DiPS (Diversified Plasma Simulator): Philosophy, Diagnostics and Plans

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Abstract

DiPS(Diversified Plasma Simulator), a new versatile linear machine (length=4000mm, diameter=200-600mm), is developed for the simulation of divertor, space and processing plasmas with various electric probes: fast-scanning single probe, triple probe, Mach probe, slow-scanning water-cooled single probe, gridde-energy analyser, GET(Gundestrup-Emissive-Triple) probe, and several fixed single probes. For the verification of current probe theories and develop new theories with magnetic field, collisionality, various particle sources, and wide range of plasma parameters, two different plasma sources are installed: (1) For a stable high density dc plasma, LaB6 disk is used as thermal electron emission source with 5 kW graphite heater. Initial plasma density of the LaB6 source is 5 x 10^12 cm-3, electron temperature is 8-10eV with magnetic field around 1 kG. Density would be decreased severely with grid and expanded into space simulation region without magnetic field. (2) Helicon plasma source is also installed for the space propulsion study with magnetic expansion and for a processing simulation **in DiPS and , which generates the plasma with density of 2 x 10^13 cm-3 and electron temperature 3.5eV for the rf power of 2.5kW at optimum pressure of 7.5mTorr. As a unique feature for the diversified uses of sources and divertor simulator experiments, space and processing simulation chambers can be detached from and attached to the divertor simulation chamber by rail. Along with initial data of various electric probes, the laser-induced fluorescence and optical emission spectroscopic methods have been introduced for the calibration of flow velocity and ion temperature measurements.**

Objective

● **Development/Confirmation of Various Electric Probes Theories with**

- Drift flow
- Magnetic field (magnitude, angle)
- Collisions of charged particles and neutrals, and
- New probes for T_i, $D_\perp$, $\eta_\perp$, σ_i , etc.

● **Various Applications (Fiesta)**

- FT: Divertor plasma analysis and diagnostics (collisionality, high flux).
- IT: Atmospheric DBD plasma (AC, high collisionality).
- ET: Corona/Torch (Hazardous gas detection).
- ST: space propulsion system (Flow/Detachment measurement at magnetic nozzle). Applications

Experimental Set-up (1)

■ General Operating Parameters for DiPS

● LaB6 Source

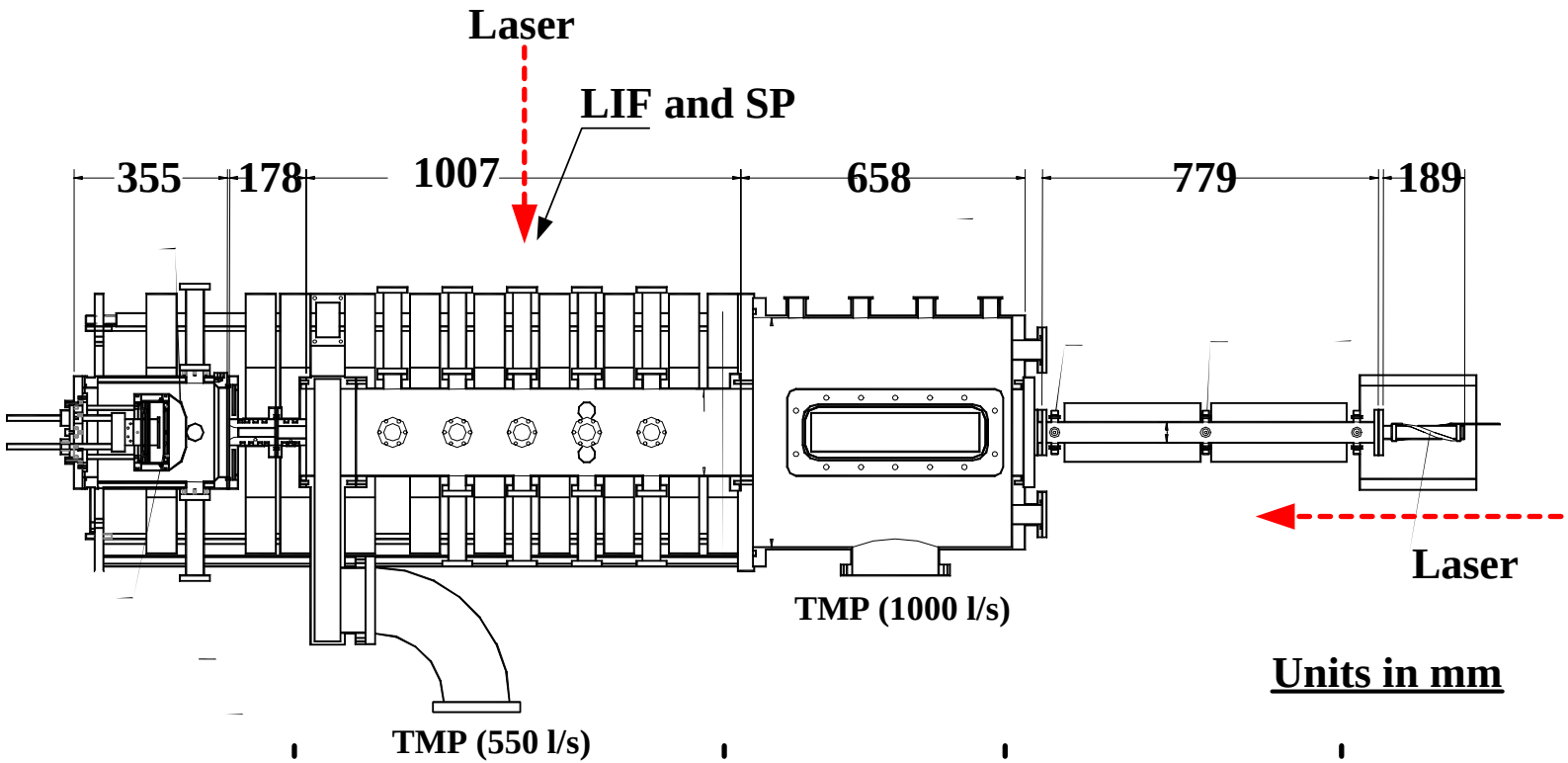
- Magnetic Field Strength: 1 ~ 2 kG
- Heating Power : ~250 A, ~16 V (4 kW ~ 6.6 kW)
- Discharge Power: up to 50A & ~45V for Ar Gas
- Operating Pressure: 10 mTorr – 250 mTorr (Source)

  1 mTorr -10 mTorr (Divertor Simulation Region)

● Helicon Source

- Magnetic Field Strength: 400-600 G (source) 1-2 kG (magnetic nozzle)
- RF Power : up to 3 kW (13.56 MHz)

Experimental Set-up (2)

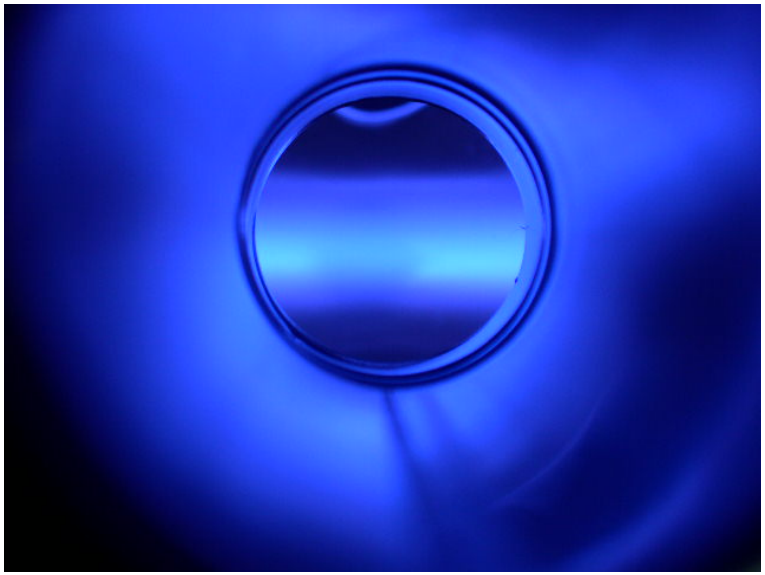


Experimental Set-up (3) - OLD

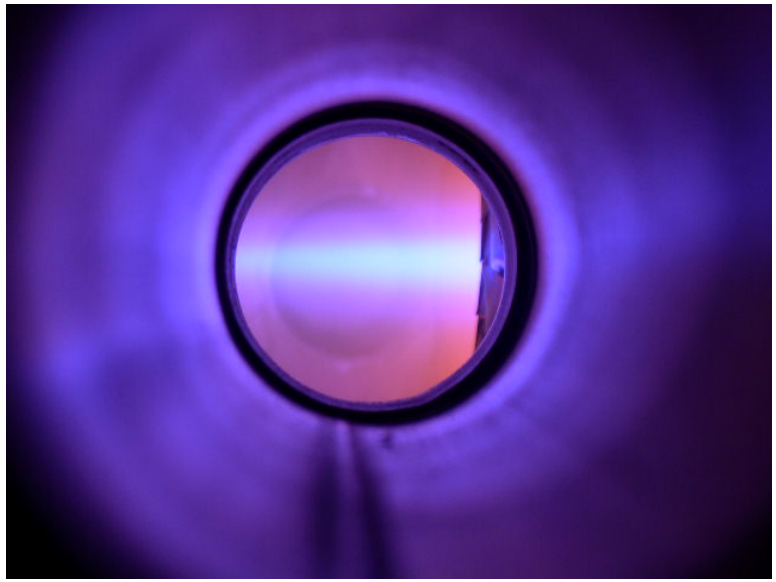
Experimental Set-up (4) - NEW

LaB6 Plasma Source (1)

