Flight Electric Propulsion Diagnostic Package (EPDP) for EP Satellite Platforms

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1 2 3 4 5

Online Event, June 8th, 2021

Content

Outline of this presentation:

1. The EPDP for the Heinrich Hertz Satellite
2. The Test Environment
3. Tests of the Plasma Sensor
4. Tests in a secondary HEMPT Plasma
5. Conclusion

Why a Diagnostic Package for EP Satellites?

Why a Diagnostic Package for EP Satellites?

Backflow from thruster to S/C very hard to assess from ground experiments

Deep Space 1

NASA

- Gridded Ion Thruster
- 0.1 µA/cm² ion flux near thruster exit
- Deposition of molybdenum: ~ 1 nm / 100 h (line-of-sight)

Wang et al., J. Spacecr. Rockets 37, 545 (2000)
Brinza et al., J. Spacecr. Rockets 38, 426 (2001)

SMART-1

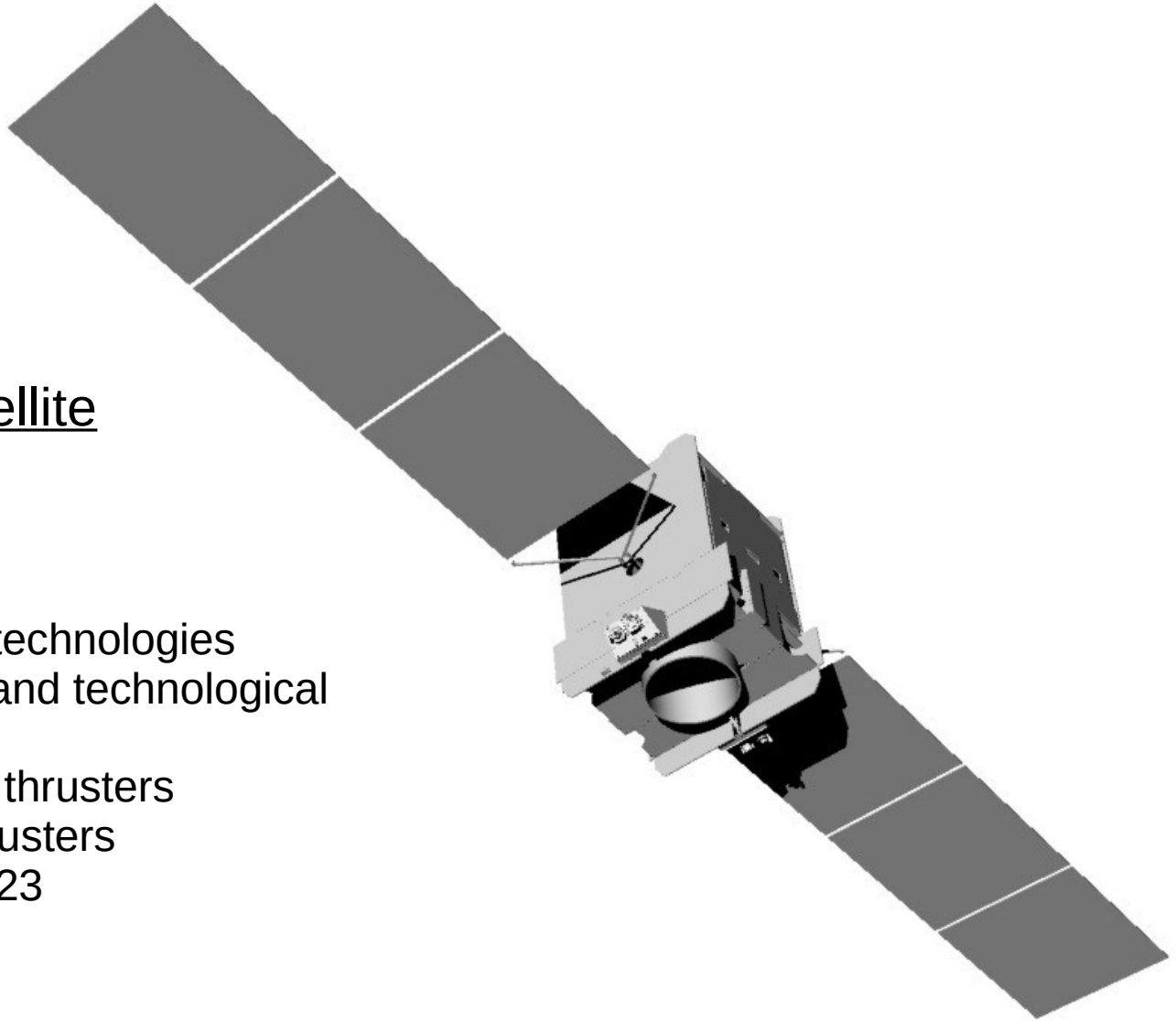
ESA

- Hall Thruster
- Ion energies: e.g. 35 eV (peak) tale up to 90 eV
- Energies vary along the orbit
- Floating potential of cathode: -5 V to +10V

González del Amo, et al., IEPC–2005–003 (2005).

The EPDP for the Heinrich Hertz Satellite

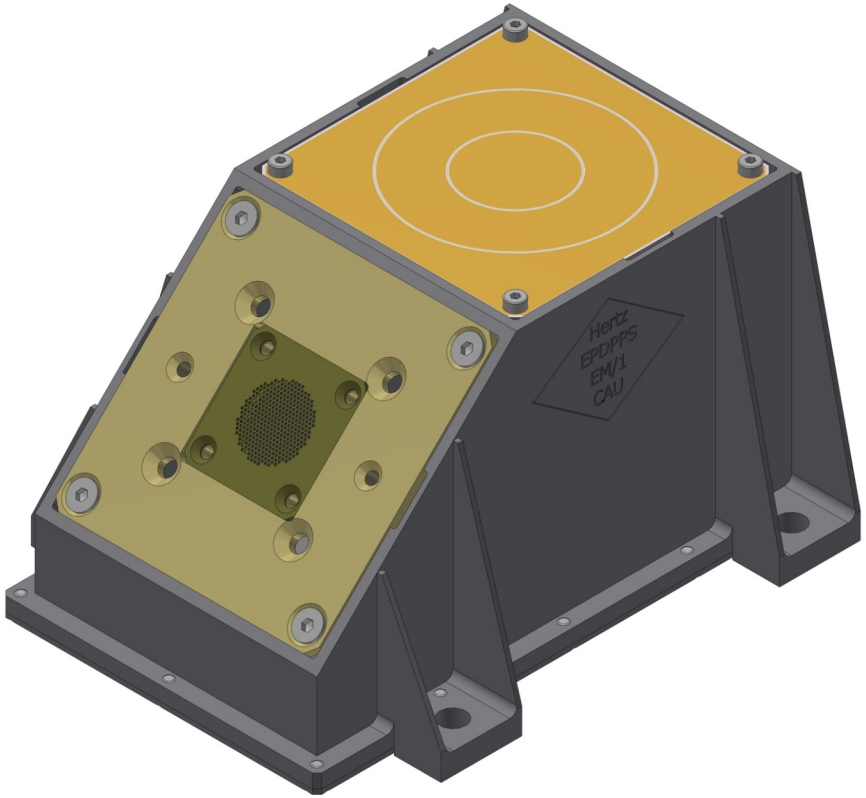
The Spacecraft



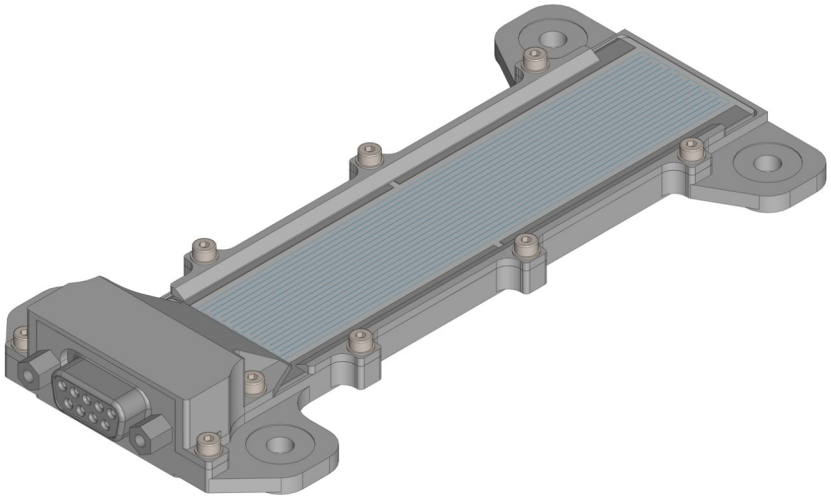
Heinrich Hertz Satellite

- Explore and test new telecommunications technologies
- Platform for sientific and technological experiments
- Pair of HEMPT 3050 thrusters + pair of SPT-100 thrusters
- To be launched in 2023
- Financed by DLR
- Integrated by OHB

