A 3D Hybrid-IFE-PIC-MCC model for the discharge chamber simulation of ion thrusters

Chang Lu, Yong Cao*
Harbin Institute of Technology, Shen Zhen

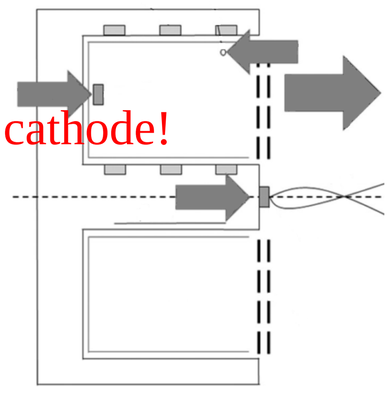
1. Background of this research

Two type Kaufman type ion thruster

- Traditional ion thruster
- Annular ion thruster

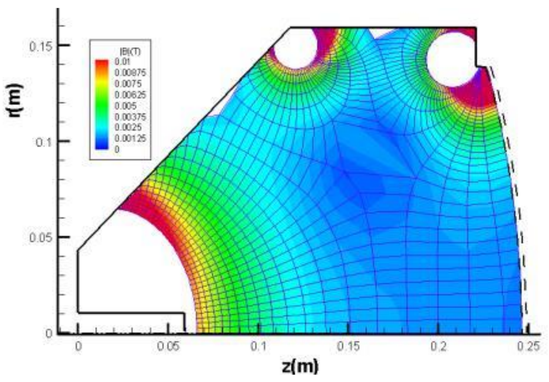
Note that:
The discharge chamber of the Annular ion thruster is non-axisymmetric!!!

Biased cathode!

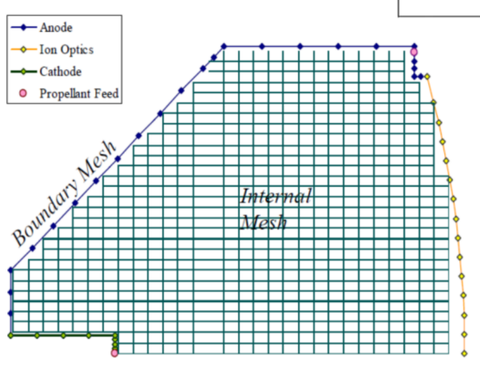


We need a 3D simulation model for the Annular discharge chamber!!!

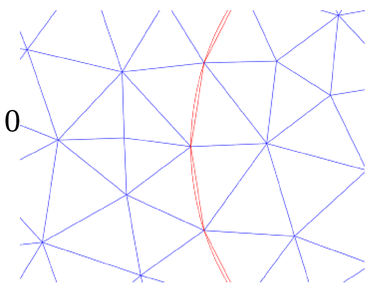
2. The mesh?

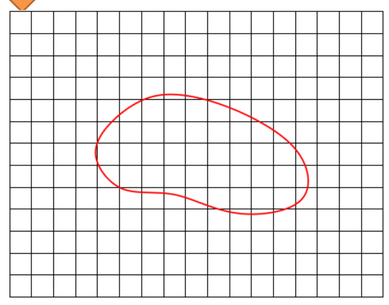


or



We need the IFE mehtod!!!





3. Governing equations

Primary electrons

① $\frac{\partial f_p}{\partial t}+\mathbf{u}_p\cdot\nabla_X f_p+\frac{q_p}{m_p}\left(\mathbf{E}+\mathbf{u}_p\times\mathbf{B}\right)\cdot\nabla_u f_p=\left.\frac{\partial f_p}{\partial t}\right|_c \longrightarrow f_p$

② $\left.\frac{\partial f_p}{\partial t}\right|_c = f\left(f_p,\rho_0\right) \longrightarrow \left.\frac{\partial f}{\partial t}\right|_c$

③ $G=\rho_0\int\sigma_i\mathbf{u}_p f_p d^3u_p \longrightarrow G$

Plasma

④ $\nabla\cdot(\mathbf{D}\nabla\rho)=-G \longrightarrow \rho$

⑤ $-\nabla\mathbf{E}=\nabla^2\phi=-\nabla\left(\mathbf{M}\frac{1}{\rho}\nabla\ln\rho\right) \longrightarrow \mathbf{E}$

⑥ $\rho\mathbf{u}=-\mathbf{D}\nabla\rho \longrightarrow \mathbf{u}$

Atoms

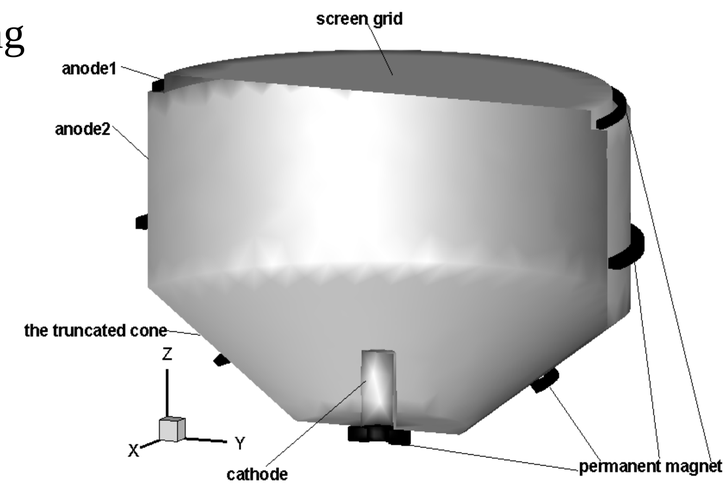
⑦ $\iint_{S_{screen}}\rho\mathbf{u}\cdot\mathbf{n}ds+\frac{\rho_0 u_{thermal}A_{screen}\eta_{screen}}{4}-\frac{Q_{in}}{m_0}=0$