LaB6 Source with Ar gas



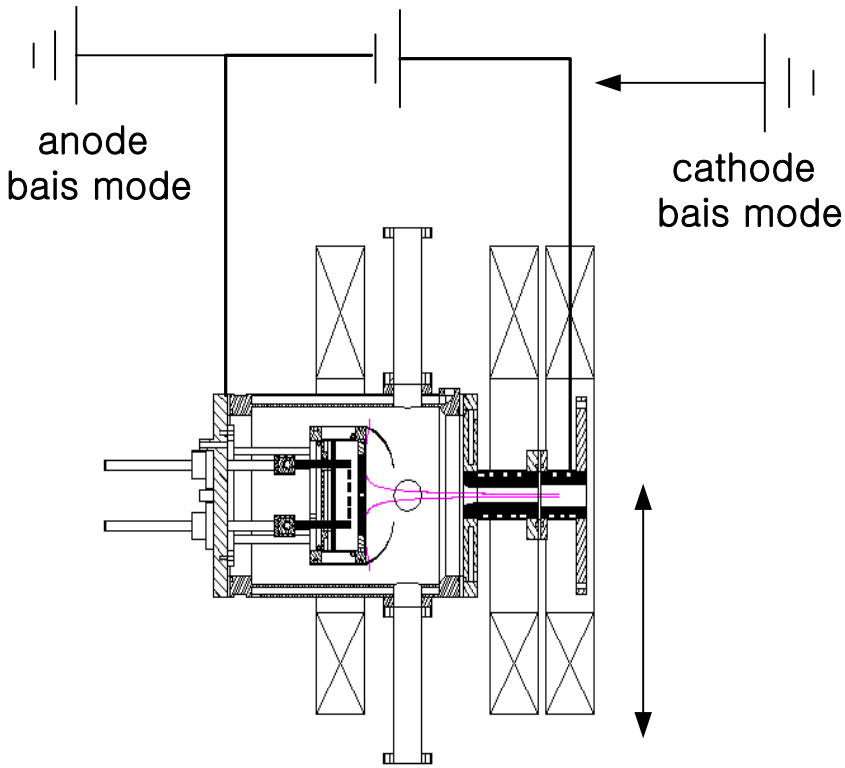
Divertor Simulation Region



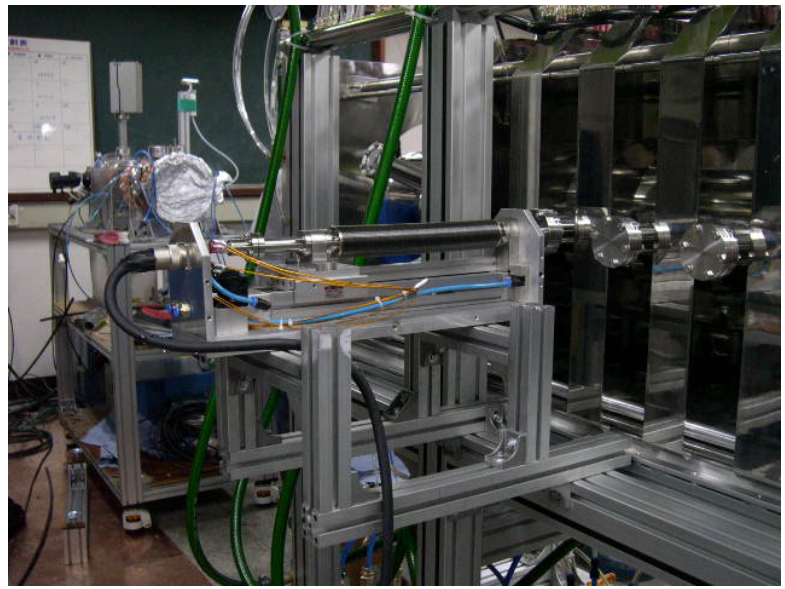
LaB6 Source region

LaB6 Plasma Source (2)

Operation Modes

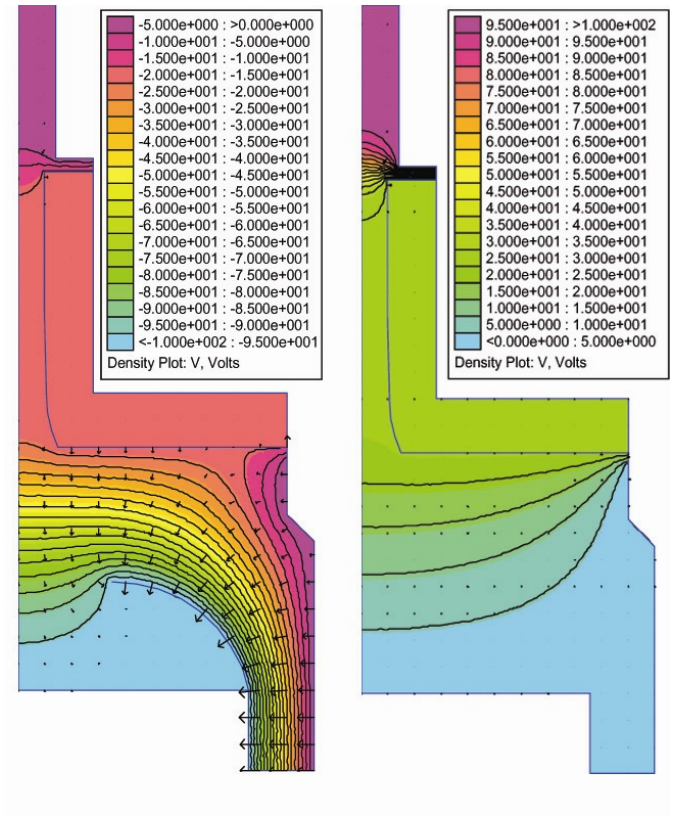


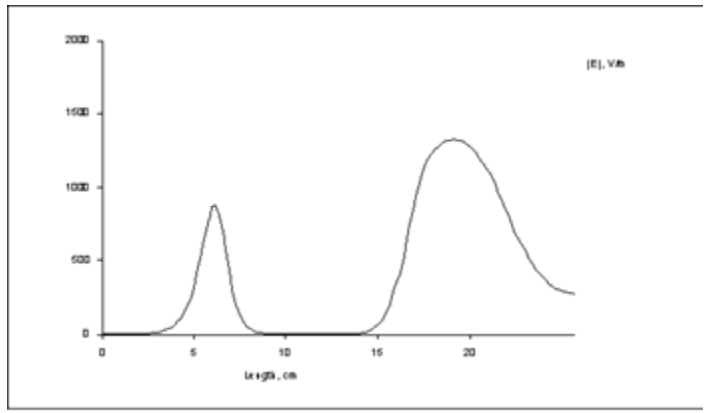
Fast Scanning Probe



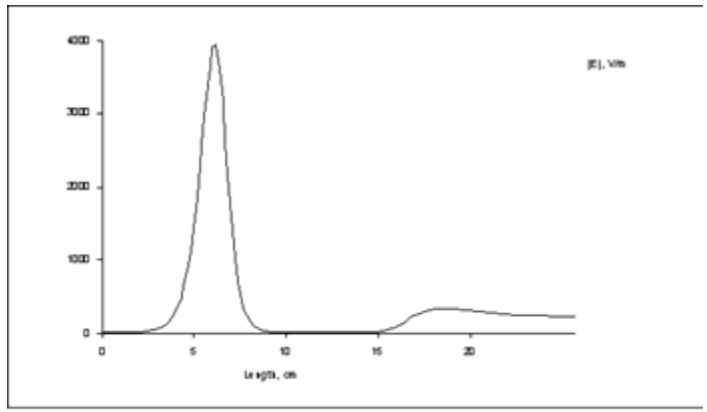
LaB6 Plasma Source (3)

Potential





cathode(−100V)

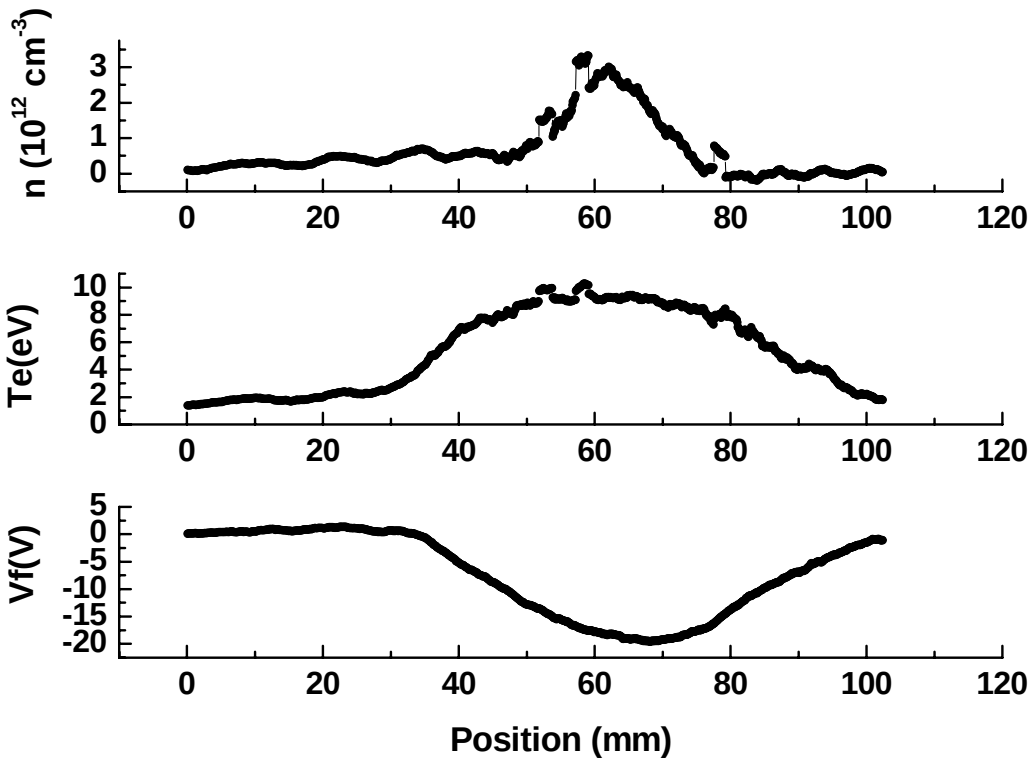


anode(100V)

(a) anode ground (cathode −100V) (b) cathode ground (anode +100V) Potential distribution

LaB6 Plasma Source (4)