The two Sensors of the EPDP

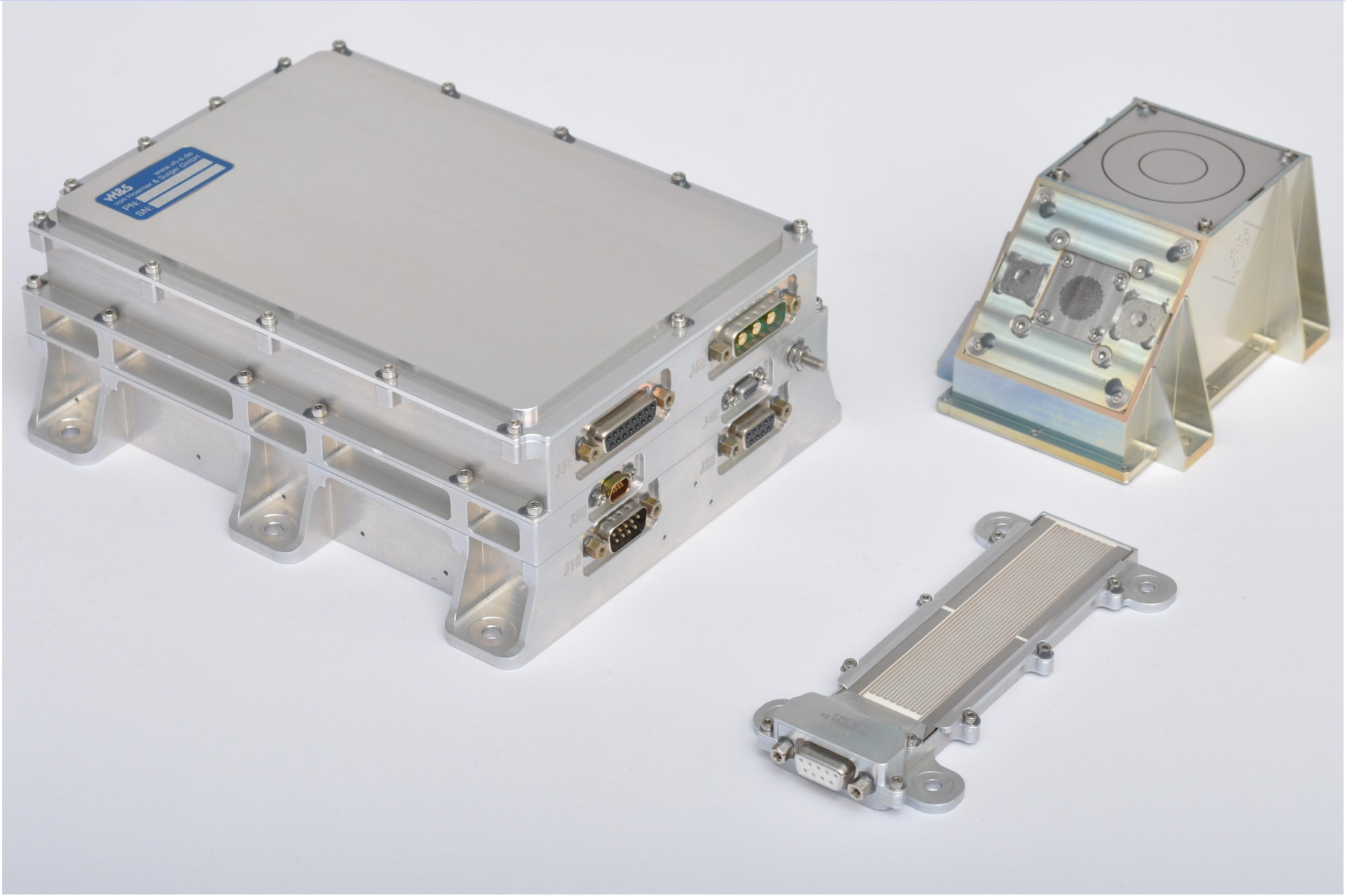


Plasma Sensor (PS)

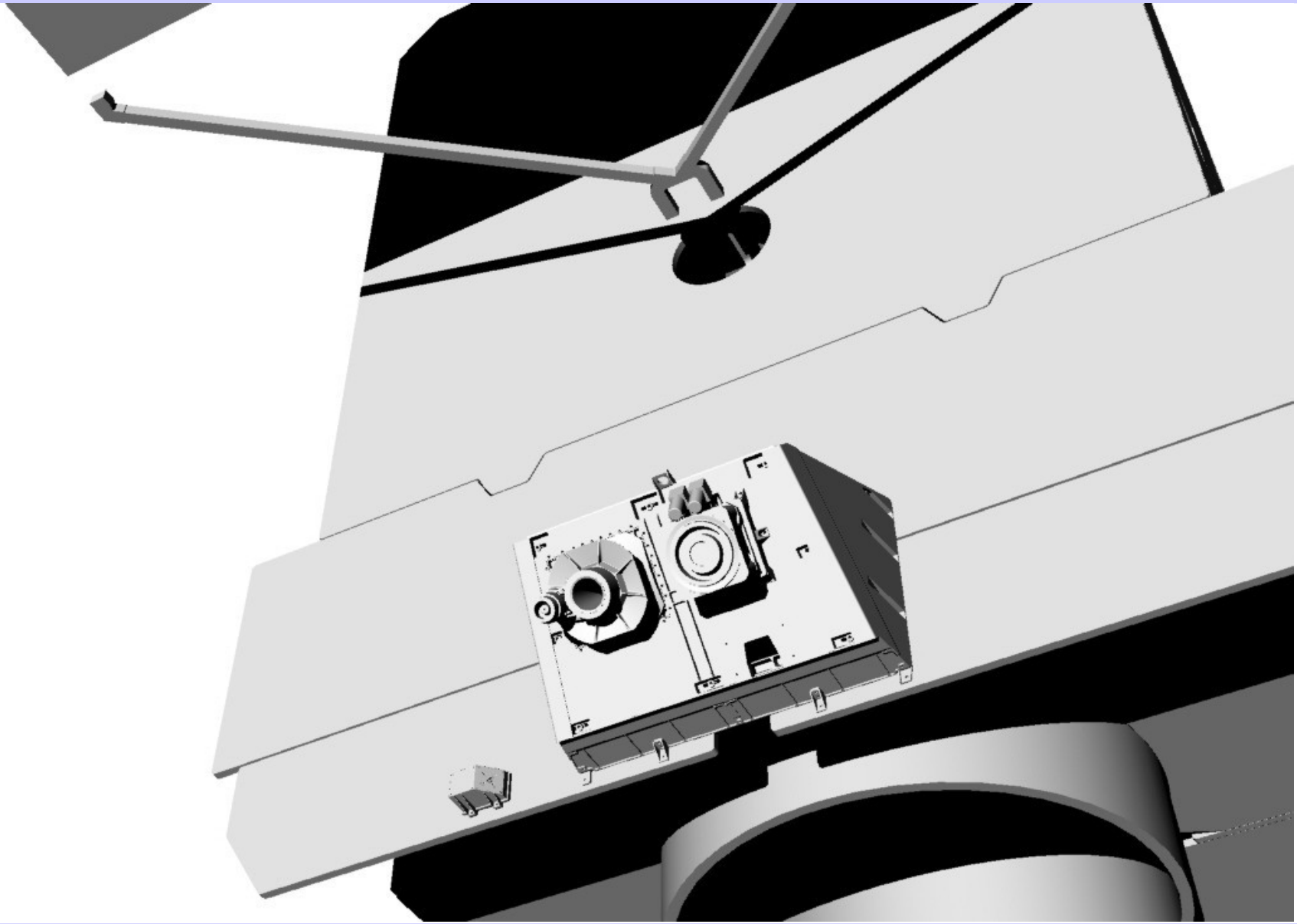


Erosion Sensor (ES)

The two Sensors of the EPDP



The EPDP abord the Spacecraft



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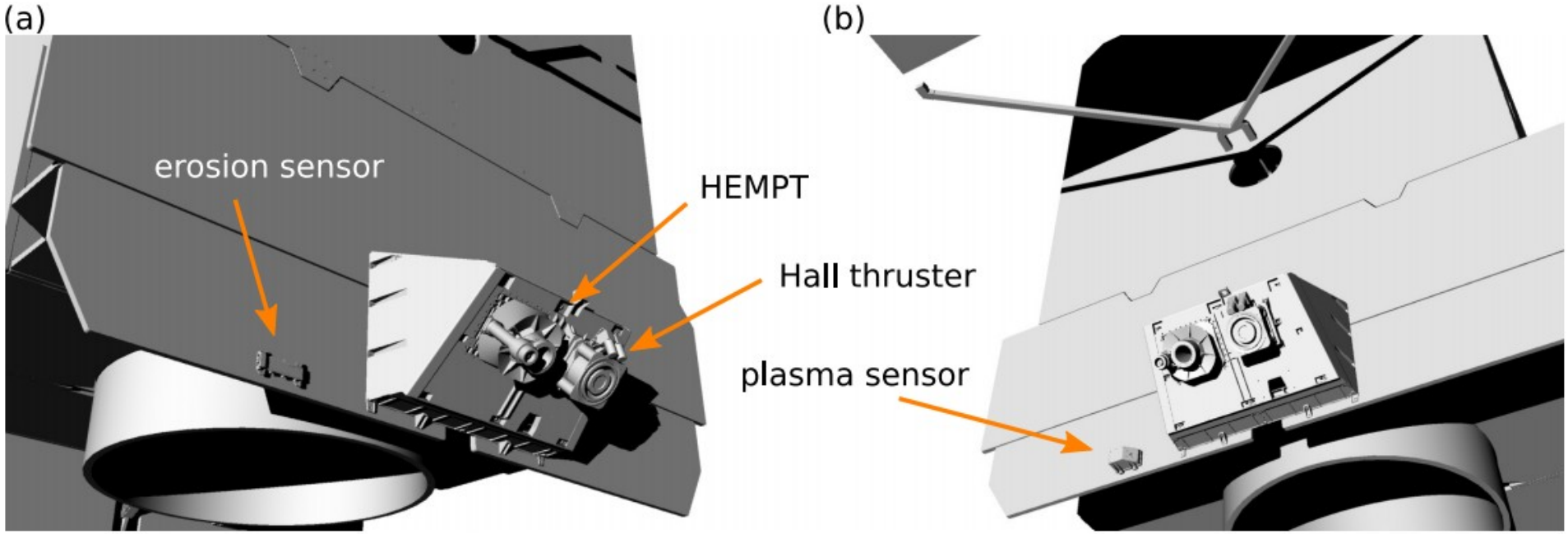

