

Electron dynamics in magnetron sputtering discharges

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Outline

- Particle-In-Cell/Monte Carlo Collision (PIC/MCC)
- Radio Frequency Magnetron Sputtering (RFMS)
- Direct Current Magnetron Sputtering (DCMS)
- Pulsed DCMS
- High Power Impulse Magnetron Sputtering (HiPIMS)

PIC/MCC simulation

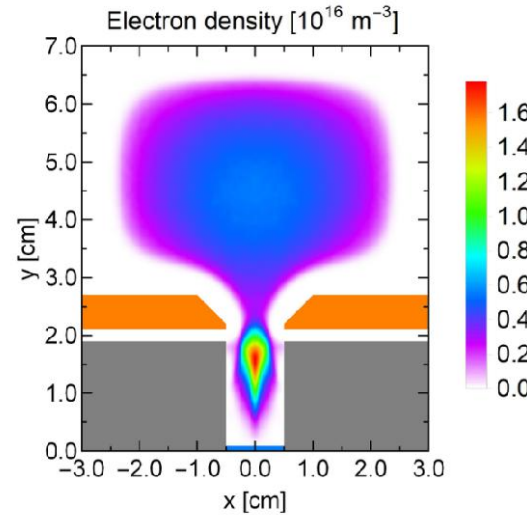
Advantages

- Self-consistent
- Complete

ASTRA

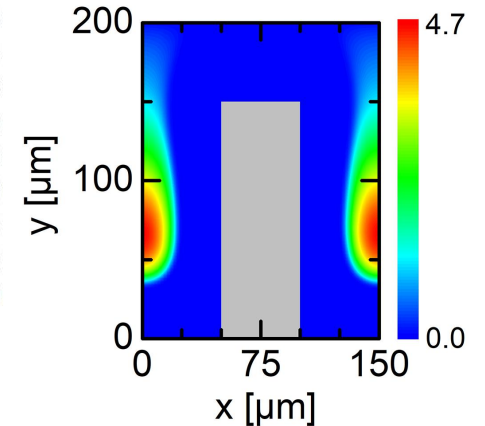
- Efficient PIC software
- Applications in
 - Ion sources
 - Microplasmas
 - RF plasmas
 - Magnetized plasmas
 - etc.

Ion sources

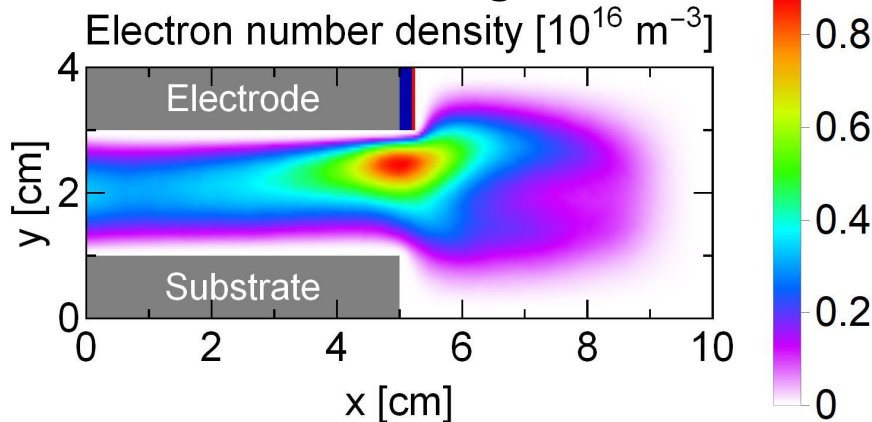


microhollow cathode discharges

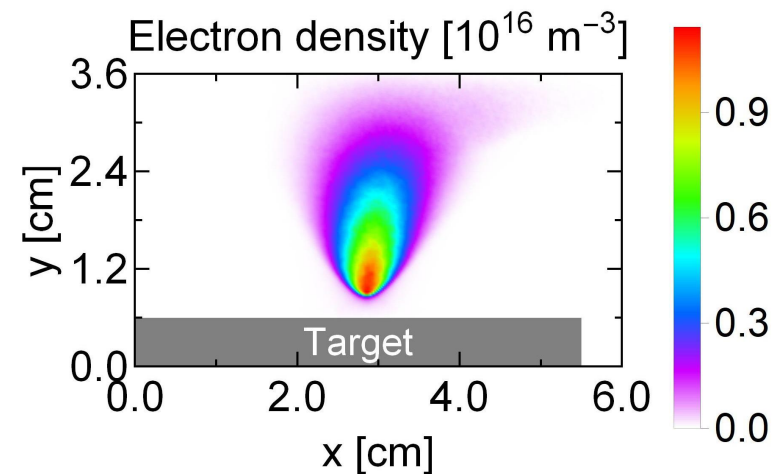
Electron density [$\times 10^{20} \text{ m}^{-3}$]