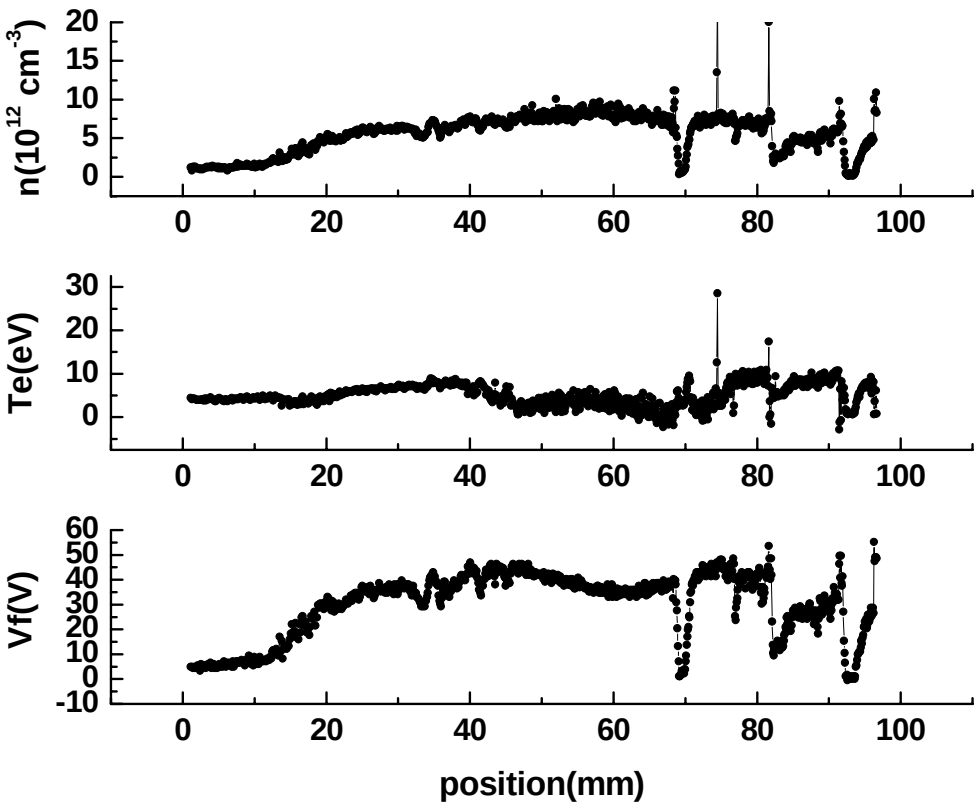
Cathode Mode Plasma Measured with Triple Probe



Cathode Biased Mode
Heating Power: 240A, 13.6V,
Discharge Power: 57V, 5A
Magnet Field: 1kG
Pressure: 3 mTorr (source)

LaB6 Plasma Source (5)

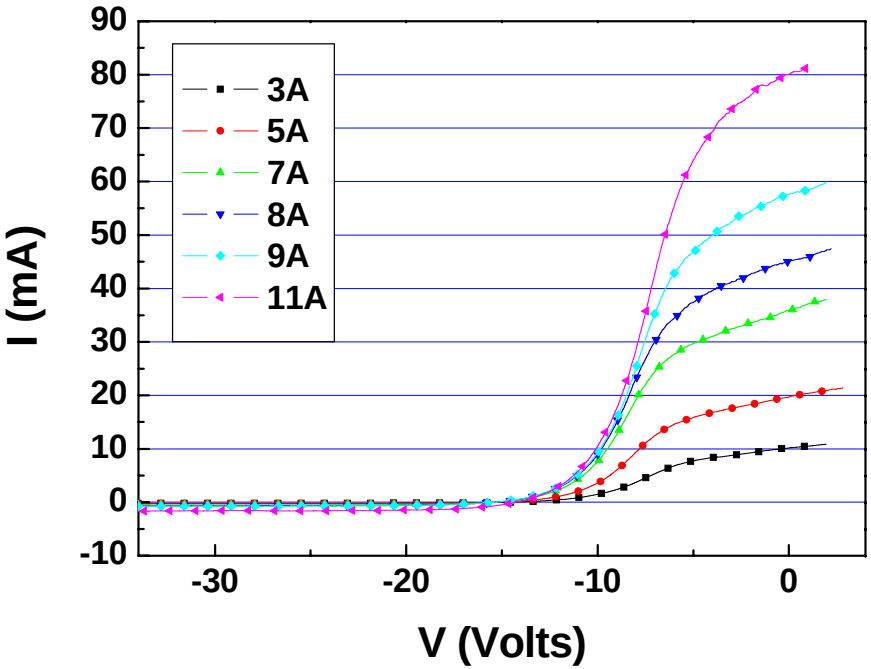
Anode Mode Plasma Measured with Triple Probe

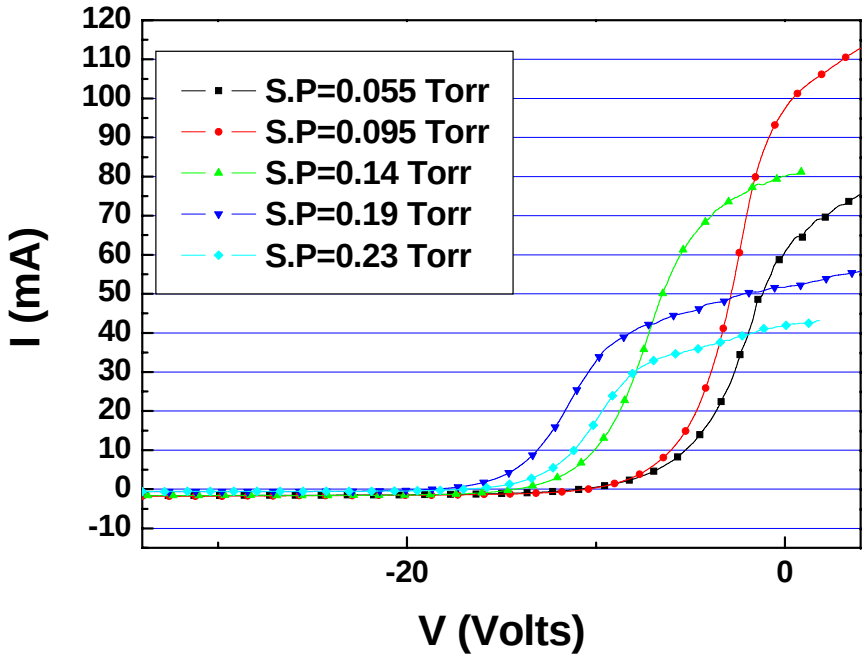


Anode Biased Mode
Heating Power: 280A, 16.4V
Discharge Power: 85.5V 10A
Magnet: 1kG
Pressure: 21 mTorr

LaB6 Plasma Source (6)

I-V Characteristics of the Single Probe at the end point of Divertor Simulation Region





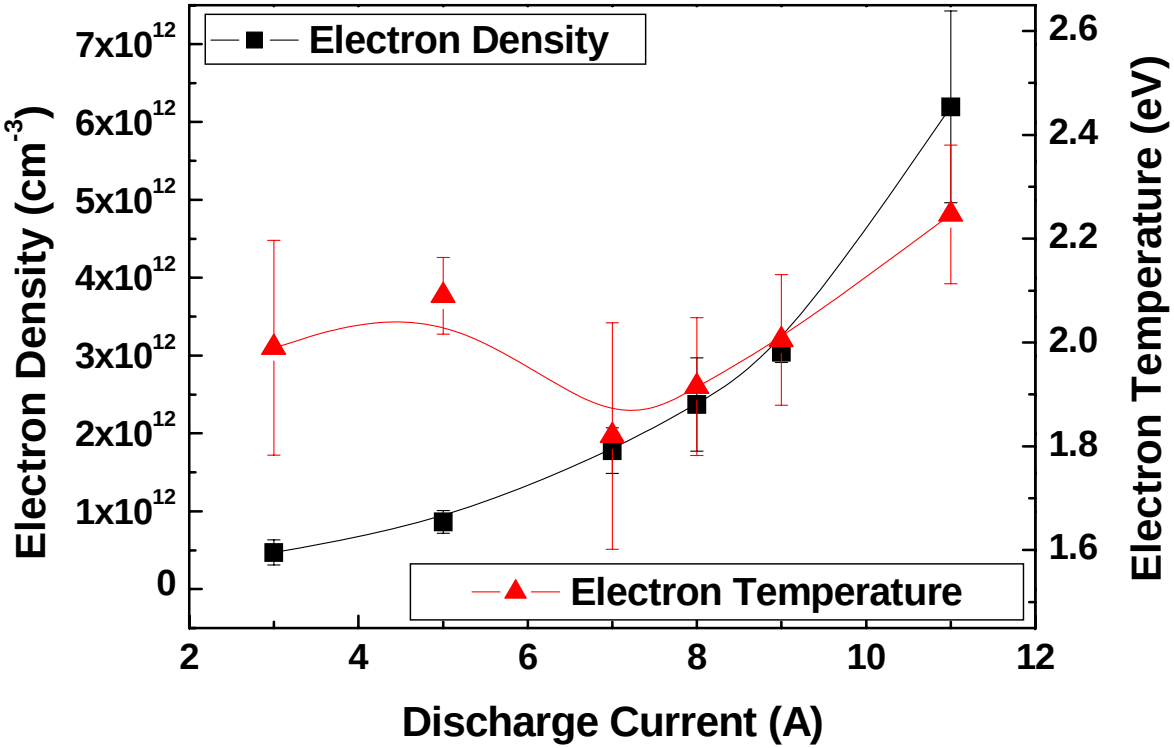
Discharge Voltage~45 V, Source Pressure=0.14 Torr, Diagnostic Region Pressure=3.5 mTorr

Discharge Current =11 A, Discharge Voltage~45 V

Dimensions of Probe Tip: 0.254 mm x 4 mm (Dia. x Length)

LaB6 Plasma Source (7)

Single Probe - different discharge current

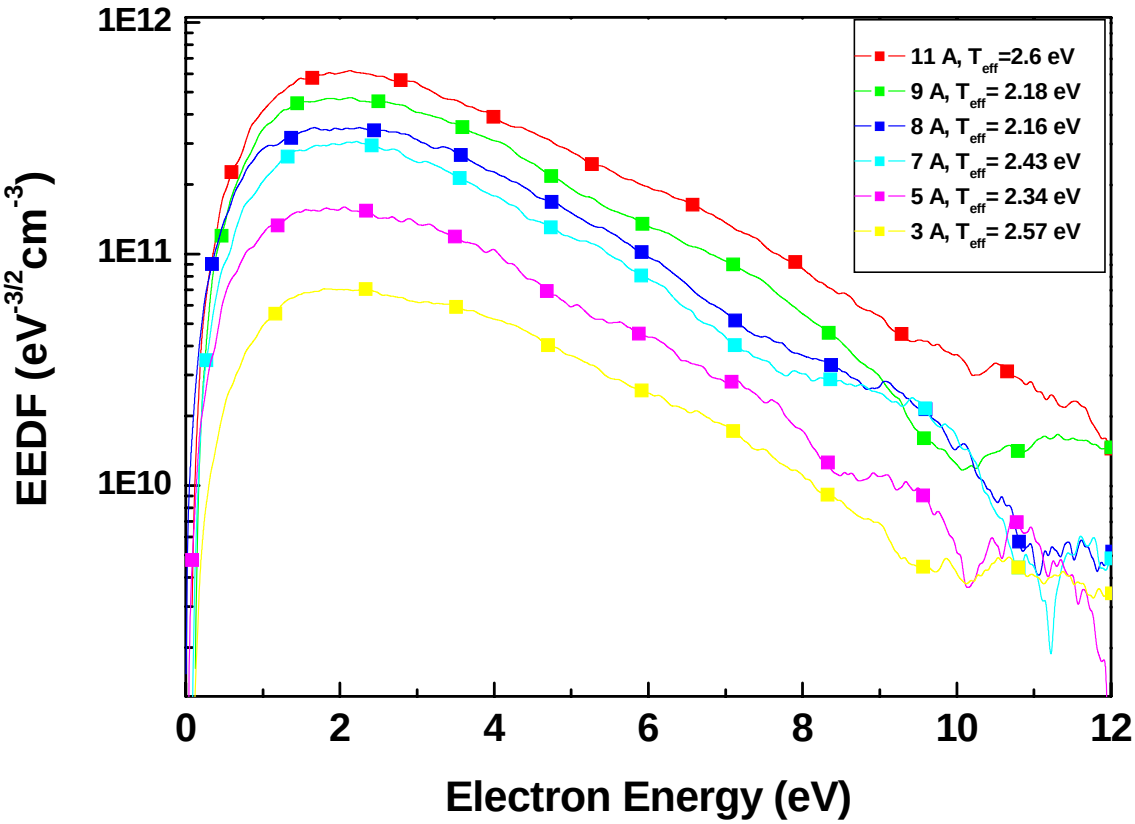


Dependence of electron density and temperature on the discharge current

Discharge Voltage~45 V, Source Pressure=140 mTorr, Diagnostic Region Pressure=3.5 mTorr