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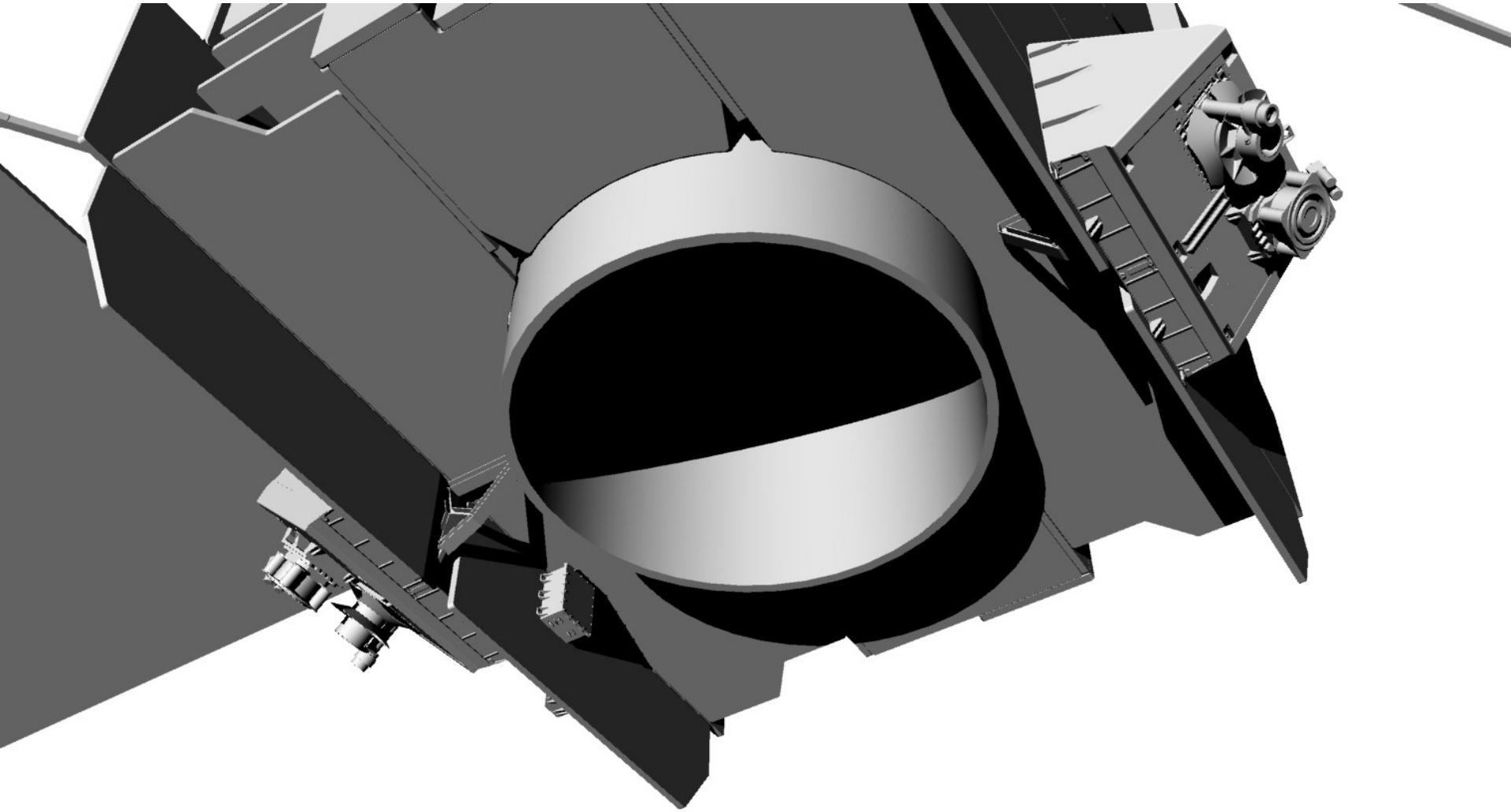
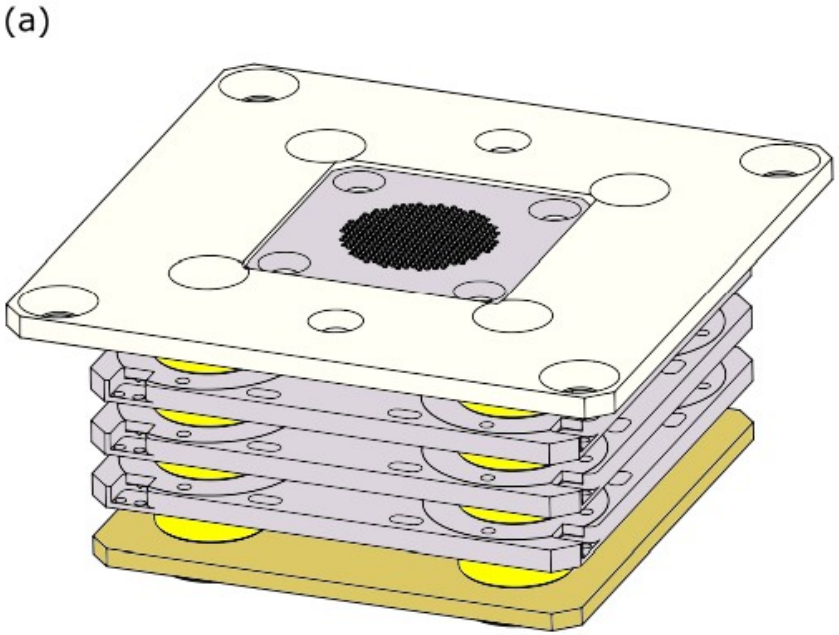
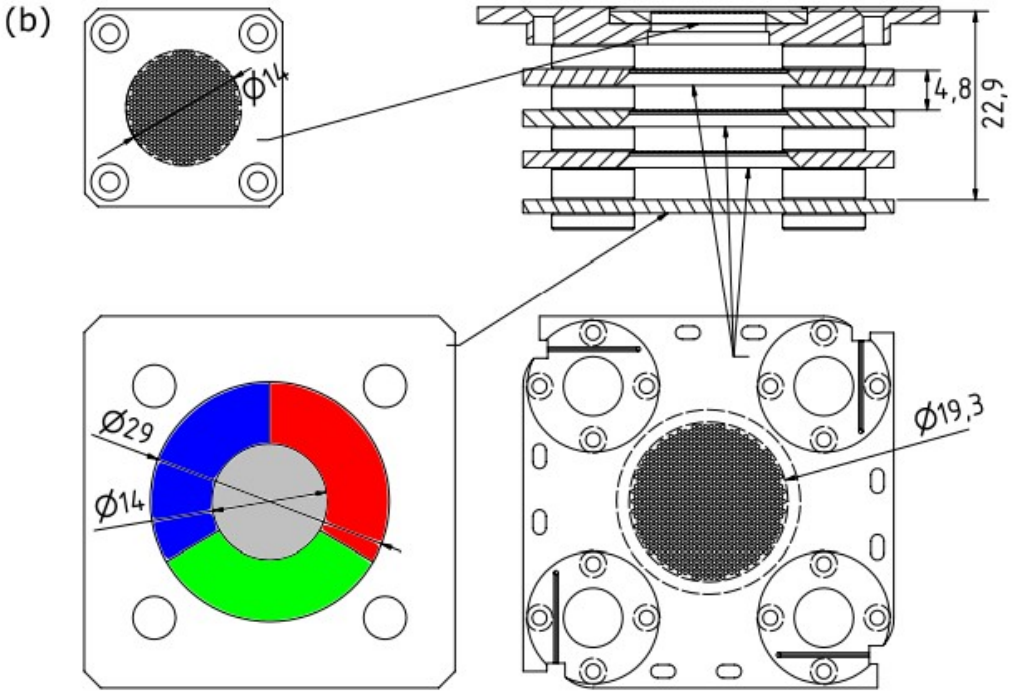


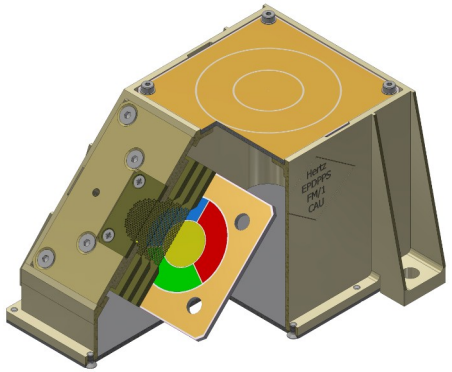
The EPDP Plasma Sensor (PS)

Retarding Potential Analyzer

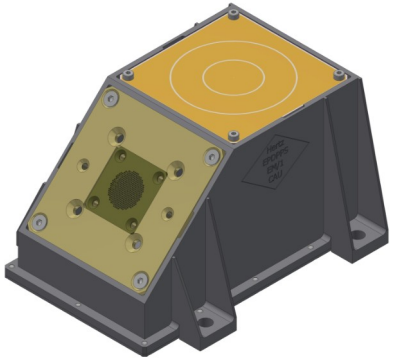


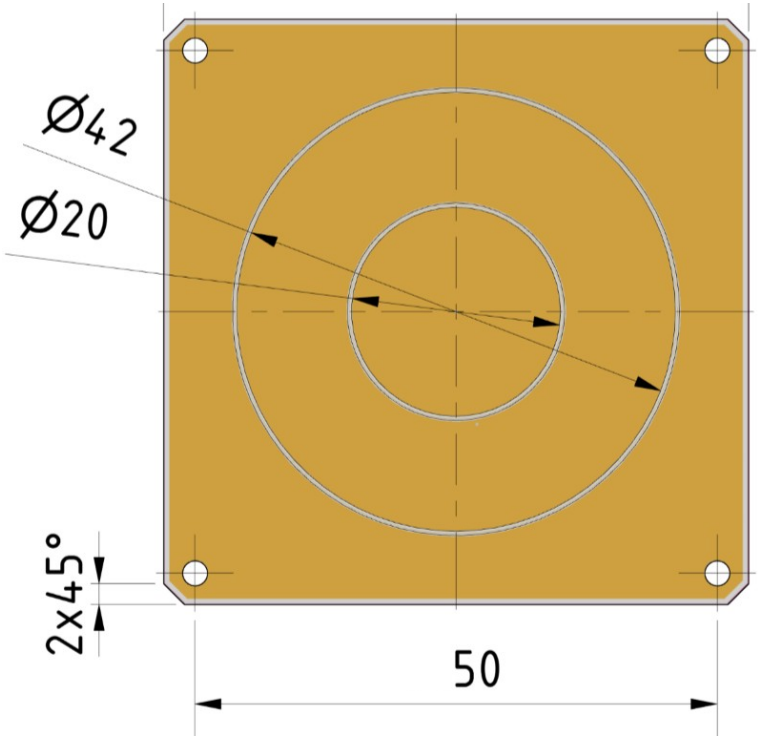


- Four grids
- Segmented collector
- 0.5 mm holes, 0.2 mm separated



Planar Langmuir Probe





Simulations:

$$n_\mathrm{e} = (5 \times 10^{10} \ldots 1 \times 10^{13})\,\mathrm{m}^{-3}$$

$$k_\mathrm{B} T_\mathrm{e} = 3\,\mathrm{eV}$$

=> Screening length

$$\lambda_\mathrm{De} = \left(\frac{k_\mathrm{B} T_\mathrm{e}}{n_\mathrm{e} e^2}\right)^{\frac{1}{2}} = 4\,\mathrm{mm} \ldots 6\,\mathrm{cm}$$