CCP discharges

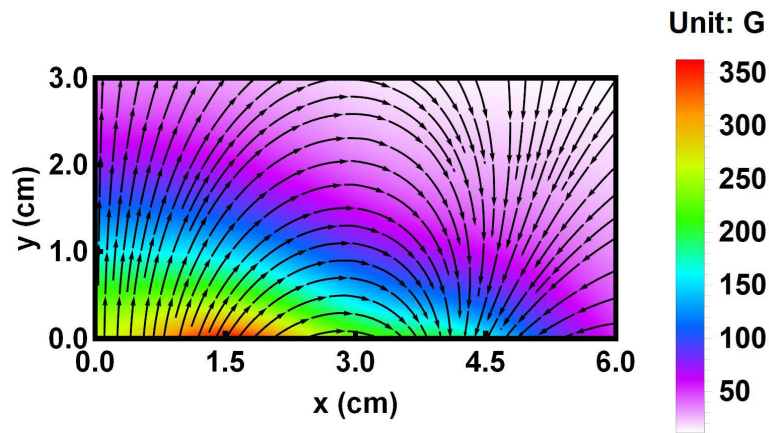
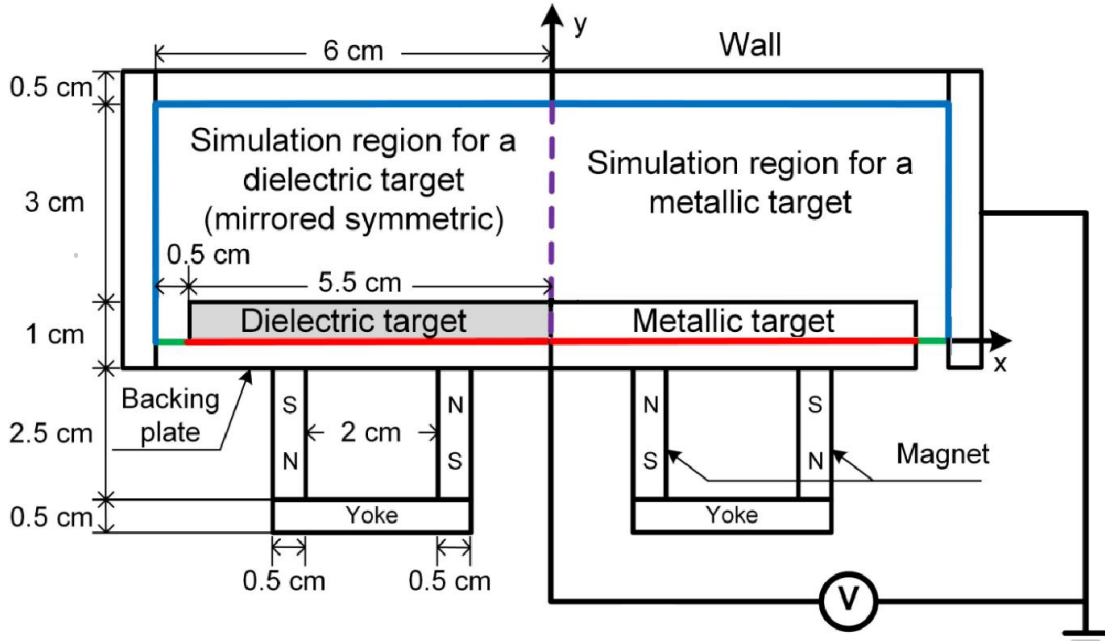