LaB6 Plasma Source (8)

Single Probe - different discharge current

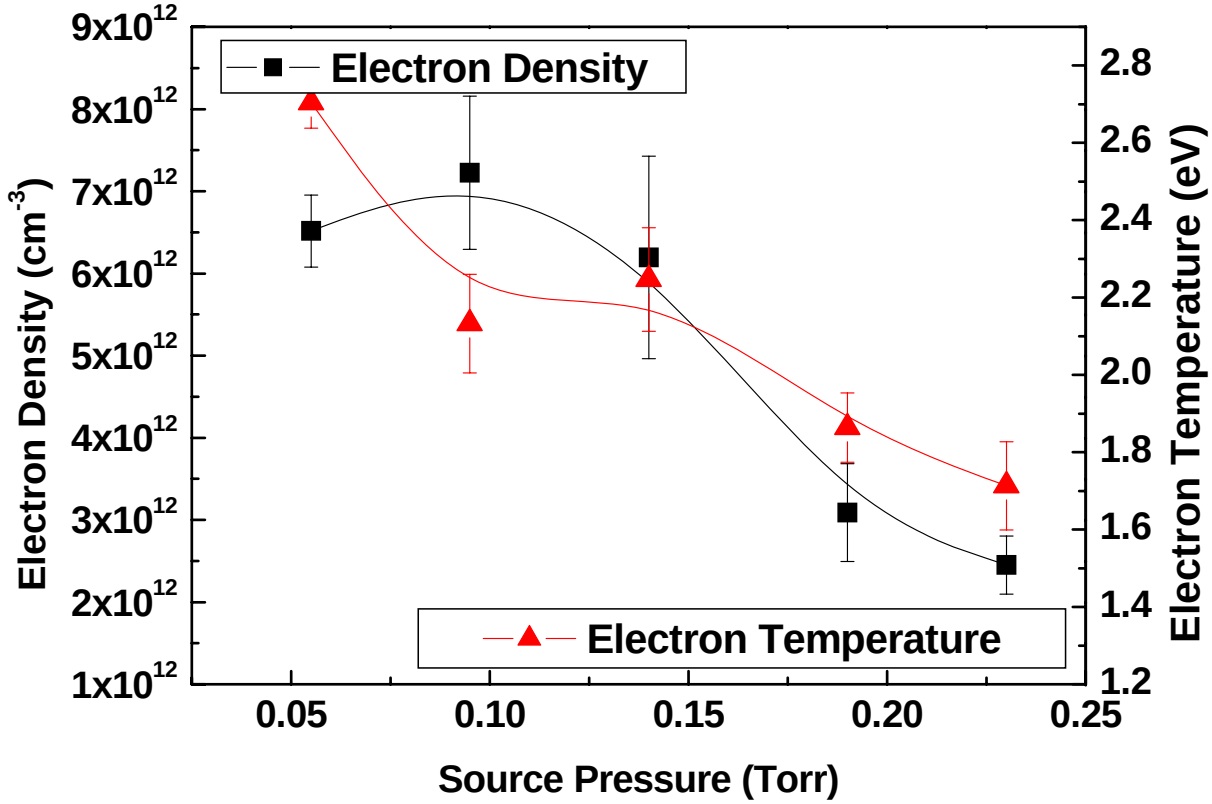


Electron Energy Distribution Function with the different discharge current

Discharge Voltage~45 V, Source Presure=0.14 Torr, Diagnostic Region Pressure=0.0035 Torr

LaB6 Plasma Source (9)

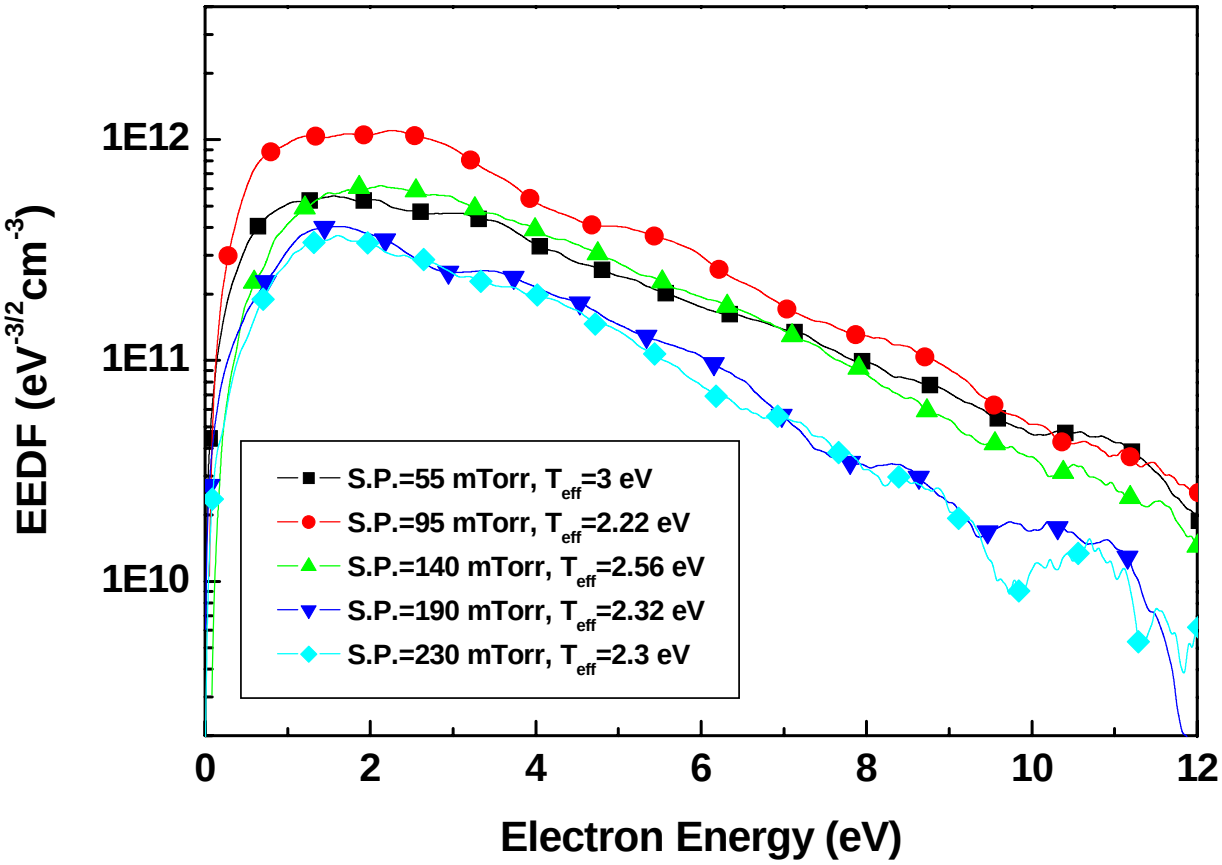
Single Probe - different operating pressure (11 A, ~45 V)



Dependence of electron density and temperature on the operating pressure

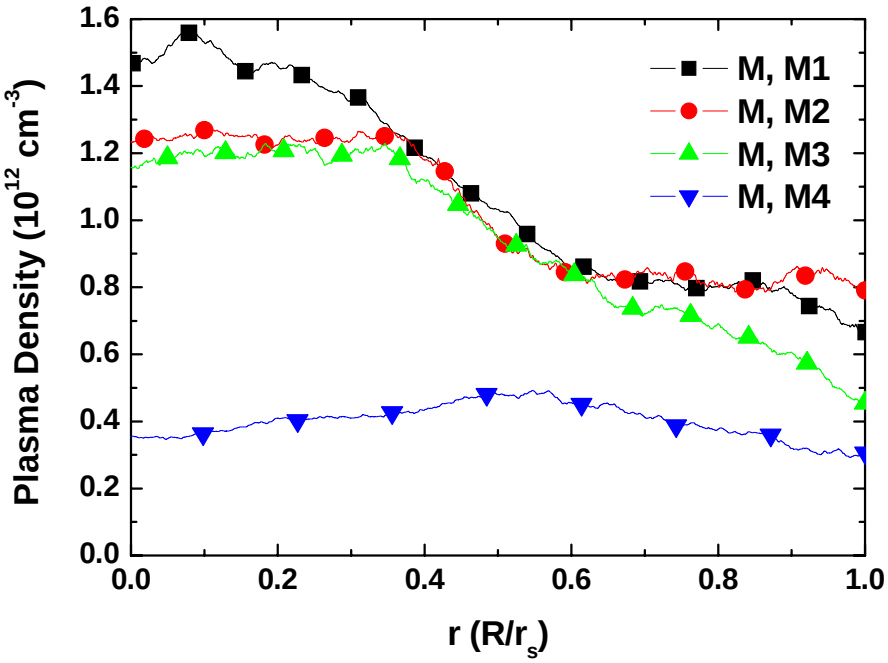
LaB6 Plasma Source (10)