Probe area $A = 3.1\,\mathrm{cm}^2$

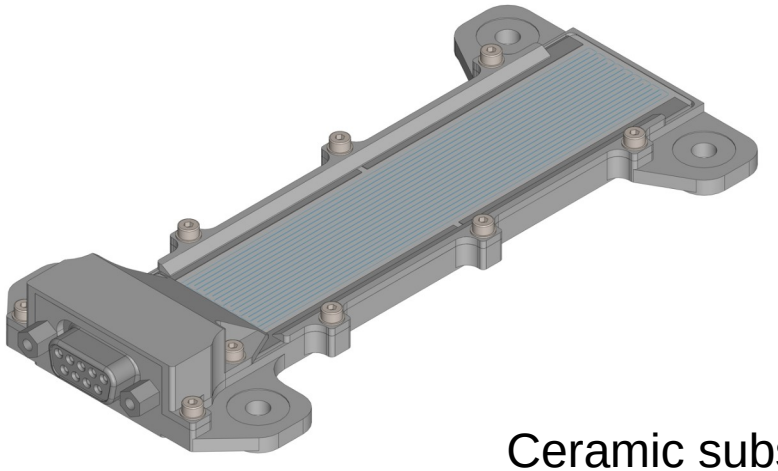
Saturation currents:

$$I_\mathrm{e} = 0.4\,\mu\mathrm{A} \ldots 90\,\mu\mathrm{A}$$

$$I_\mathrm{i} = 2\,\mathrm{nA} \ldots 0.5\,\mu\mathrm{A}$$

The EPDP Erosion Sensor (ES)

Erosion Sensor



Resistance measurement

Meander:
- 180 cm long
- 2 µm thick
- 1 mm wide

Ceramic substrate (2 x 10 cm²)
with silver thin film path (15 Ohms)

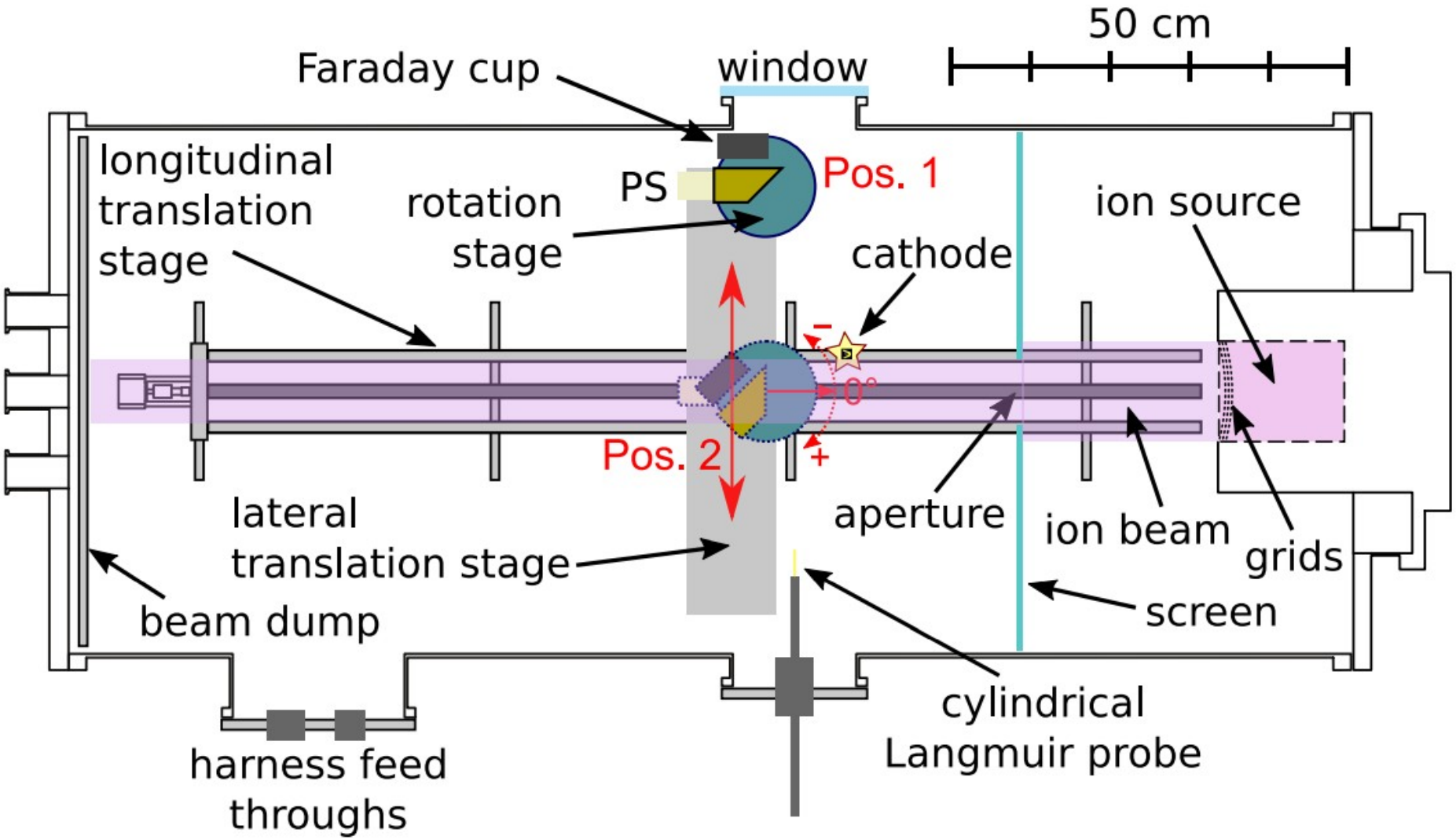
Hardware is simpler than QCM, but data evaluation is more challenging:

- Temperature drifts (-80 … +110 °C)
- Additional currents from plasma (thruster-generated, solar wind)
- Electromagnetic interference from the HEMP thruster?

=> filtering + AC measurement techniques

The Test Environment

Imitation of the Thruster-Generated Secondary Plasma



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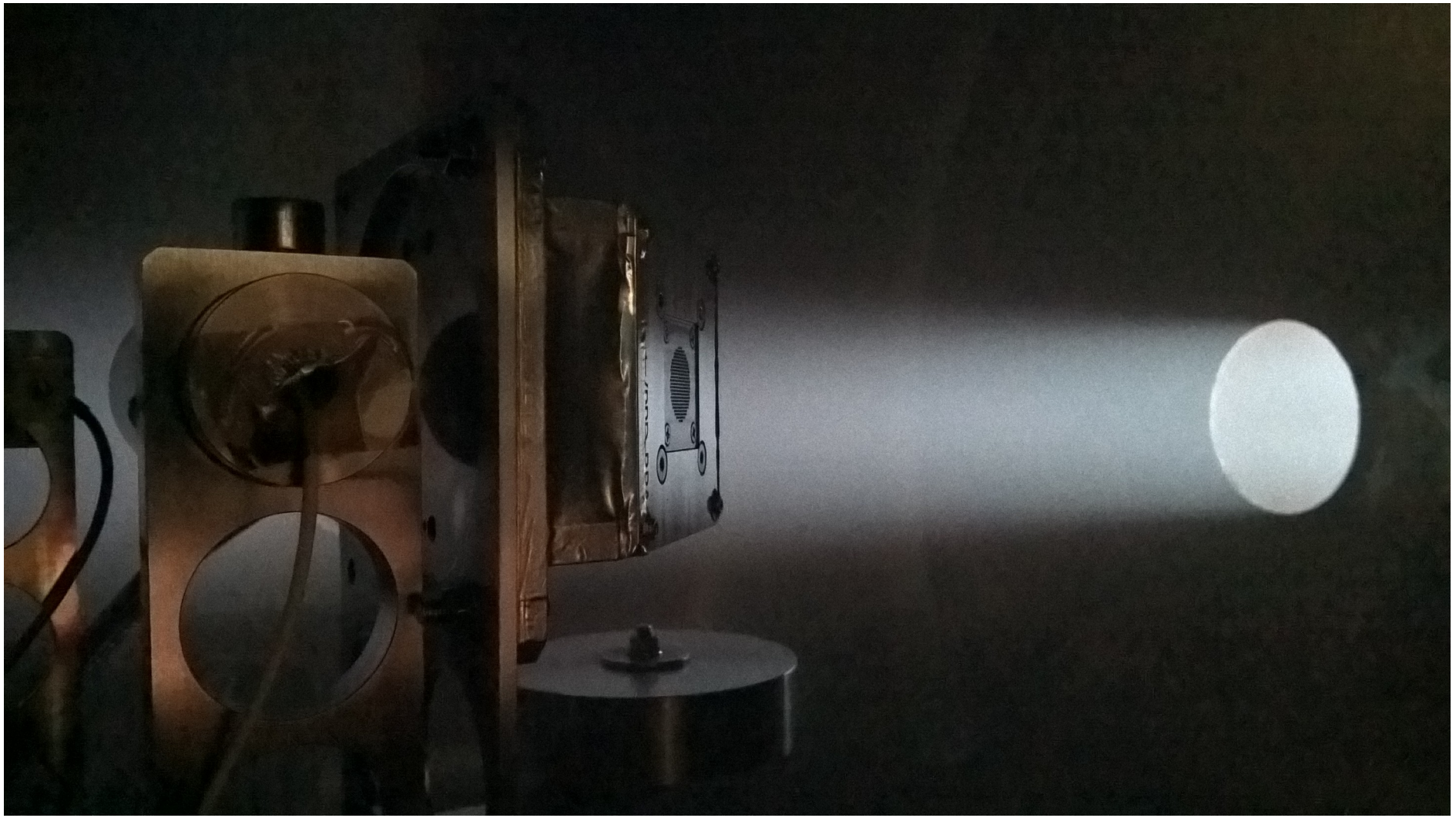