Magnetron discharges



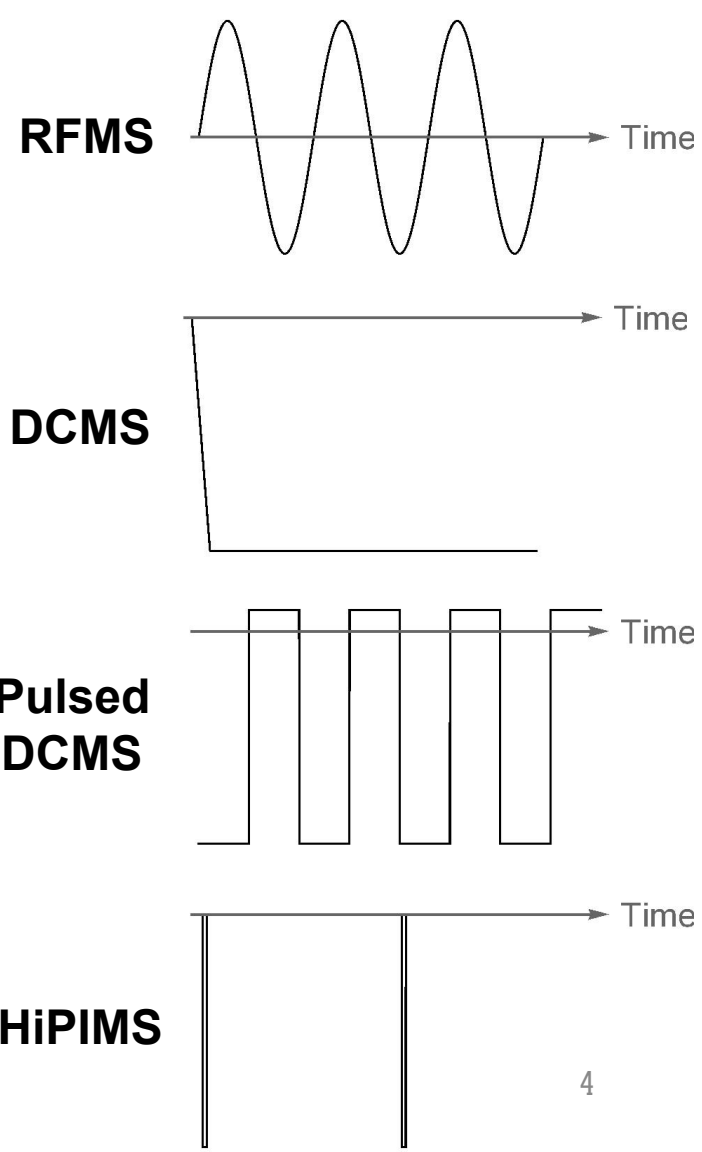
Magnetron sputtering discharges

Schematic of a magnetron sputtering set-up

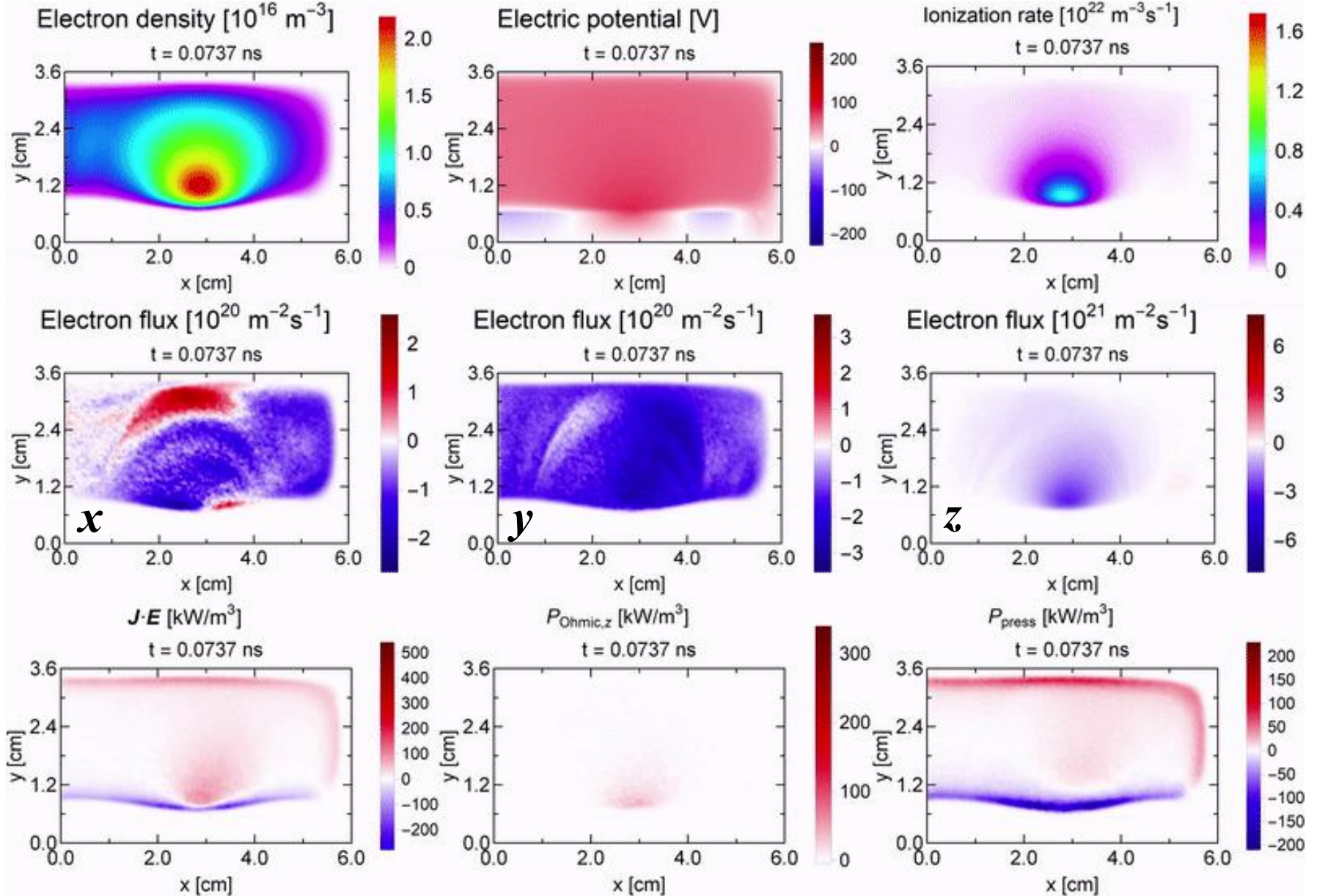


Magnetic field