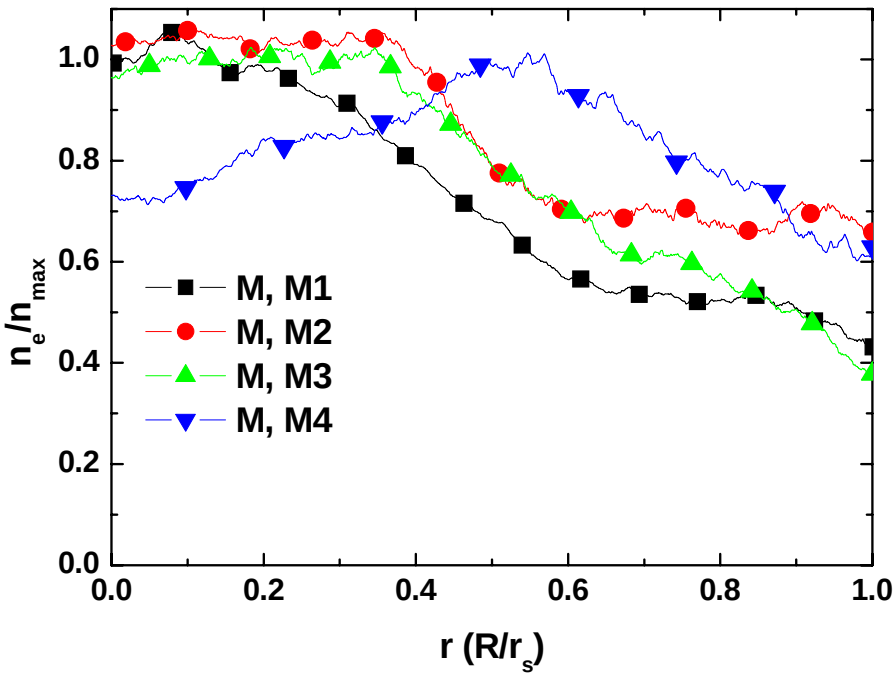
Single Probe - different operating pressure (11 A, ~45 V)



Electron Energy Distribution Function with the different discharge current

PROBE Measurement - Density Profile (MP)

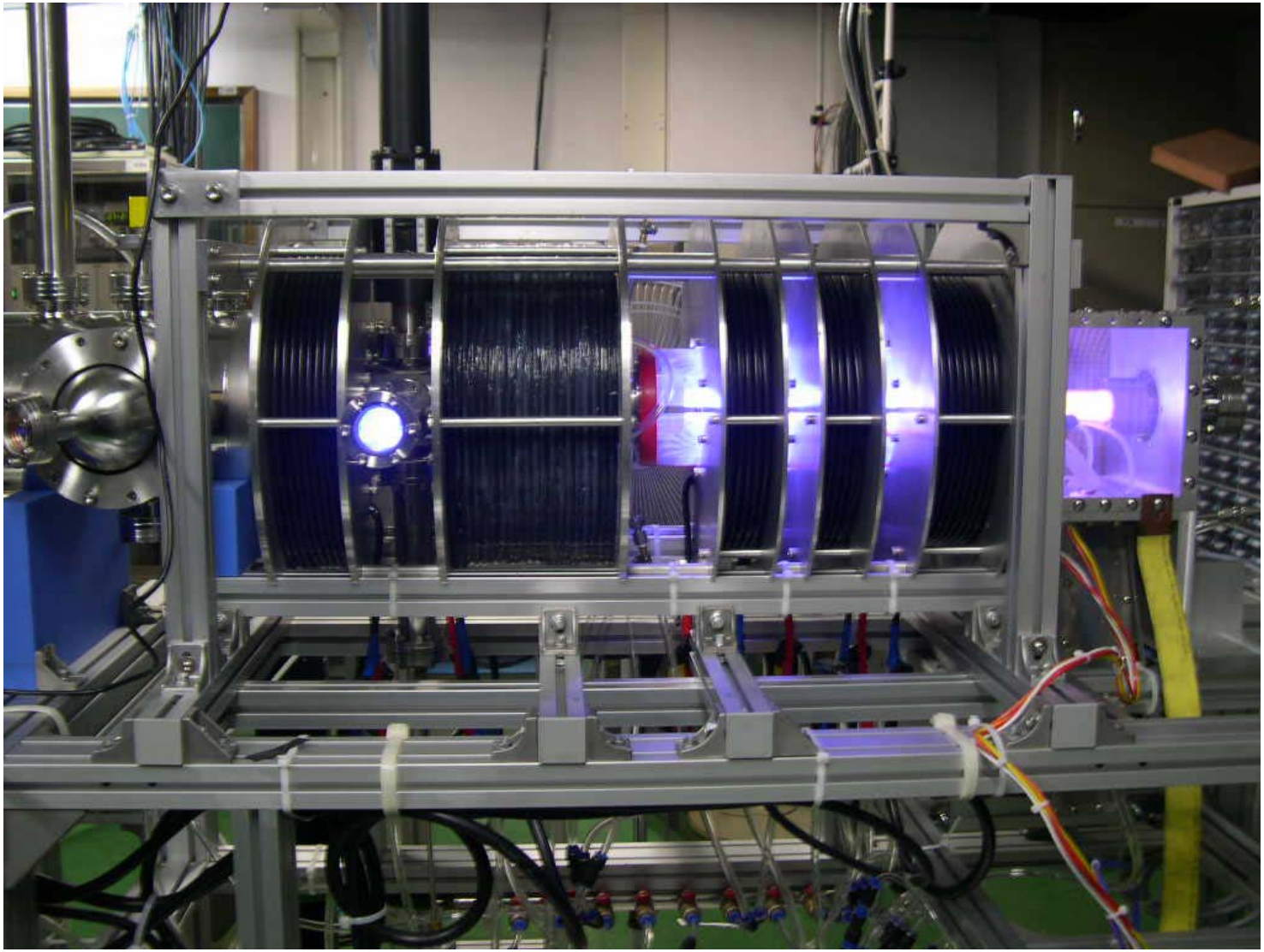




M1 = 0.8 mTorr, M2 = 4.8 mTorr, M3 = 27 mTorr, M4 = 53 mTorr,
r_e = e-folding length (~ 2- 5 centimeters ~ recombination)

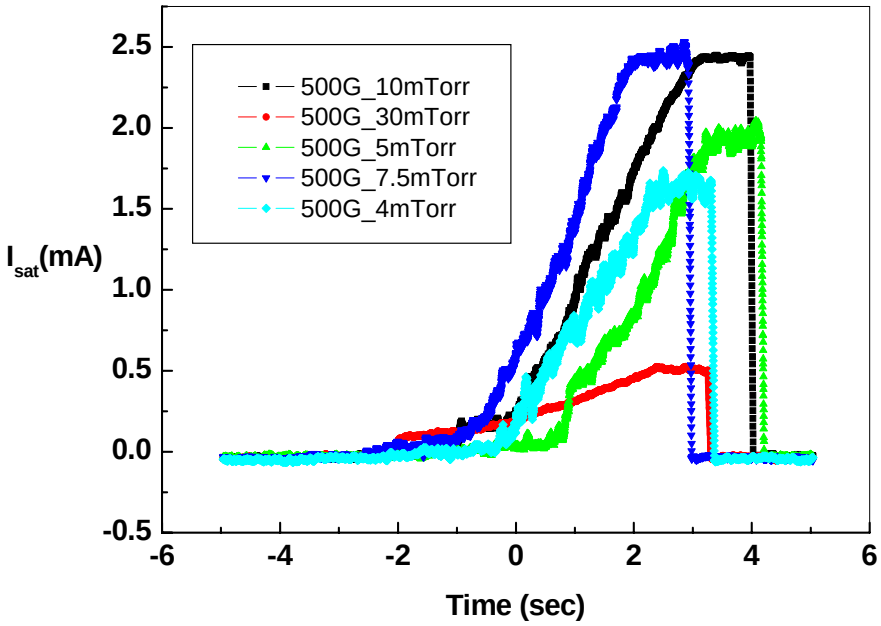
Helicon Plasma Source (1) - OLD

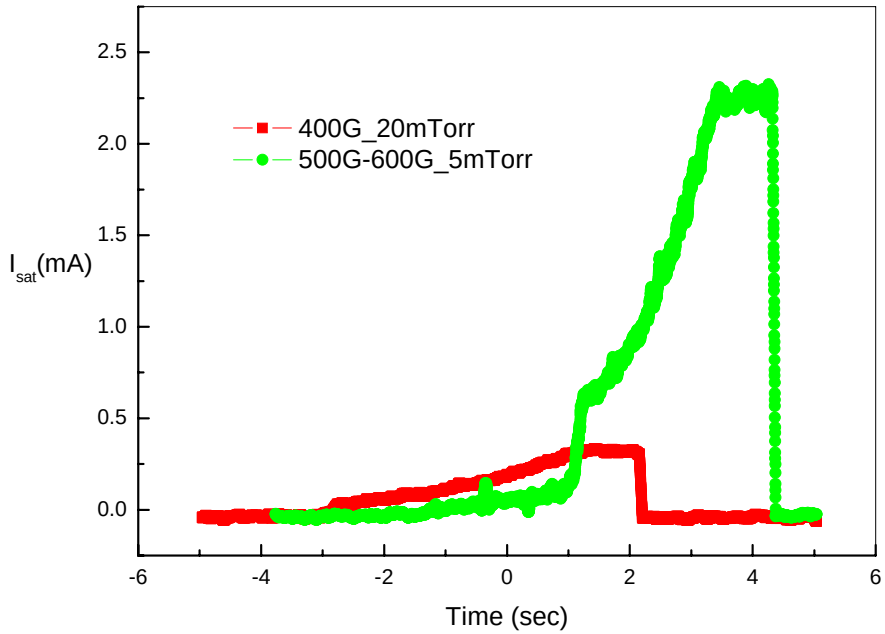
Helicon Plasma Source (2) - NEW



Helicon Plasma Source-OLD (3)