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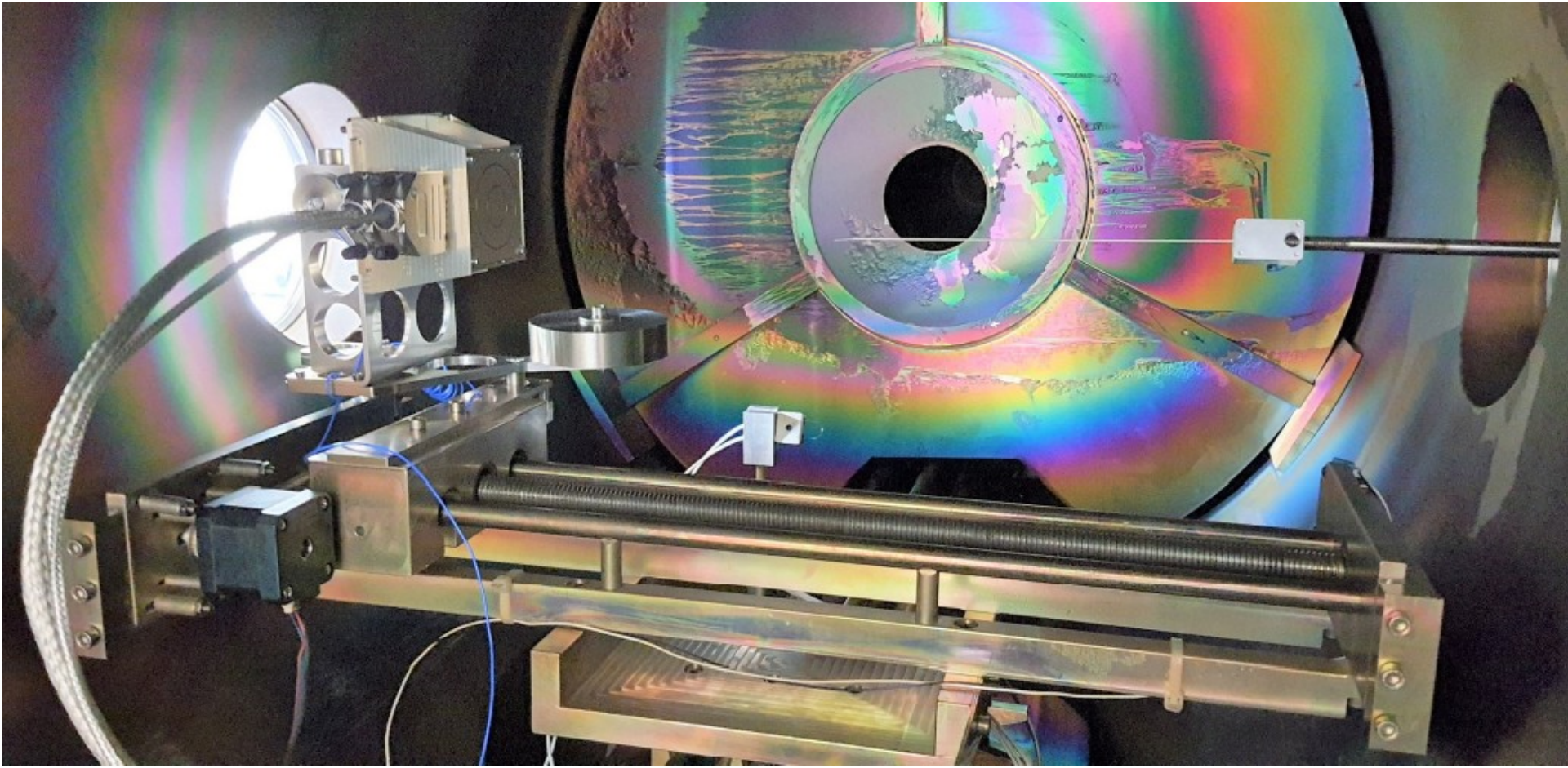
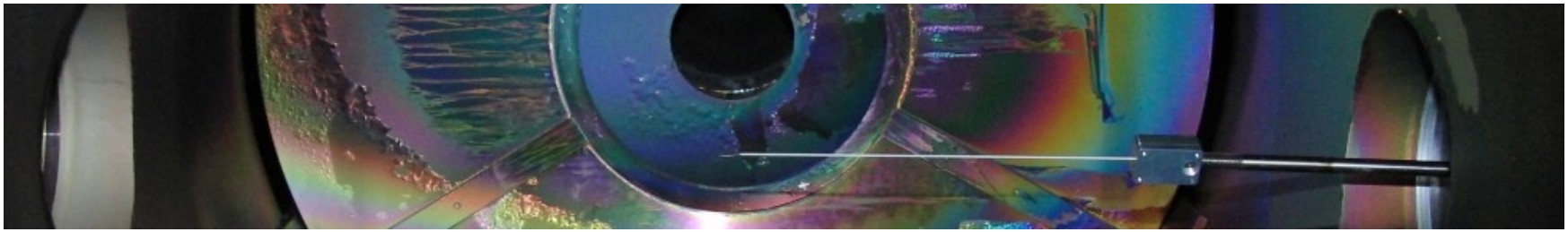
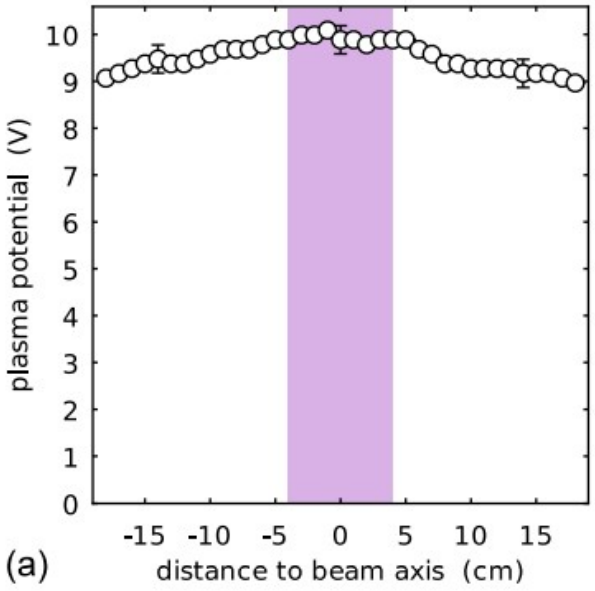
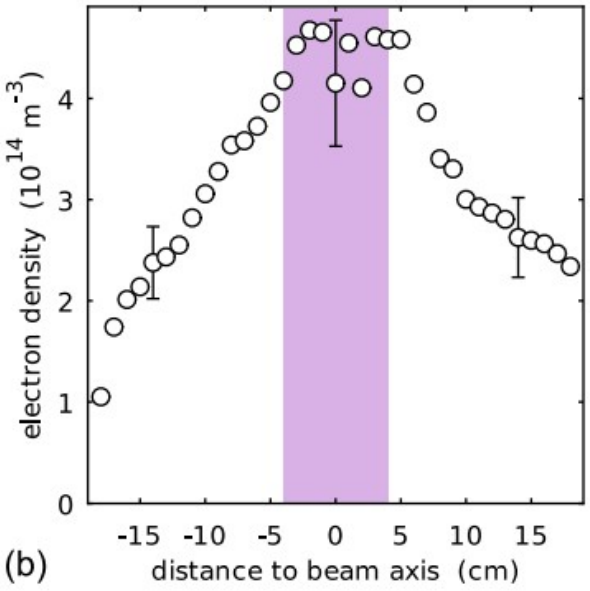