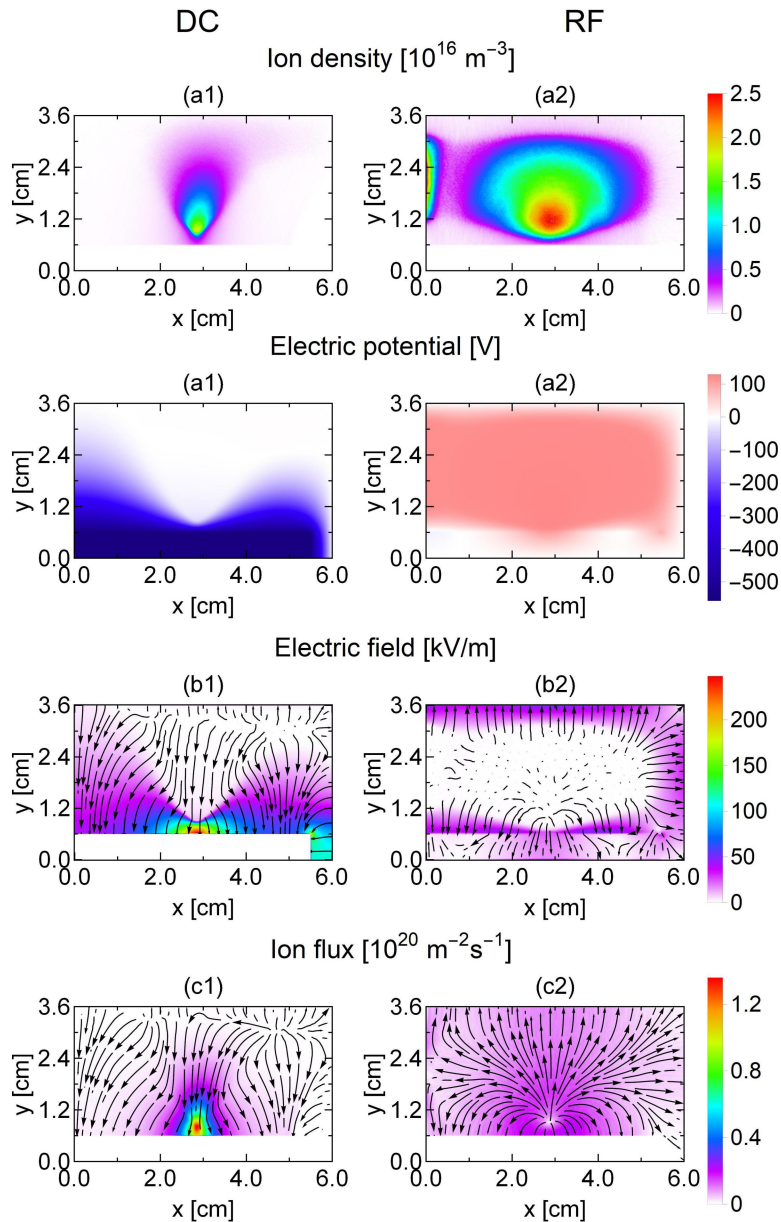
Voltage waveforms



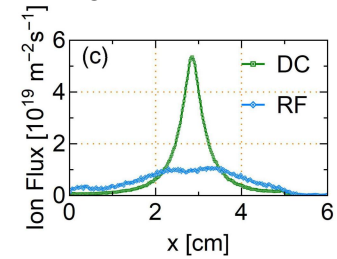
Electron dynamics in RFMS discharges



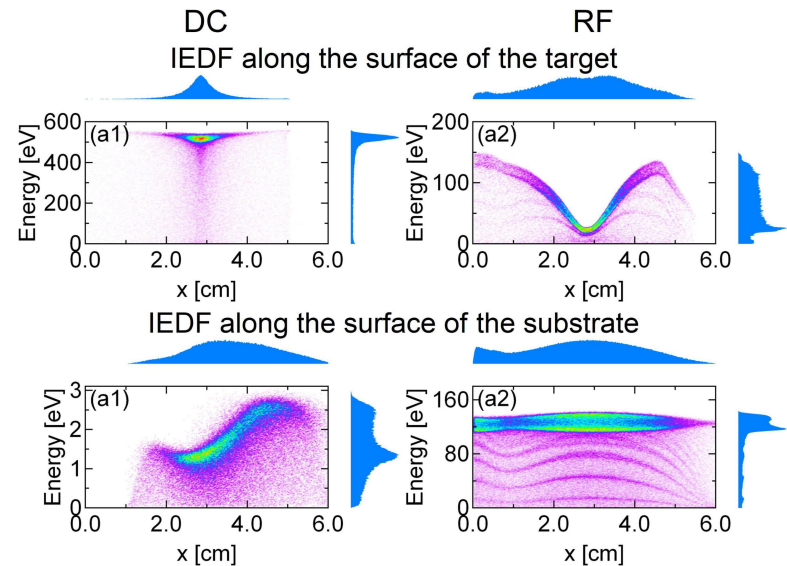
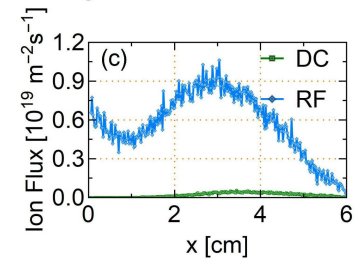
RFMS vs DCMS