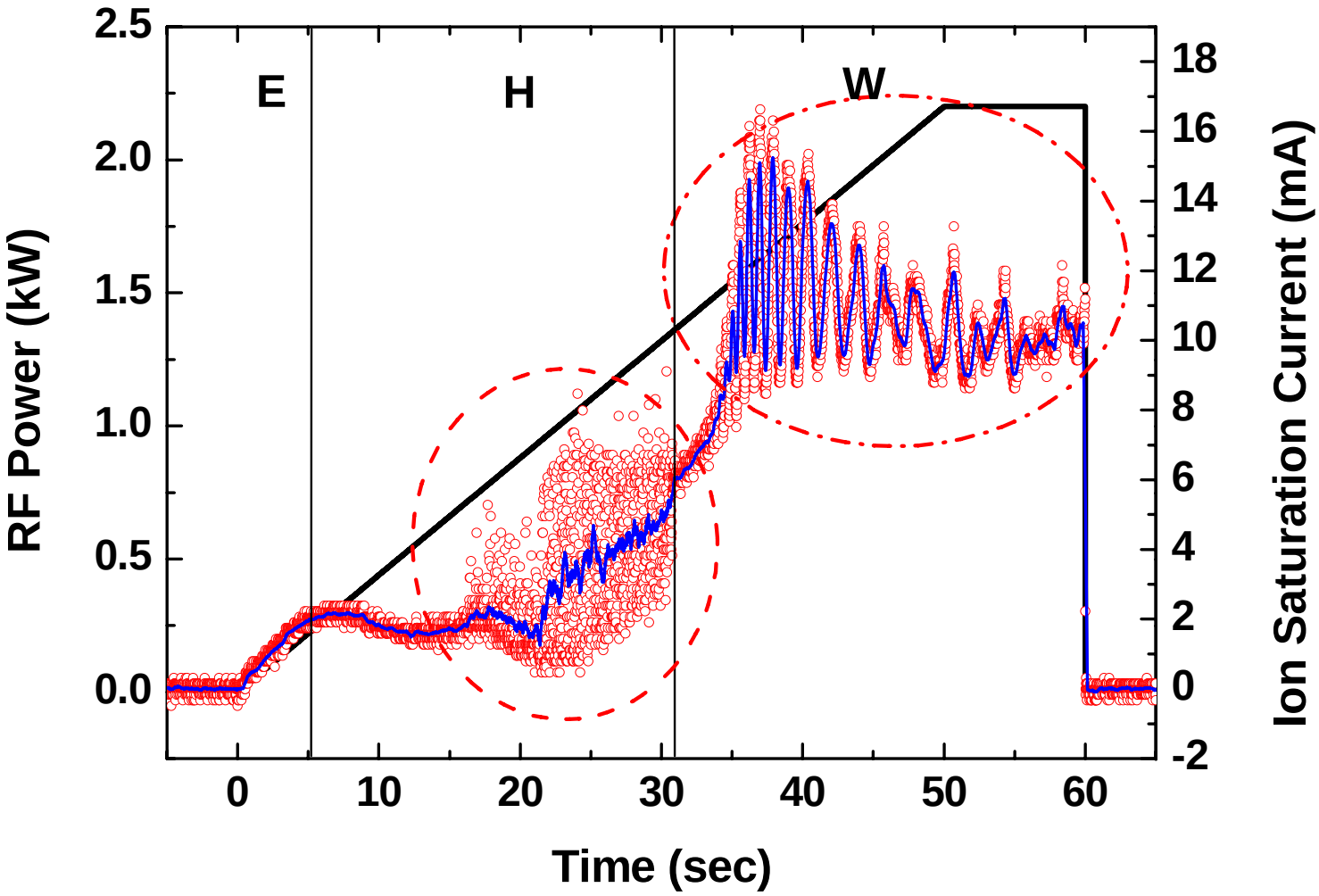
Ion Saturation Current vs. RF power





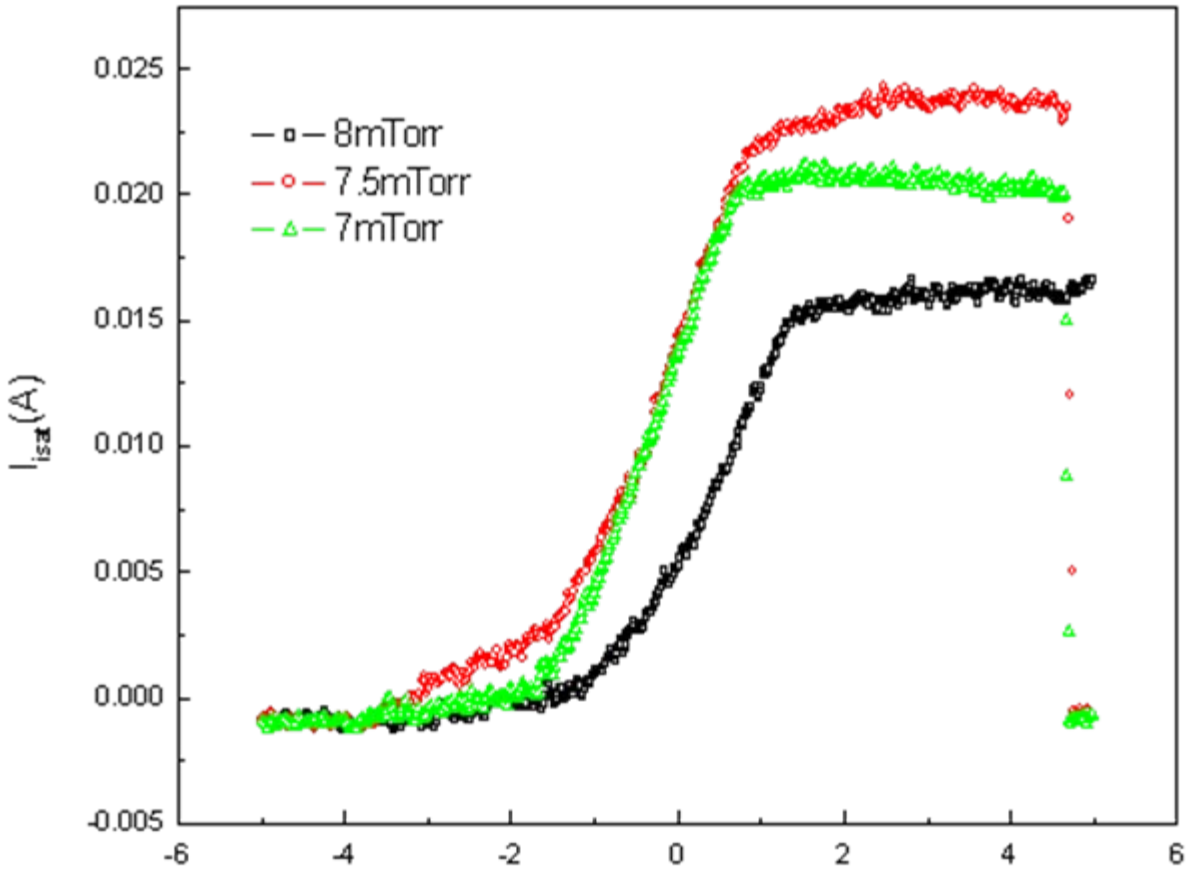
Ion saturation current (averaged) with RF power increase in various experimental conditions.

Mode Changes : Capacitive(E) – Inductive(H) – Helicon(W)



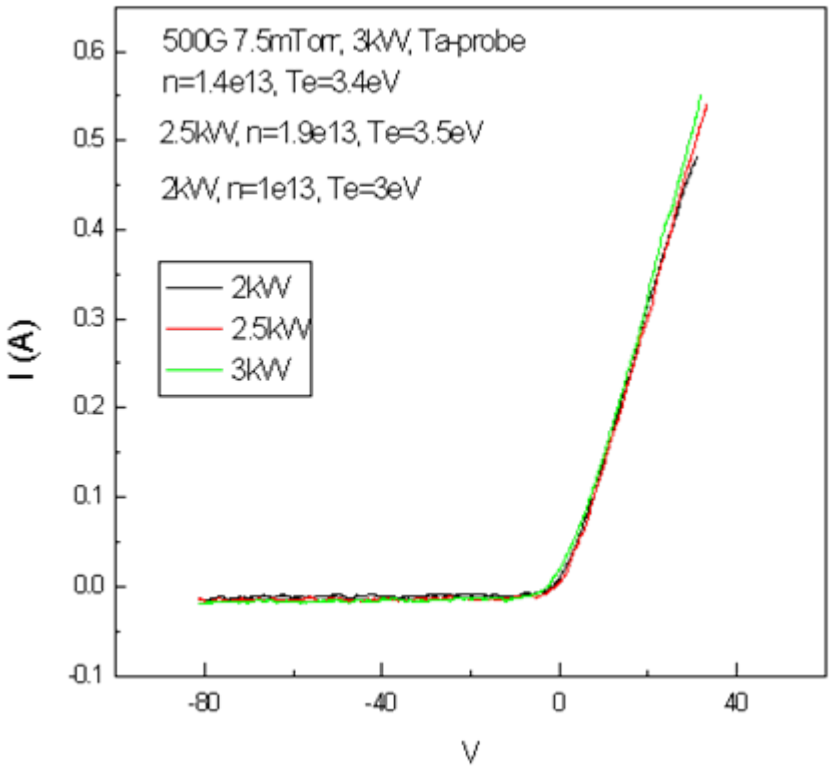
Helicon Plasma Source-OLD (4)

