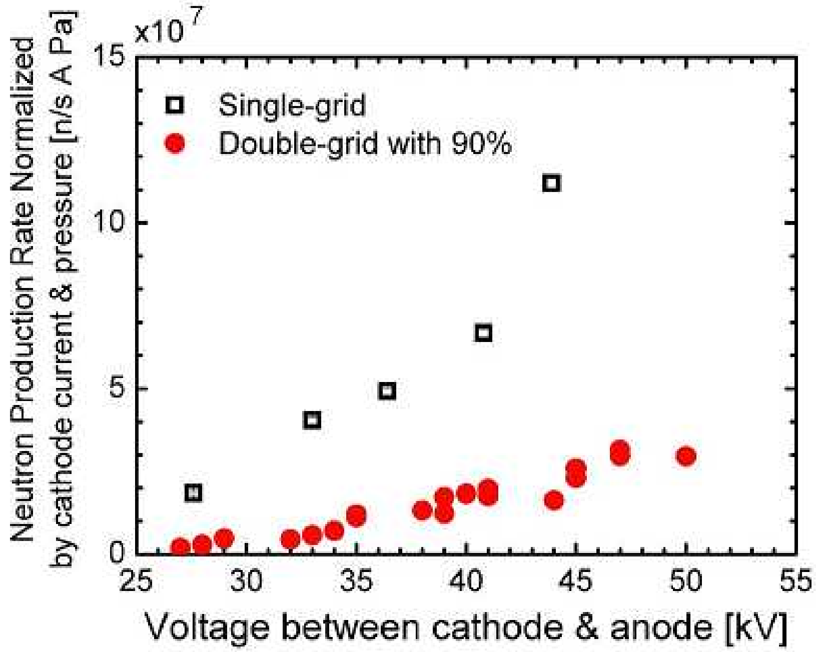


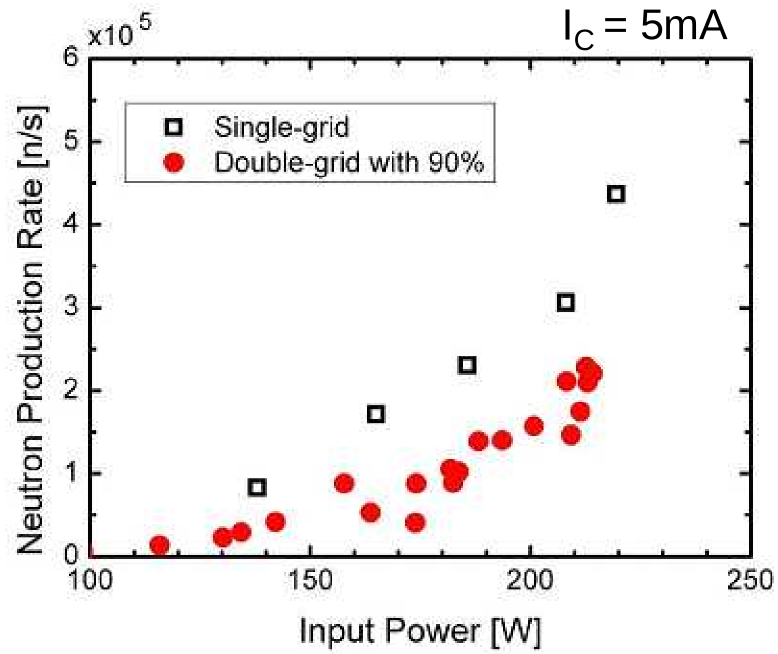
Through suppression of secondary electrons;

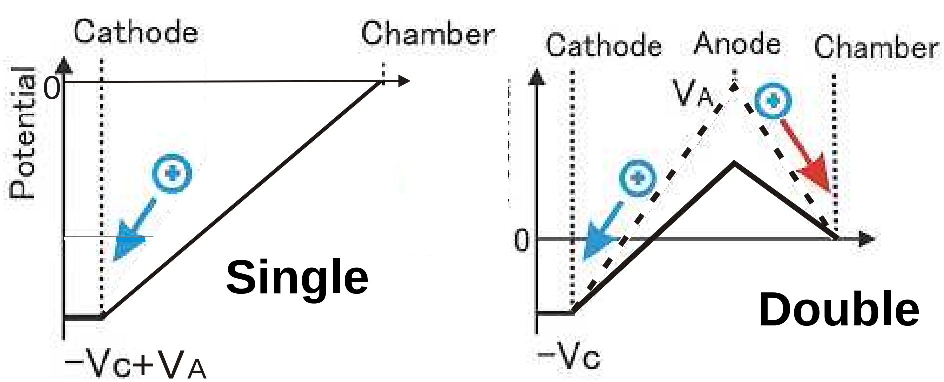
Reduction of input power
→Efficiency of double-grid IEC was improved.