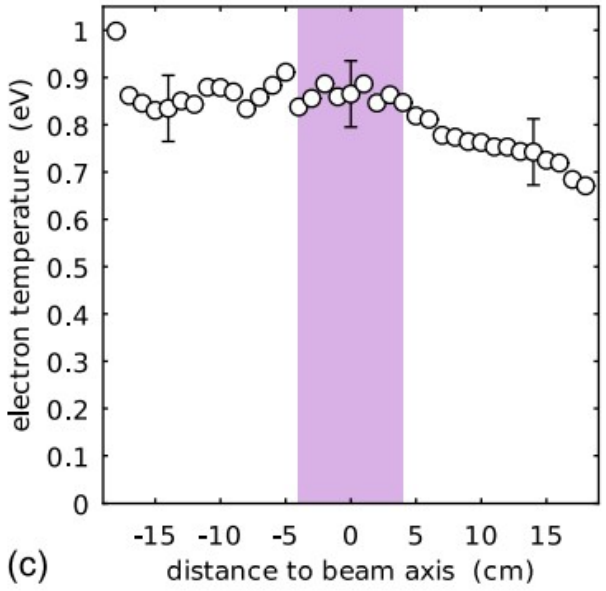
Tests of the PS

Characterization of the Test Environment



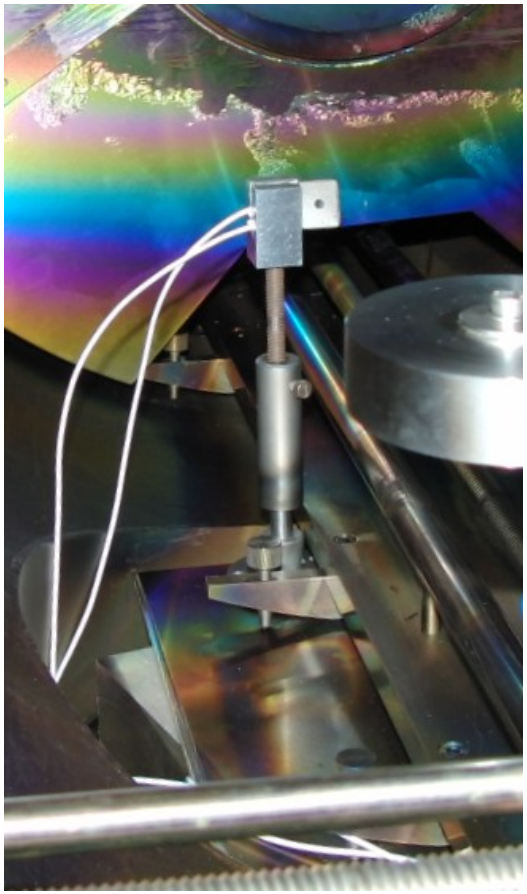




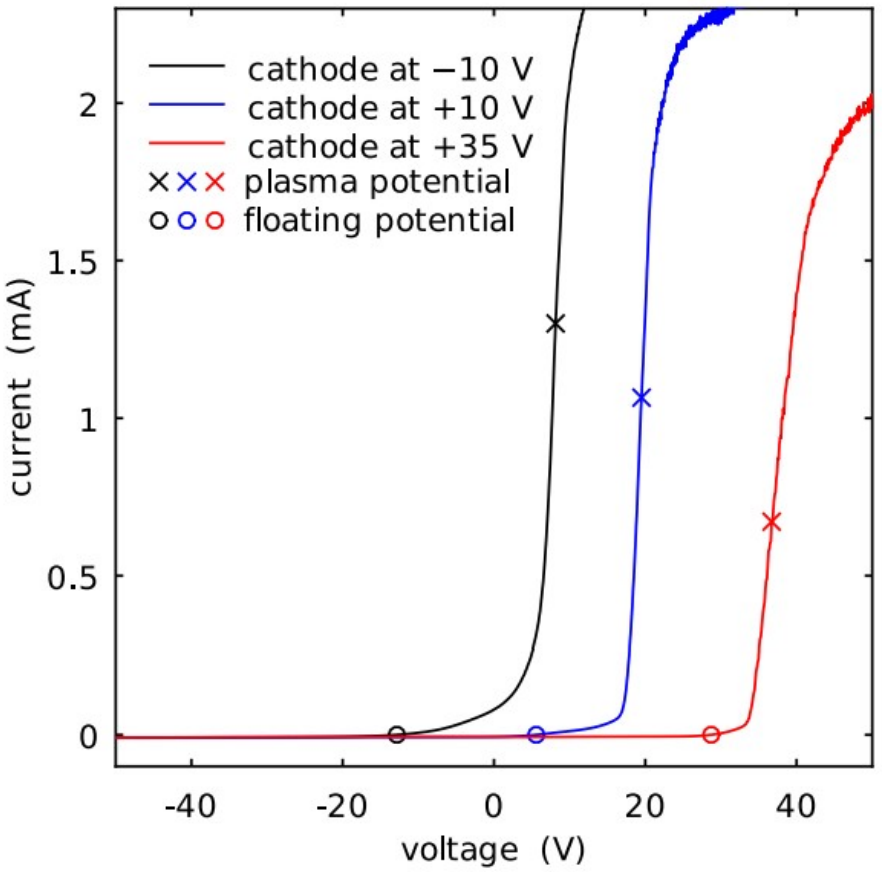


Characterization of the Test Environment

Systematic manipulation of the plasma potential by means of a biased hot filament

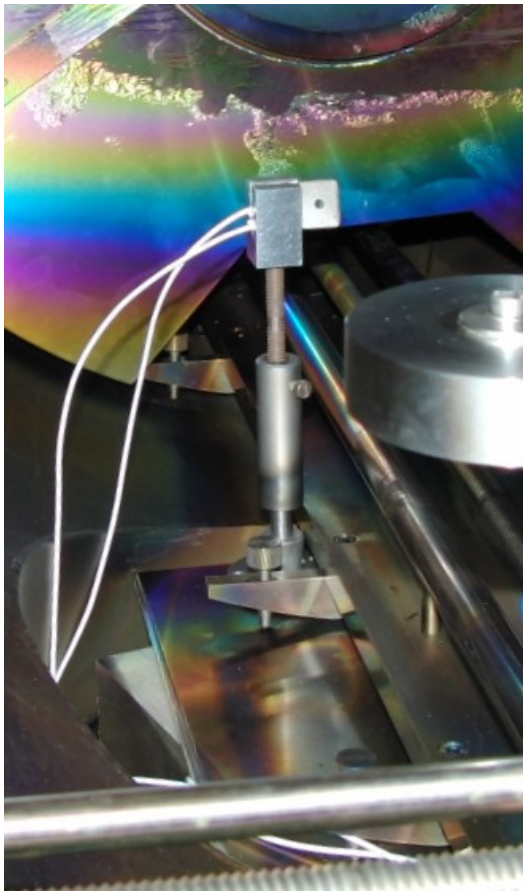


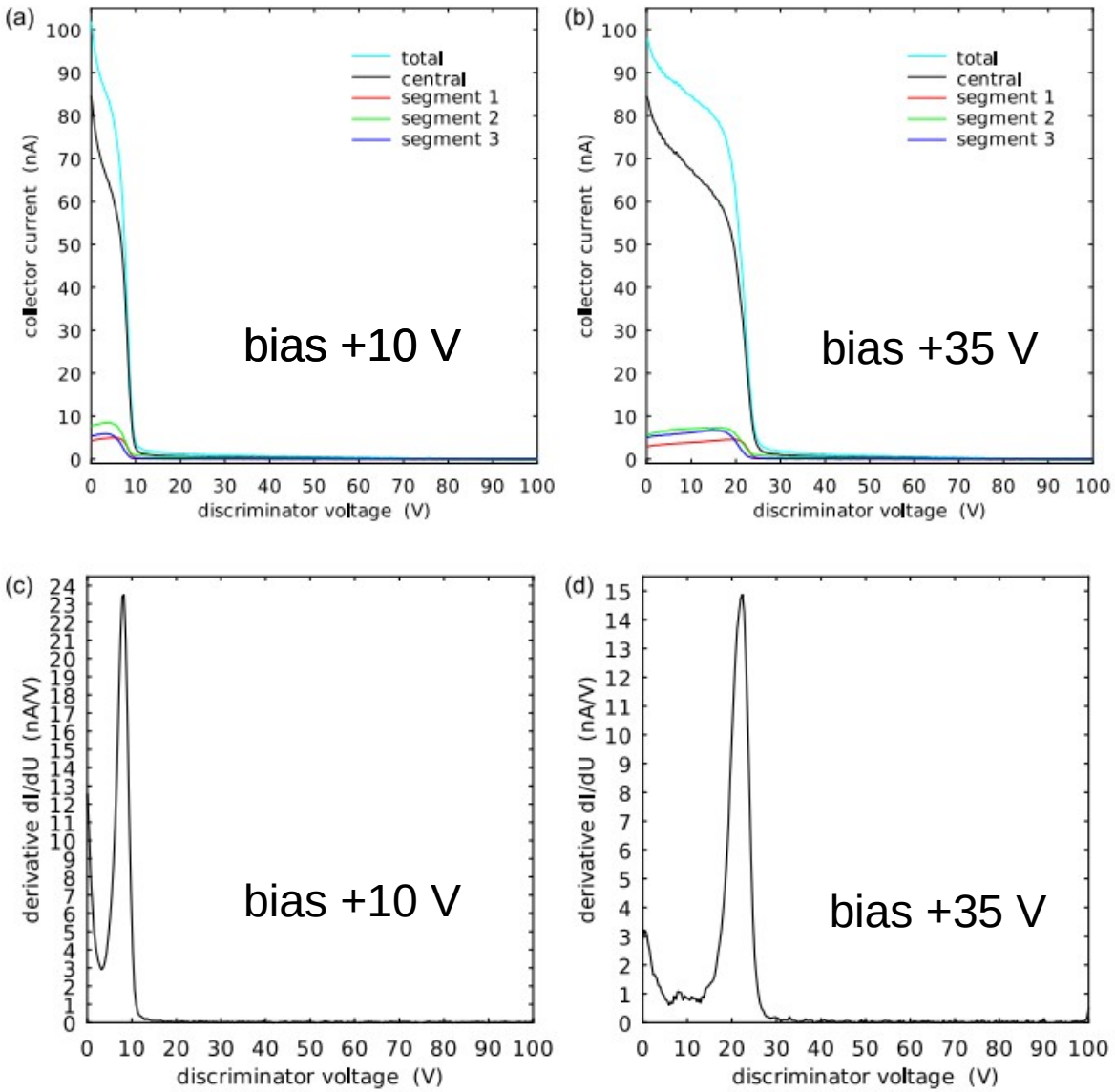
Measured 18 cm away from the beam



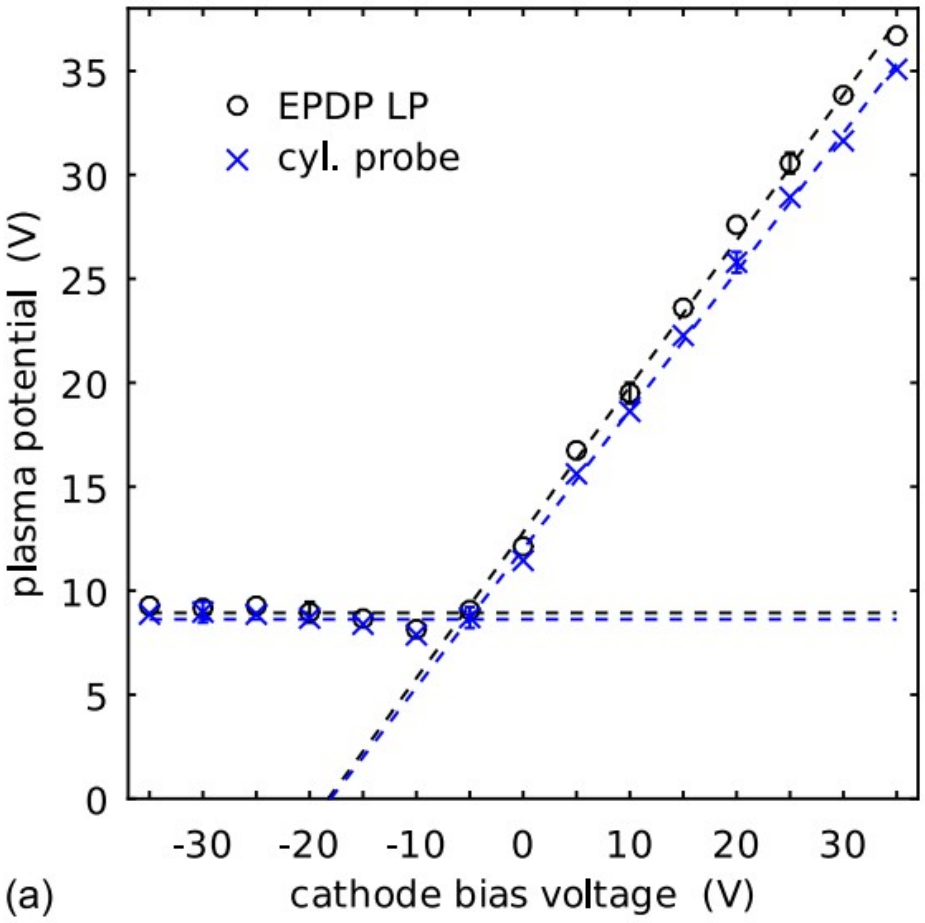
Shifts of the Ion Energies outside the beam