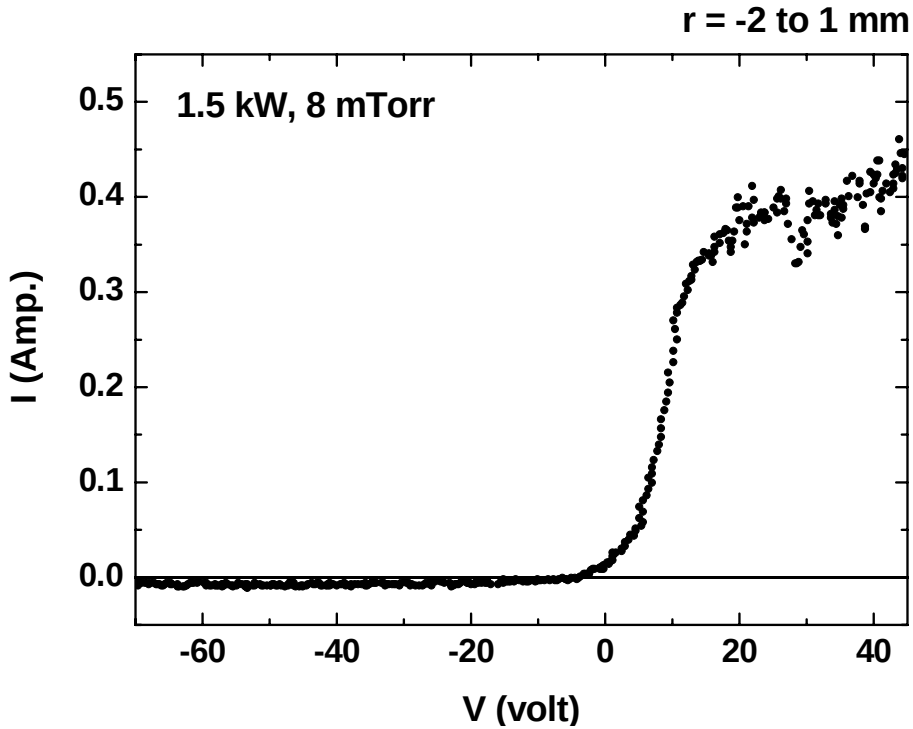
Optimum pressure range



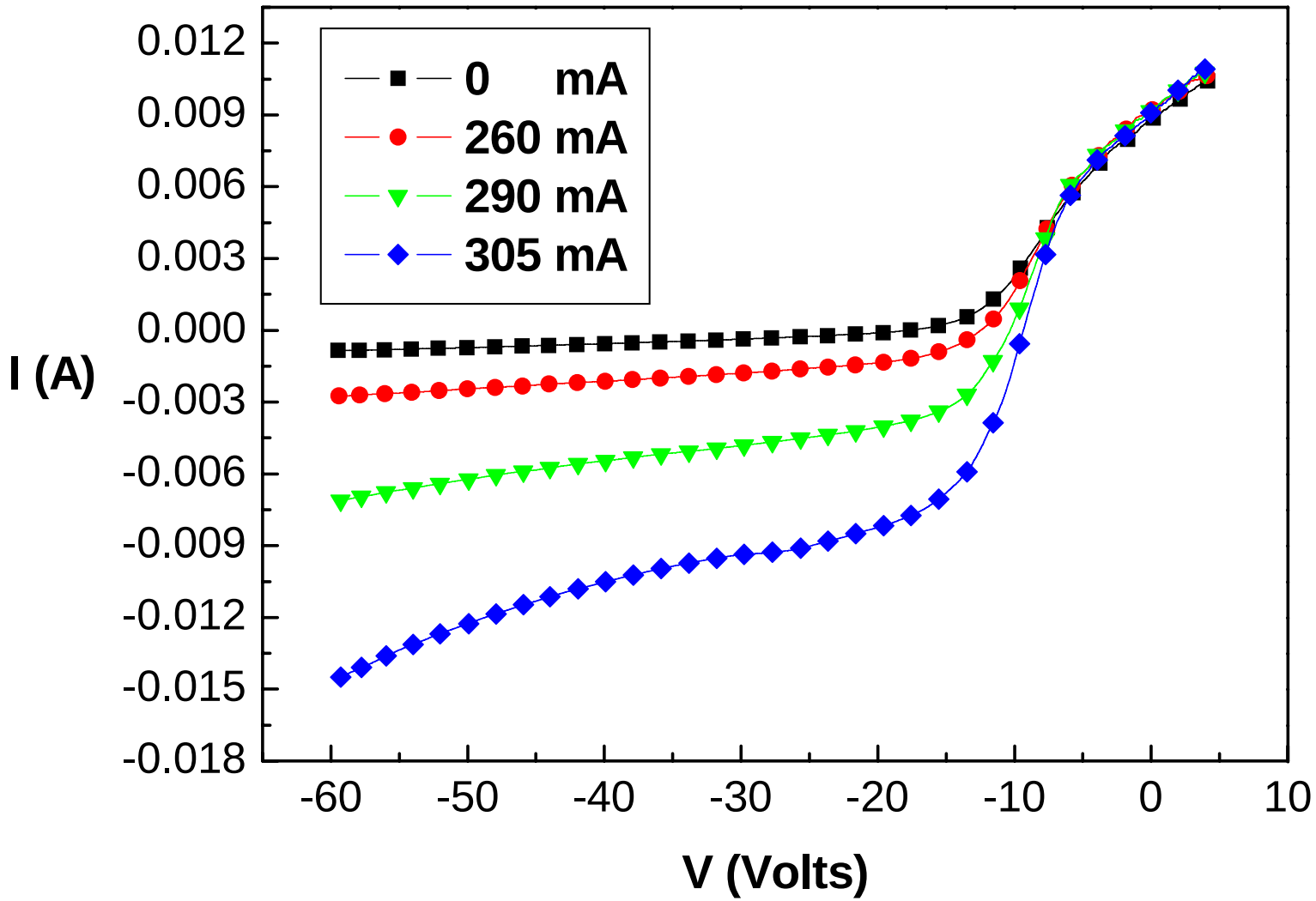
Helicon Plasma Source-OLD & NEW (5)

Plasma density > 10^{13} cm^{-3}

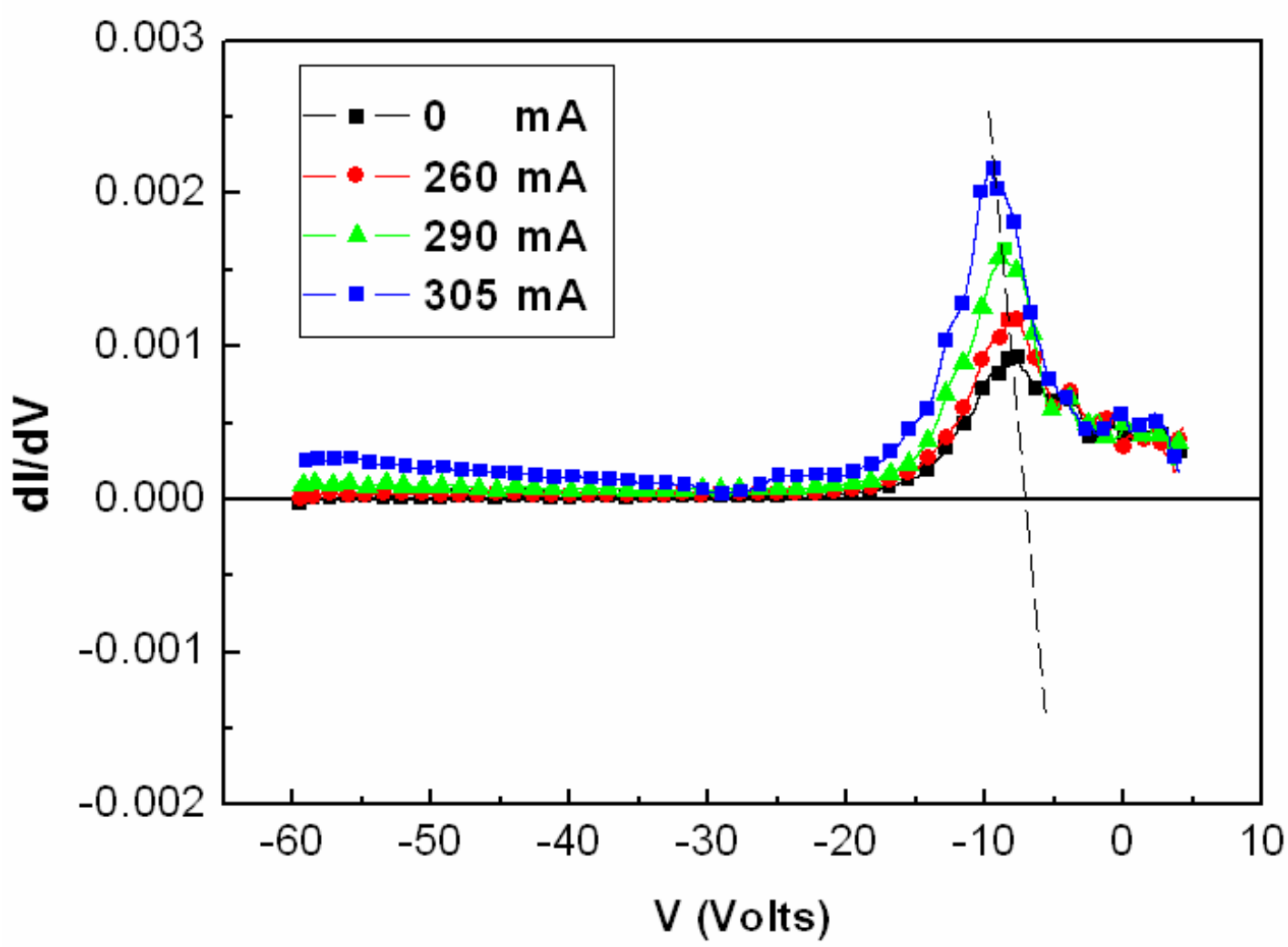




Emissive Probe (1)

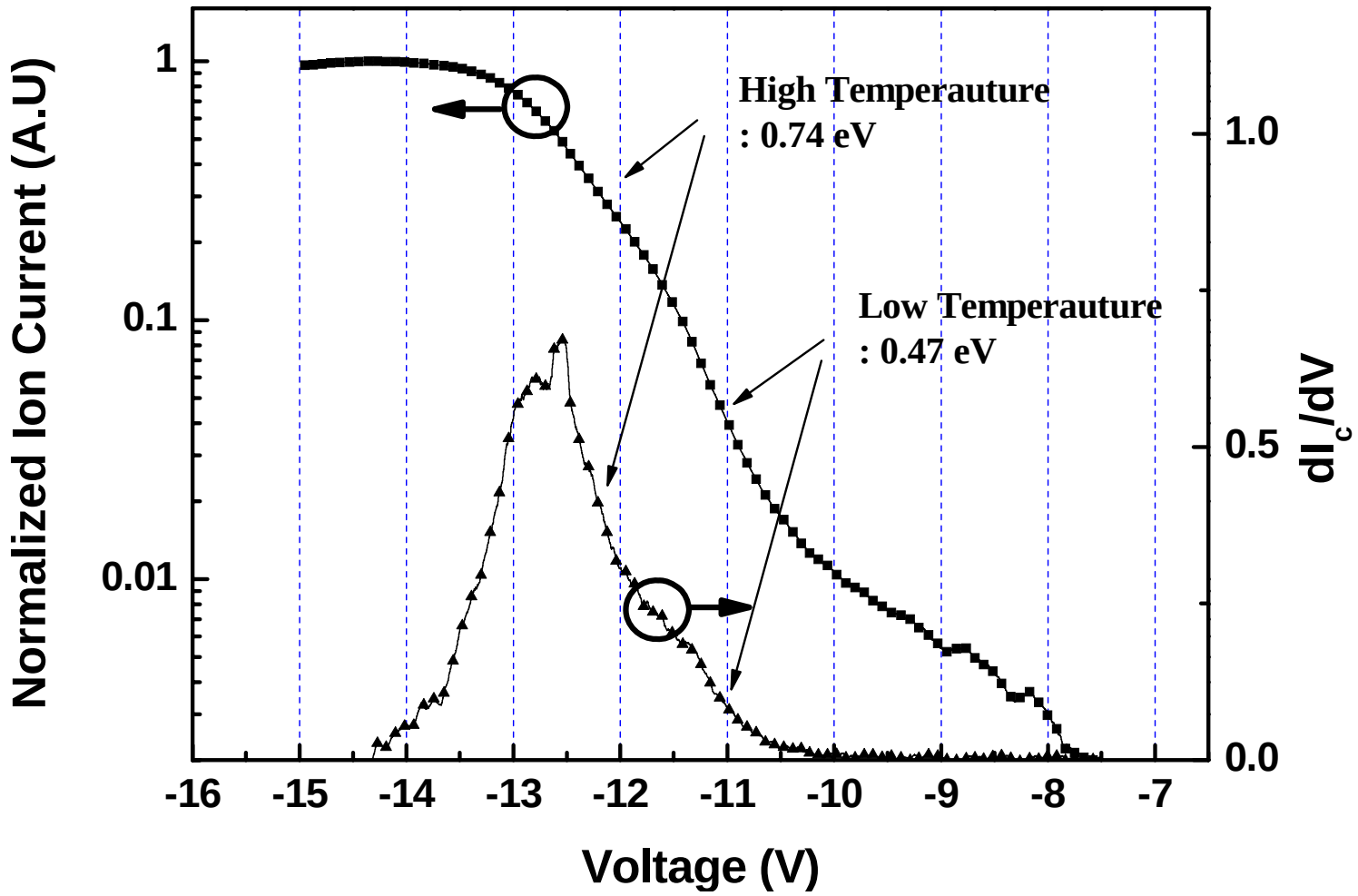


Emissive Probe (2)