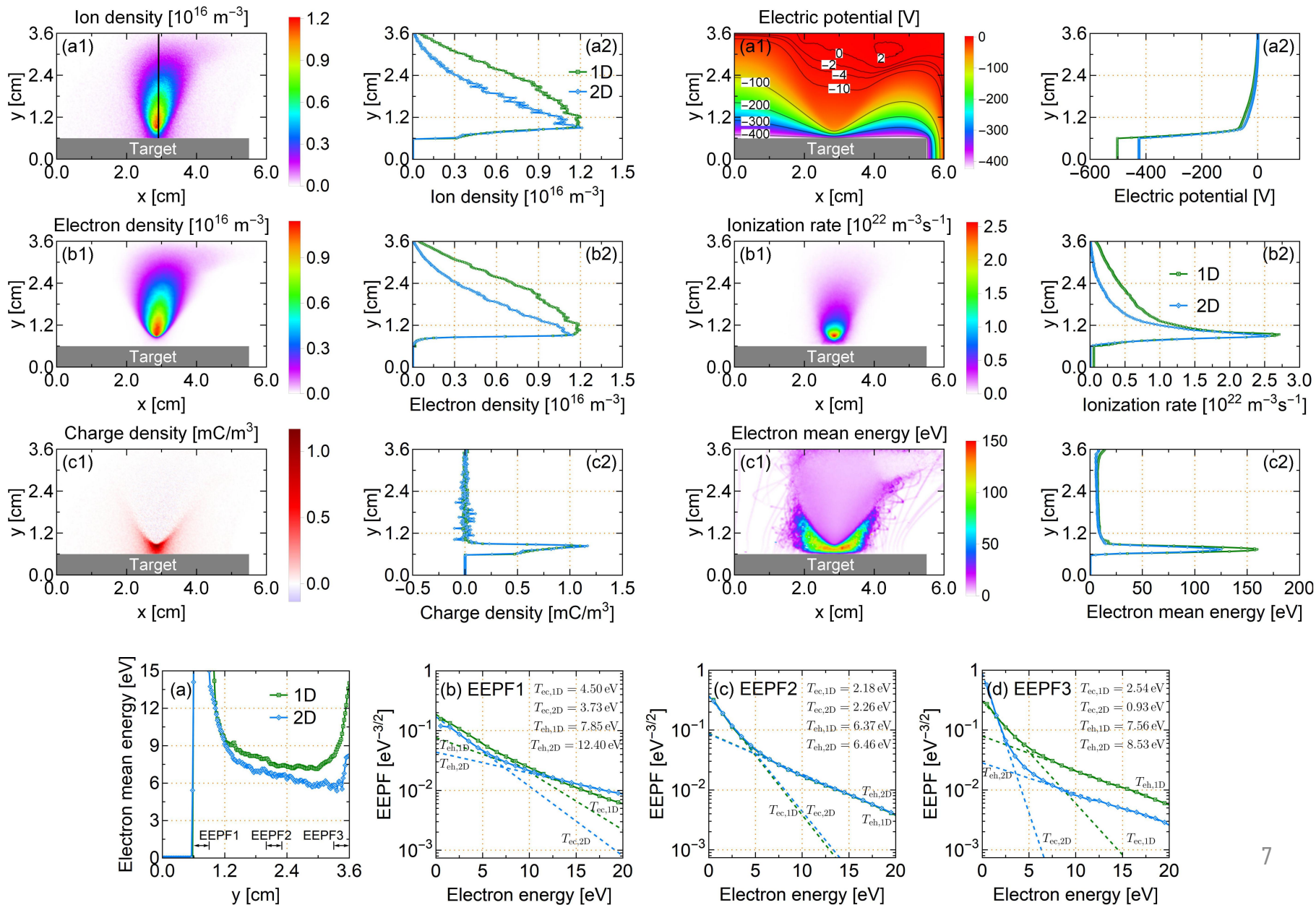
Ion flux along the surface of the target



Ion flux along the surface of the substrate

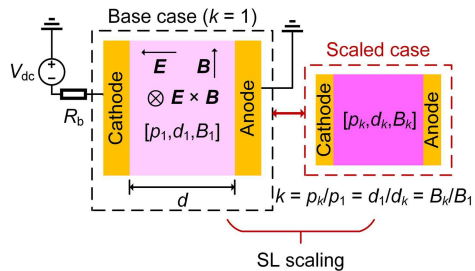


Simulation: 1D vs 2D

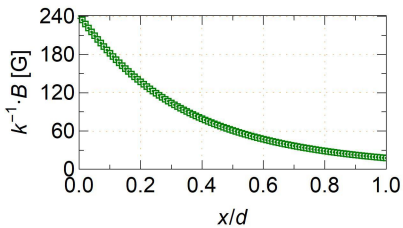


DCMS: breathing oscillations and electron energization

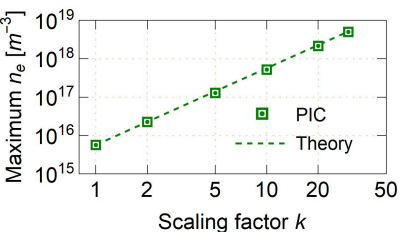
(a) Similarity law (SL) scaling



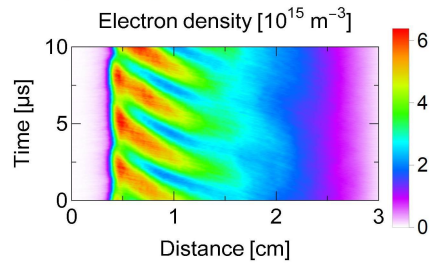
(b) Magnetic field distribution



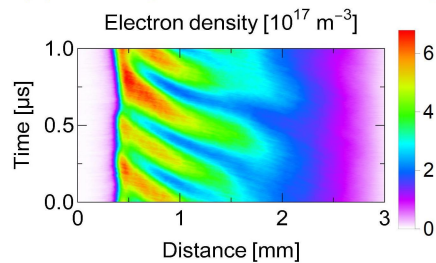
(c) SL scaling for electron density



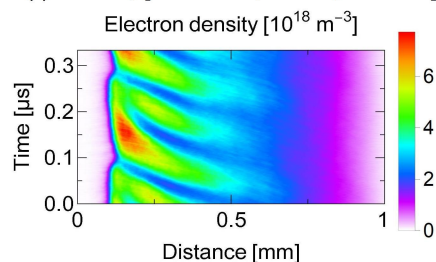
(d) $k = 1$, [3 mTorr, 3 cm, 240 G]