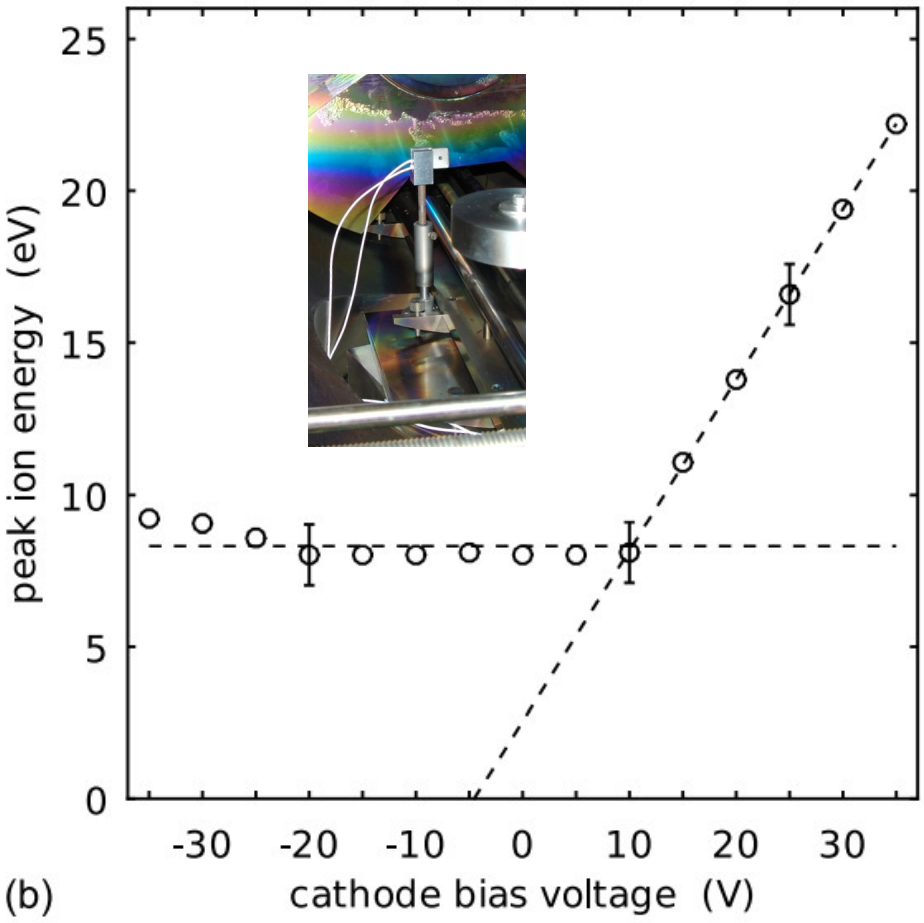
Measured 18 cm away from the beam





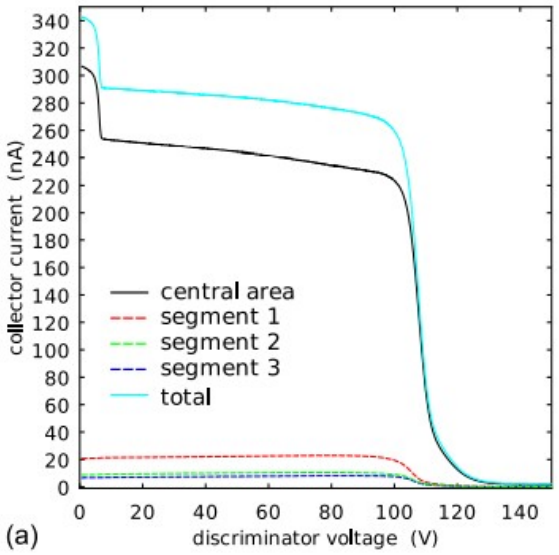
Shifts of the Plasma Potential and Ion Energies outside the beam

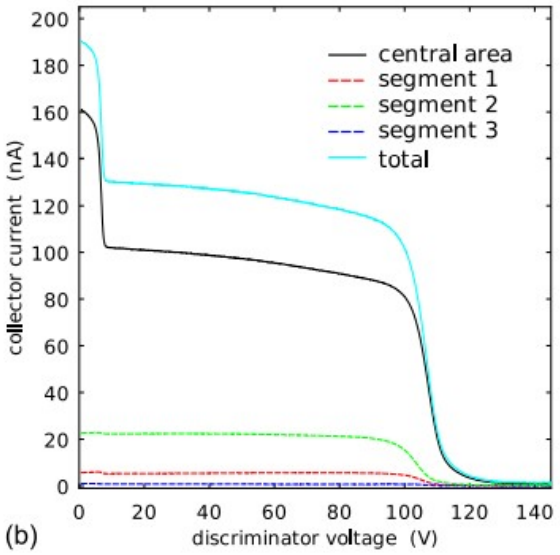


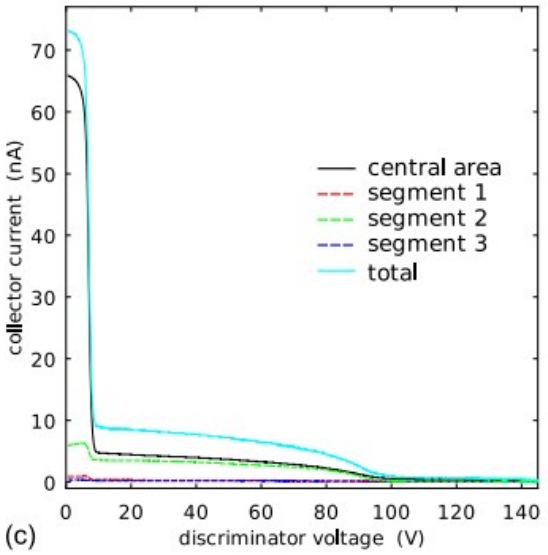


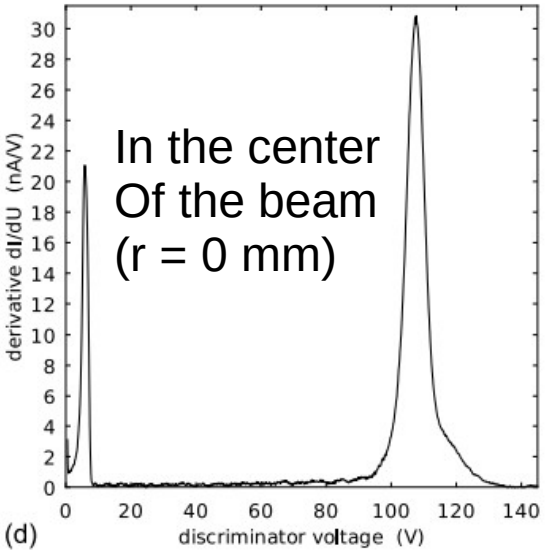
=> Biased hot filament is a useful tool for manipulation of the secondary plasma

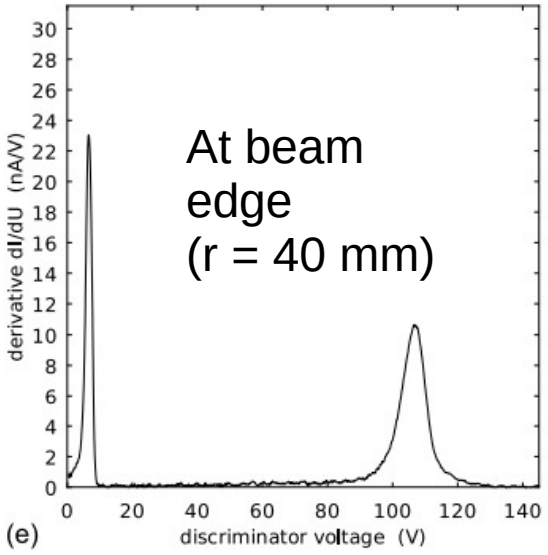
Ion Energies in and outside the “idling” beam