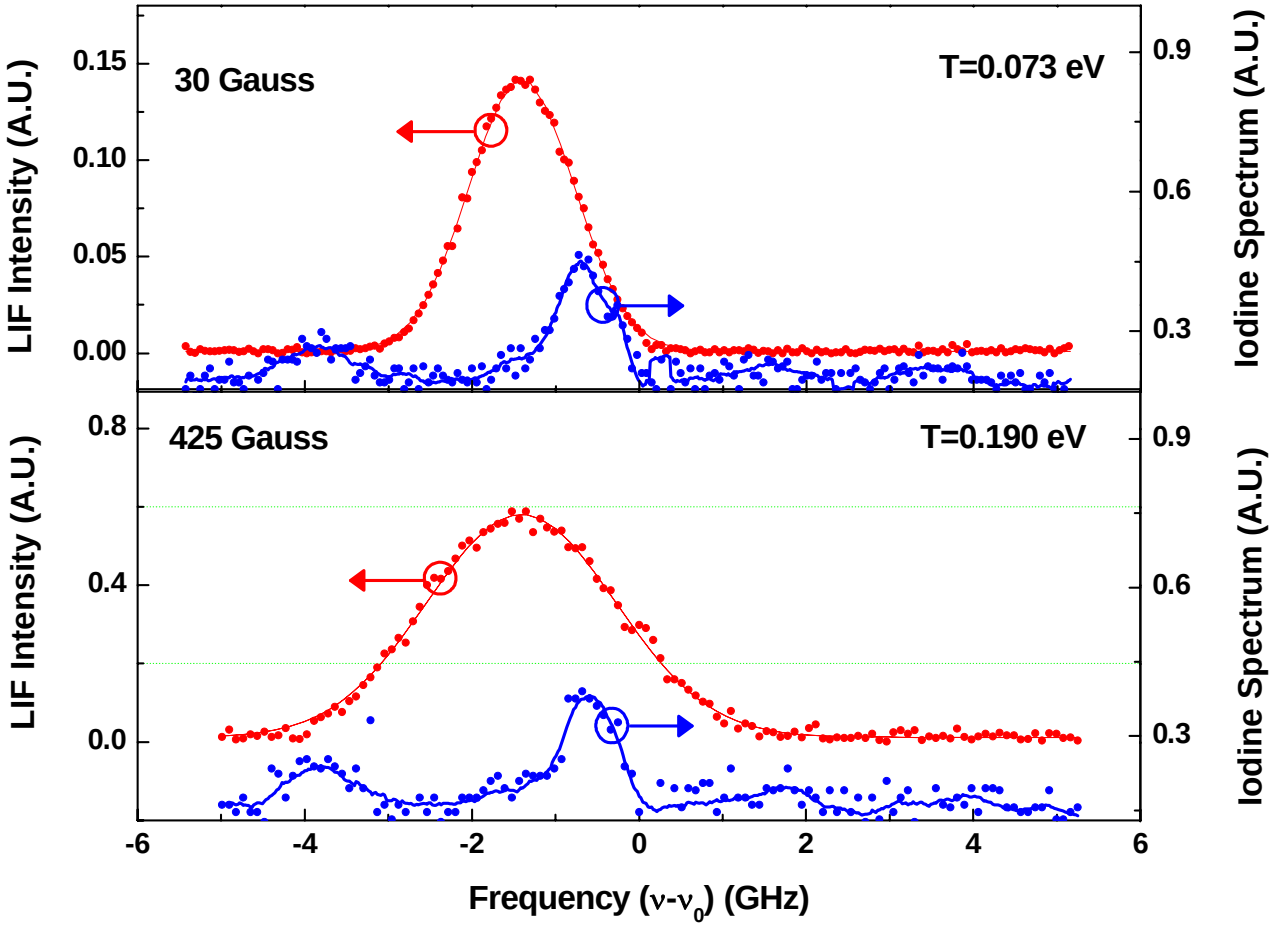
Gridded Energy Analyzer (1)

At Space Simulator

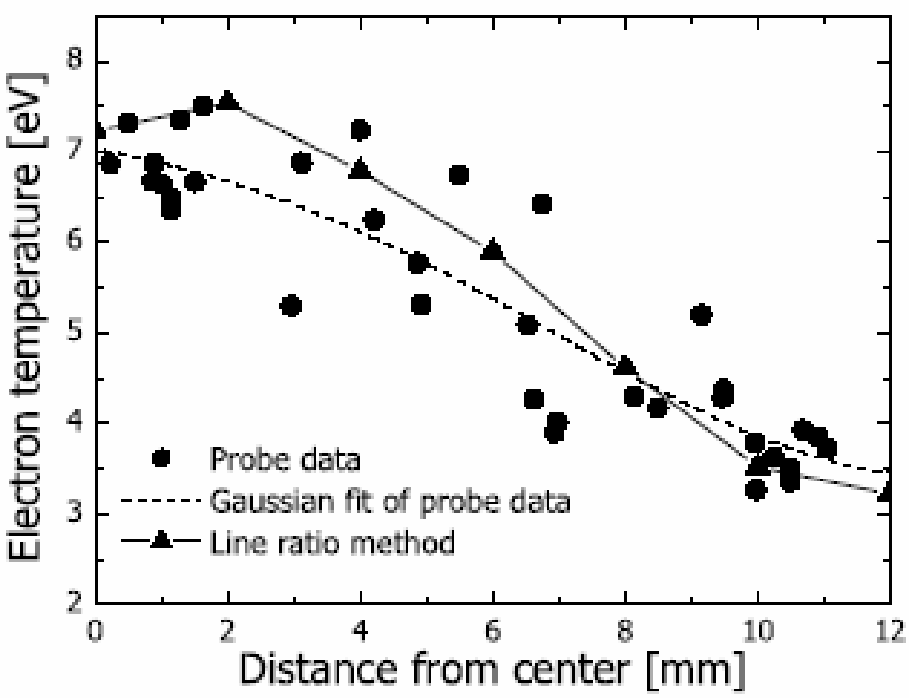


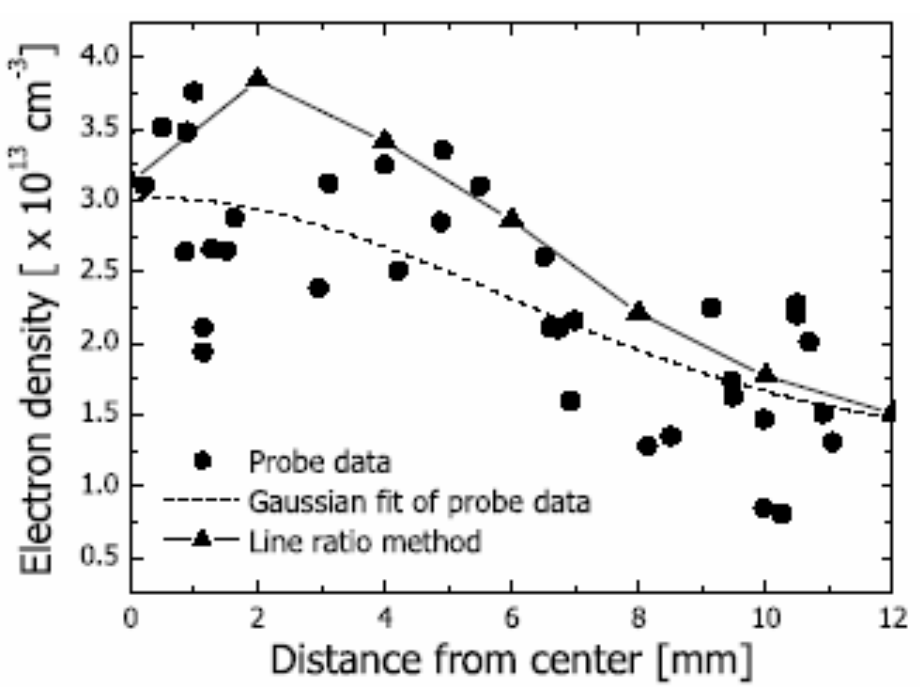
Laser Induced Fluorescence (1)

$T_{i\perp}$ at the center of divertor simulator



Optical Emission Spectroscopy (1)





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Summary (1)

● **DiPS (Diversified Plasma Simulator) is for the development of various probe theories and is going to simulate**

1)Divertor Plasma

2)Space (Propulsion) Plasma

3)Processing Plasma,

by utilizing two plasma sources

(LaB6 DC source, Helicon source) and

by detaching/attaching two chambers on the rail

Summary (2)

●Various probes for divertor and space plasmas have been developed:

- Conventional SP, TP, EP (Fast scanning)
- Vector Probe : Parallel and Perpendicular Mach Probes
- MET/GET Probe: Mach/Gunderstrup+Emissive+Triple Probes
- VPAS: Versatile Probe for Artificial Satellite
  → one MP+two GEA's
  → SP, MP, and Ion Probe mode

● Spectroscopic systems for calibration of probes and for physics study have been developed:

- OES: Optical Emission Spectroscopy
- LIF: Laser Induced Fluorescence
- LTS: Laser Thomson Scattering (to be installed)

•*http://epal.hanyang.ac.kr