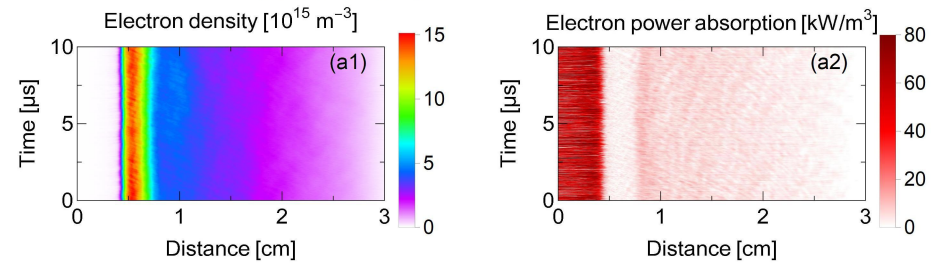
(e) $k = 10$, [30 mTorr, 3 mm, 2400 G]



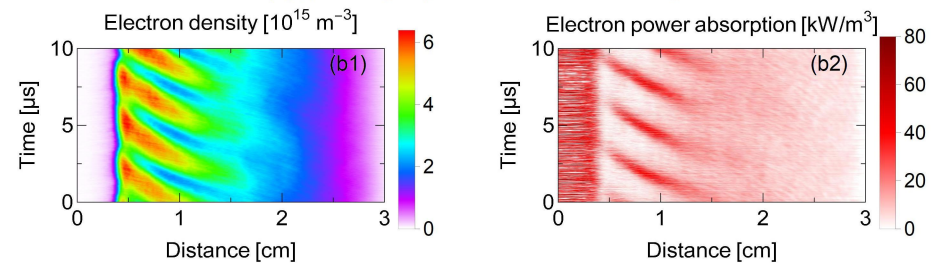
(f) $k = 30$, [90 mTorr, 1 mm, 7200 G]



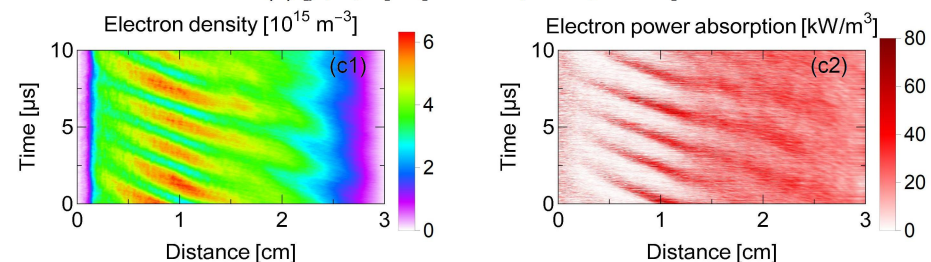
(a) [ρ, d, B] = [10 mTorr, 3 cm, 240 G]



(b) [ρ, d, B] = [3 mTorr, 3 cm, 240 G]