Decrease of NPR with double-grid arrangement

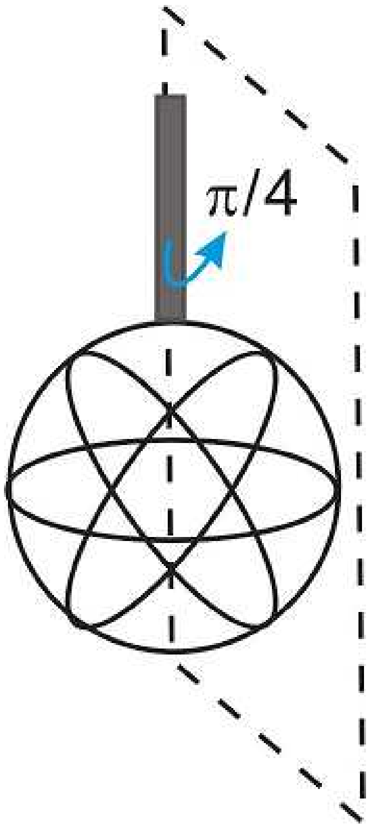




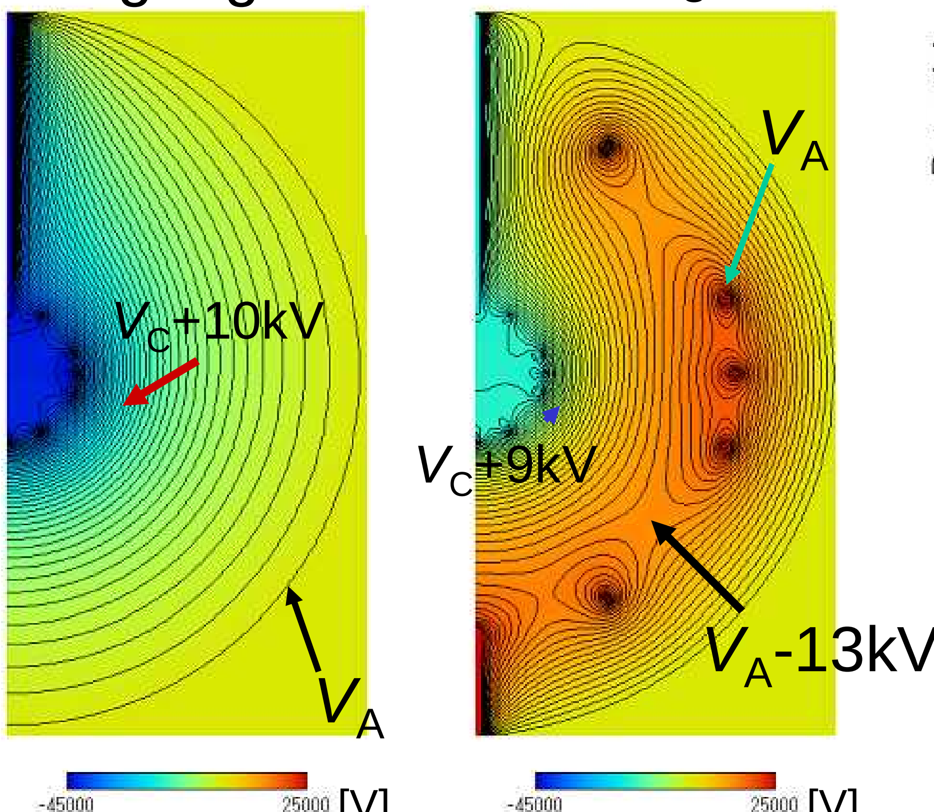


NPR decreased to 1/3
… because of the gridded sparse anode?

Examples of potential calculation result

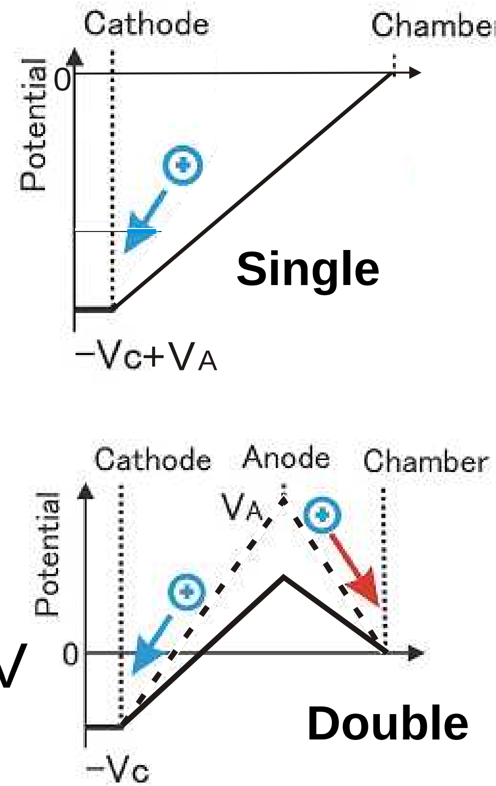


single-grid | double-grid



$-V_C$= -45kV
V_A= 0kV

$-V_C$= -20kV
V_A= 25kV



Summary and conclusions

We have proposed a double-grid system to improve the efficiency of IEC by recovery of energy from escaping electrons.

- Through suppression of secondary emission,
  - ionization outside the anode was reduced, and
  - efficiency was improved compared with one of w/o suppression.
- NPR of double-grid IEC decreased to about 1/3 of one of single-grid IEC.
- It is necessary to clarify the causes of such decrease of NPR.
  - Potential calculation didn't show the reason obviously for that decrease.
  - The volume difference inside the anode may be one of the causes.
  - Stability of discharge should be examined.