$\downarrow$

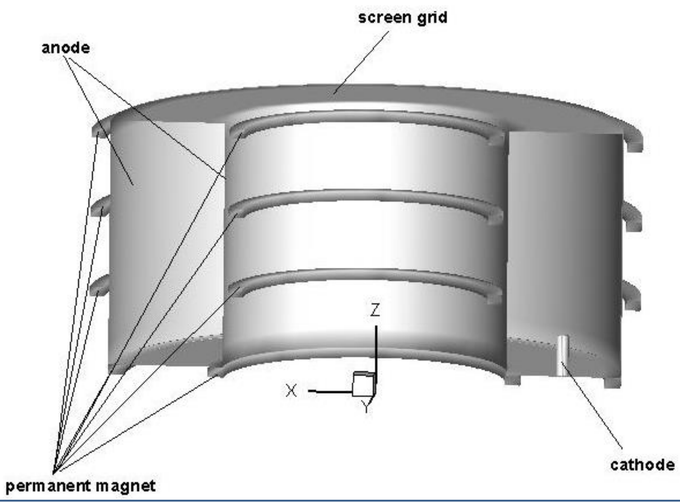
ρ_0

Decoupling and Iteration!!!

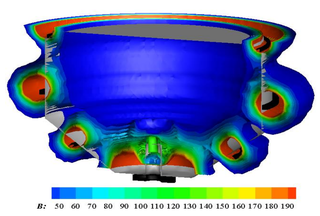
4. Simulation setting

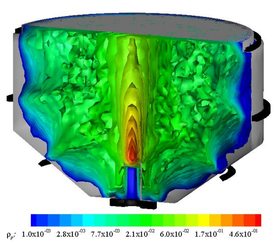


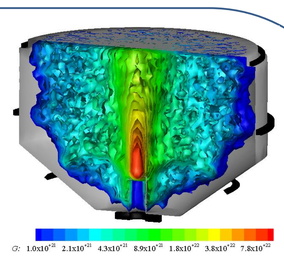
and

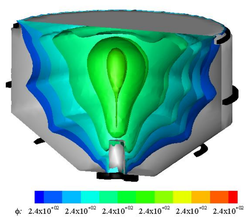


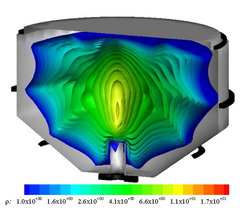
5. Key simulation results and analysis

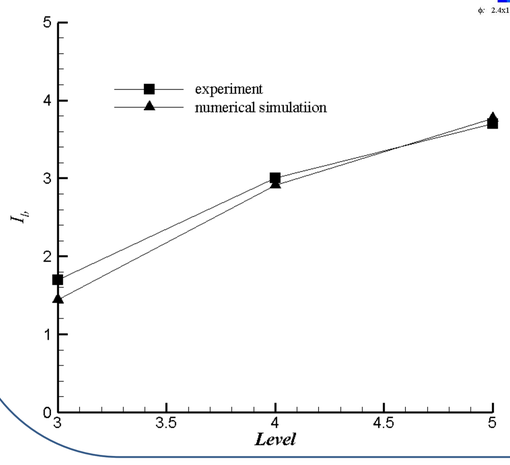




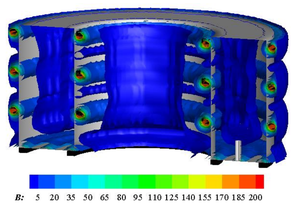


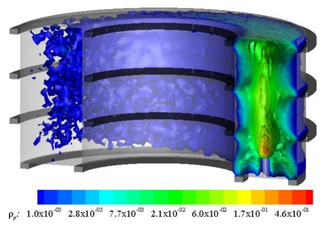


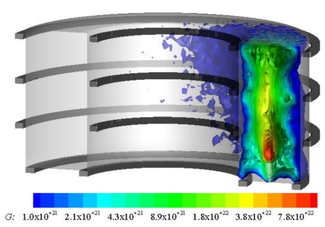


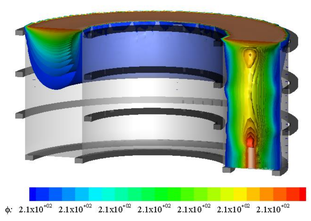


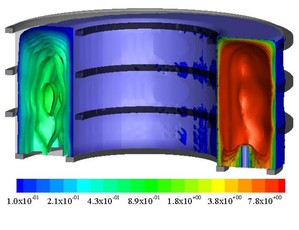
The simulation results are in good agreement with the experimental results !

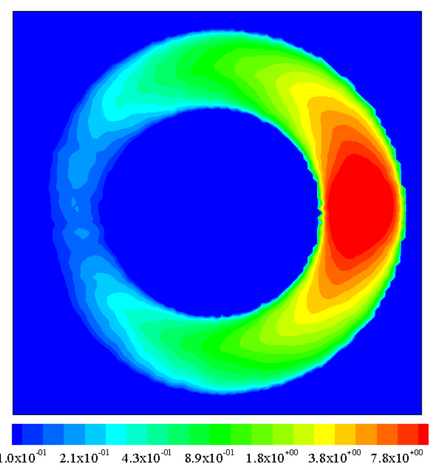












The circumferential distribution of plasma is very inhomogeneous !