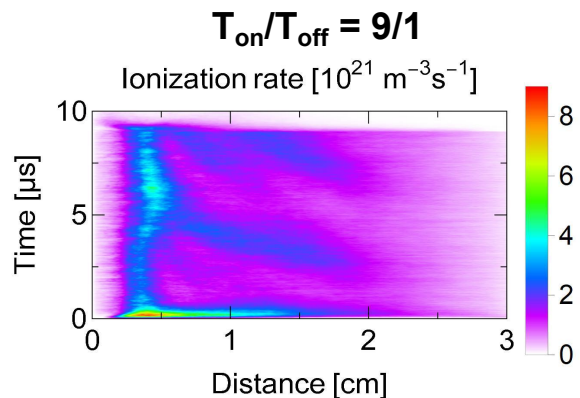
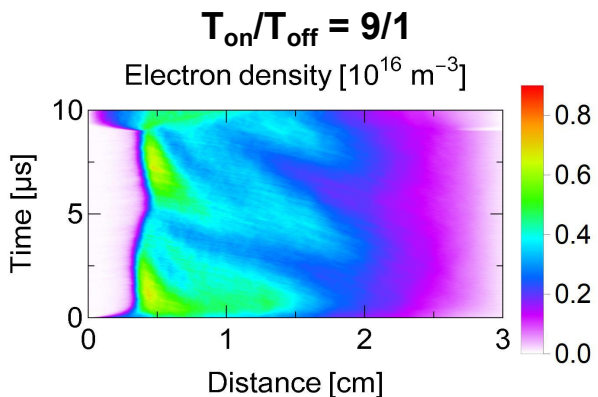
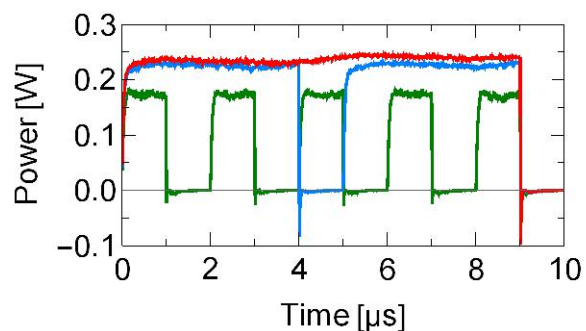
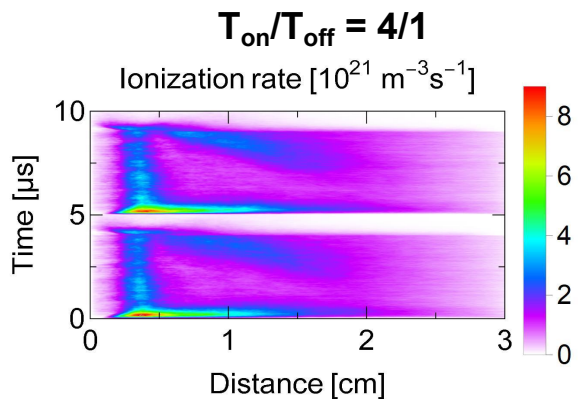
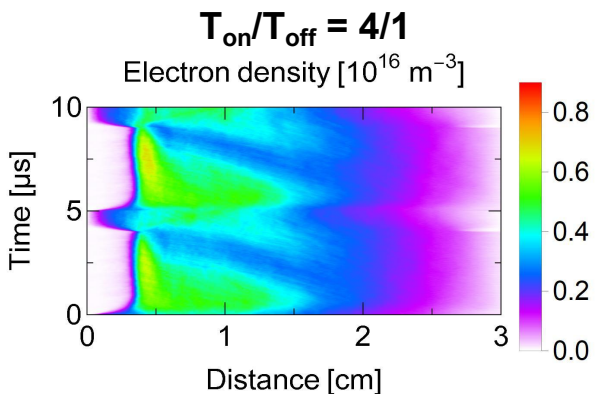
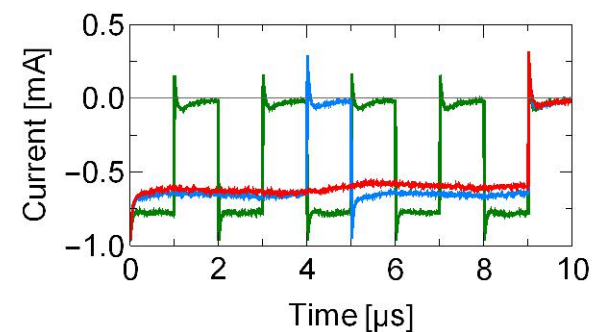
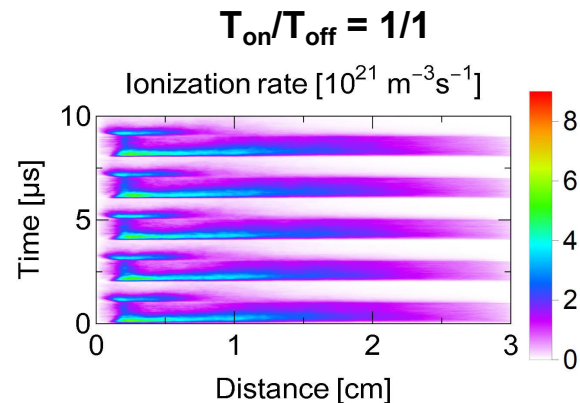
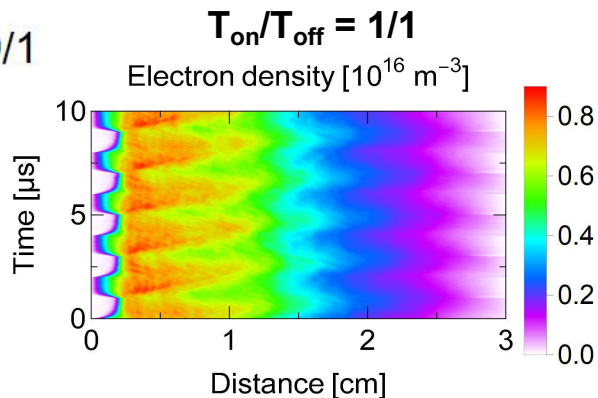
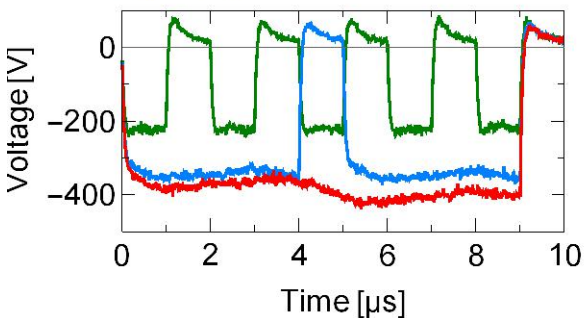


(c) [ρ, d, B] = [3 mTorr, 3 cm, 480 G]



Pulsed DCMS

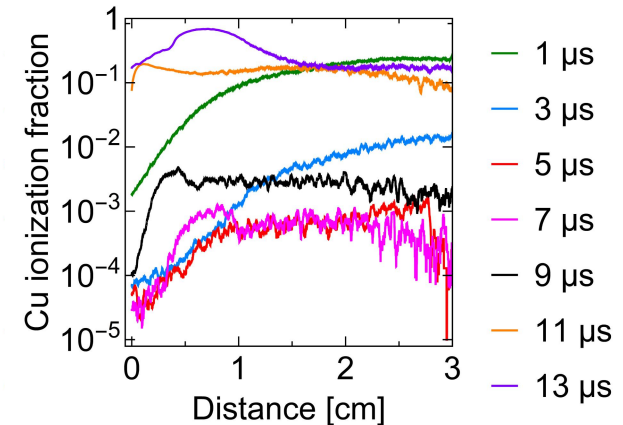
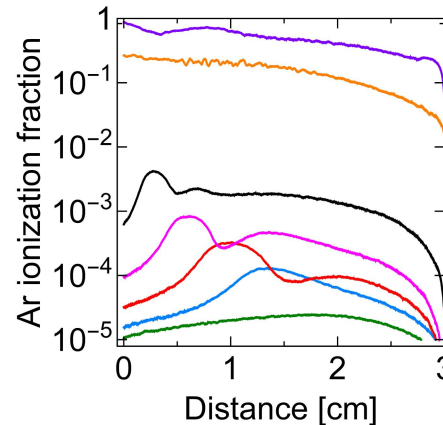
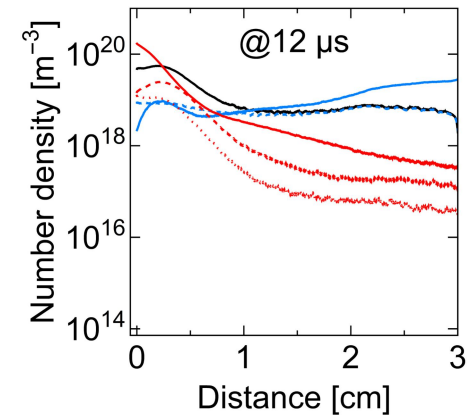
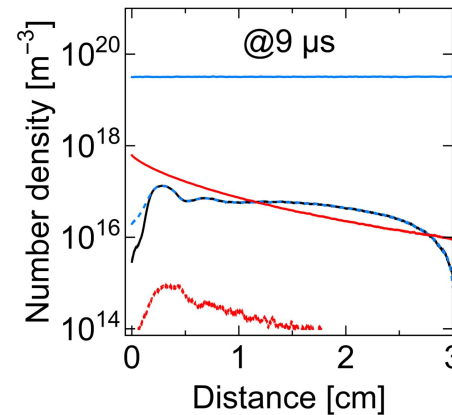
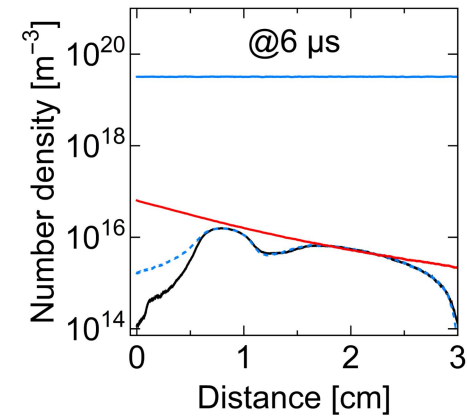
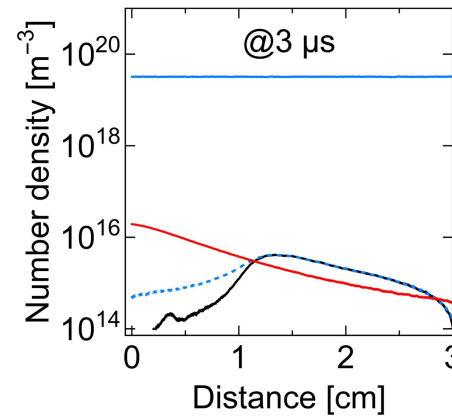
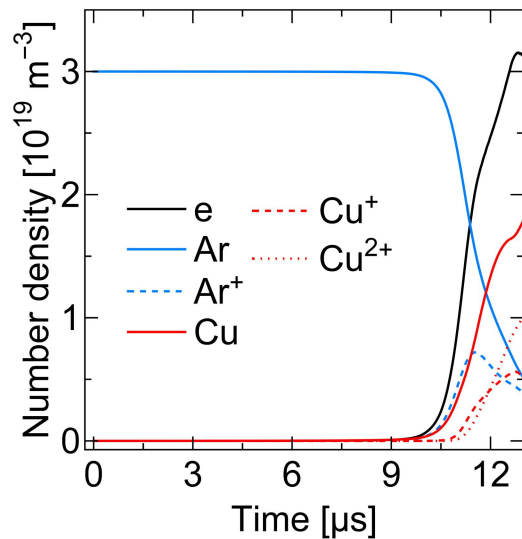
— $T_{\text{on}}/T_{\text{off}}=1/1$ — $4/1$ — $9/1$



HiPIMS

■ Additional physical processes

- Coulomb collisions
- Sputtering wind
- Metal ions
- SEE induced by metal ions



Thank you

- The slides can be downloaded at bczheng.com/talks/zheng21_icmap.pdf
- Email: bzheng@fraunhofer.org
- Website: bczheng.com