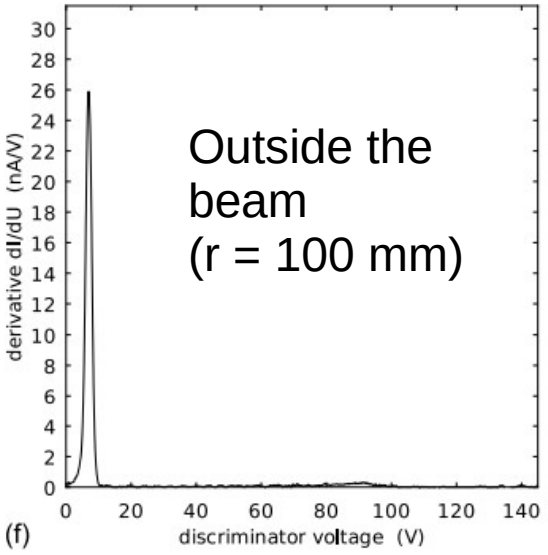




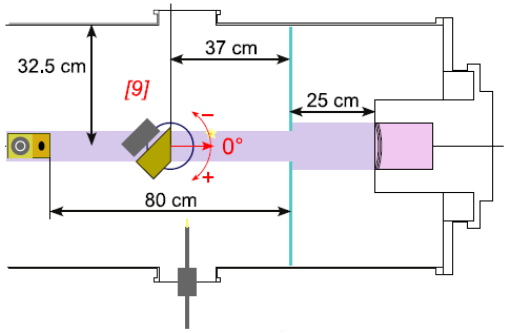


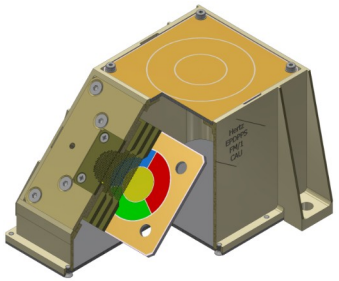


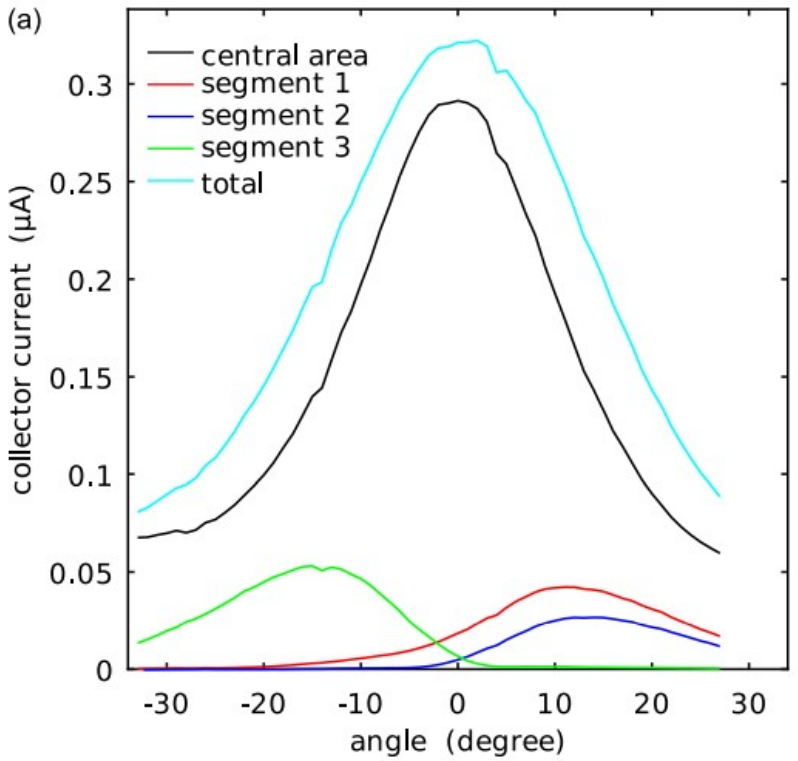


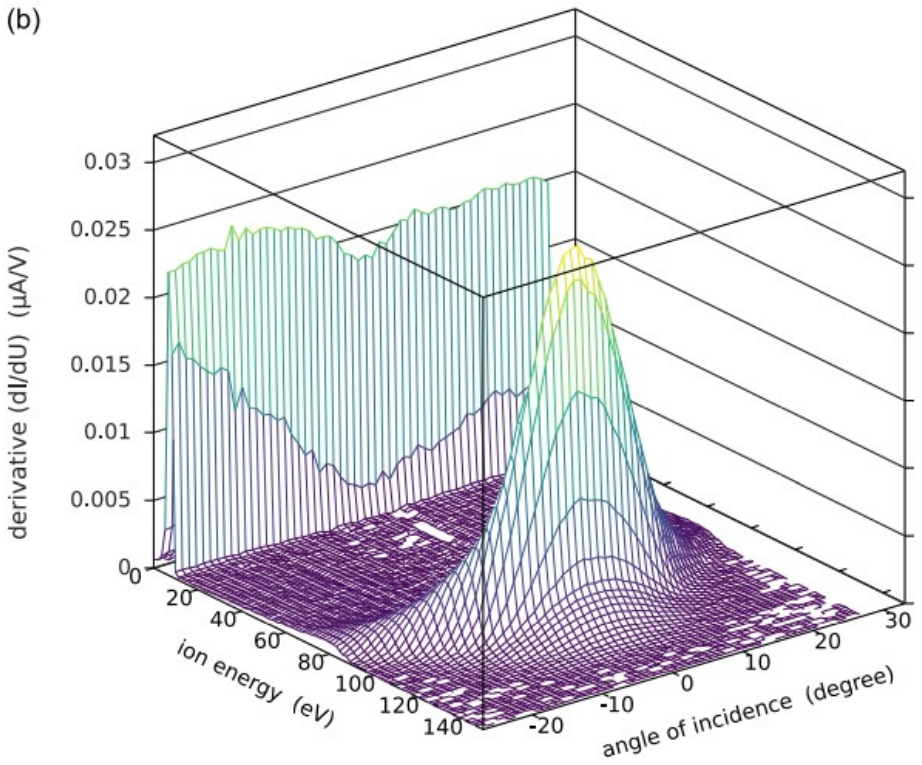


RPA signals at oblique ion incidence

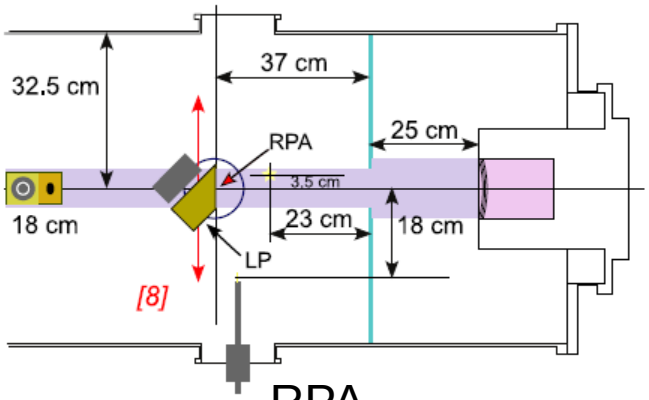




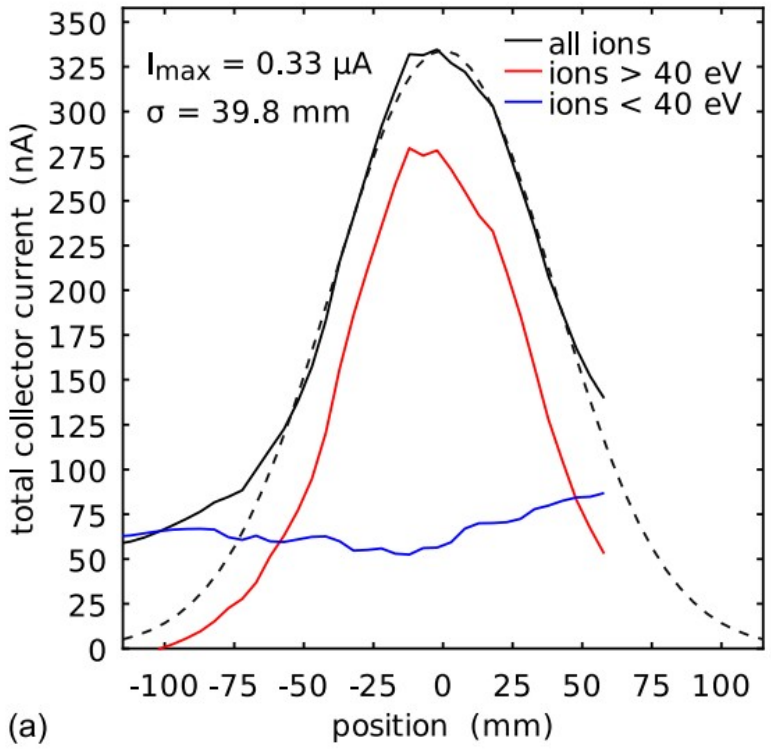




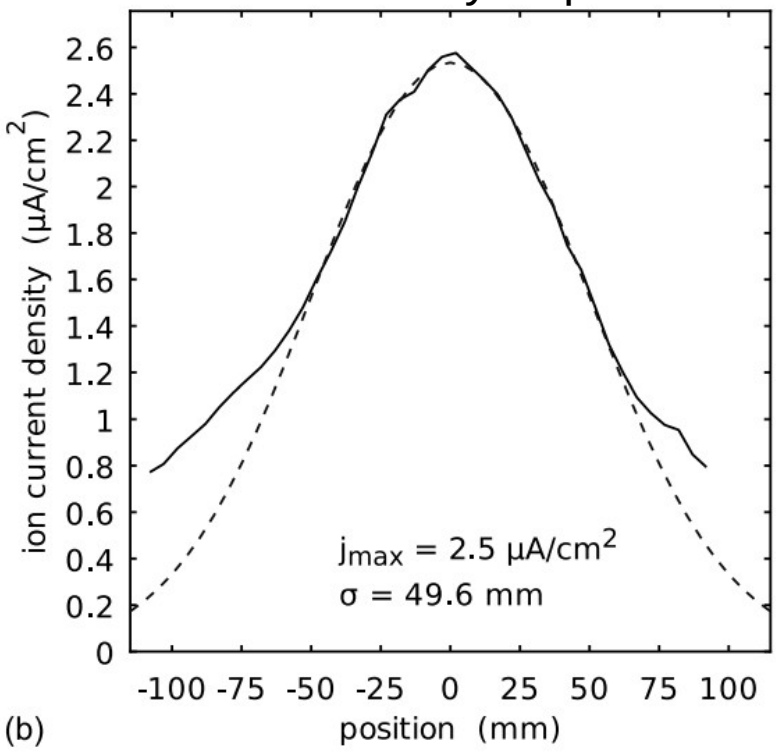
Current Calibration of the RPA



RPA

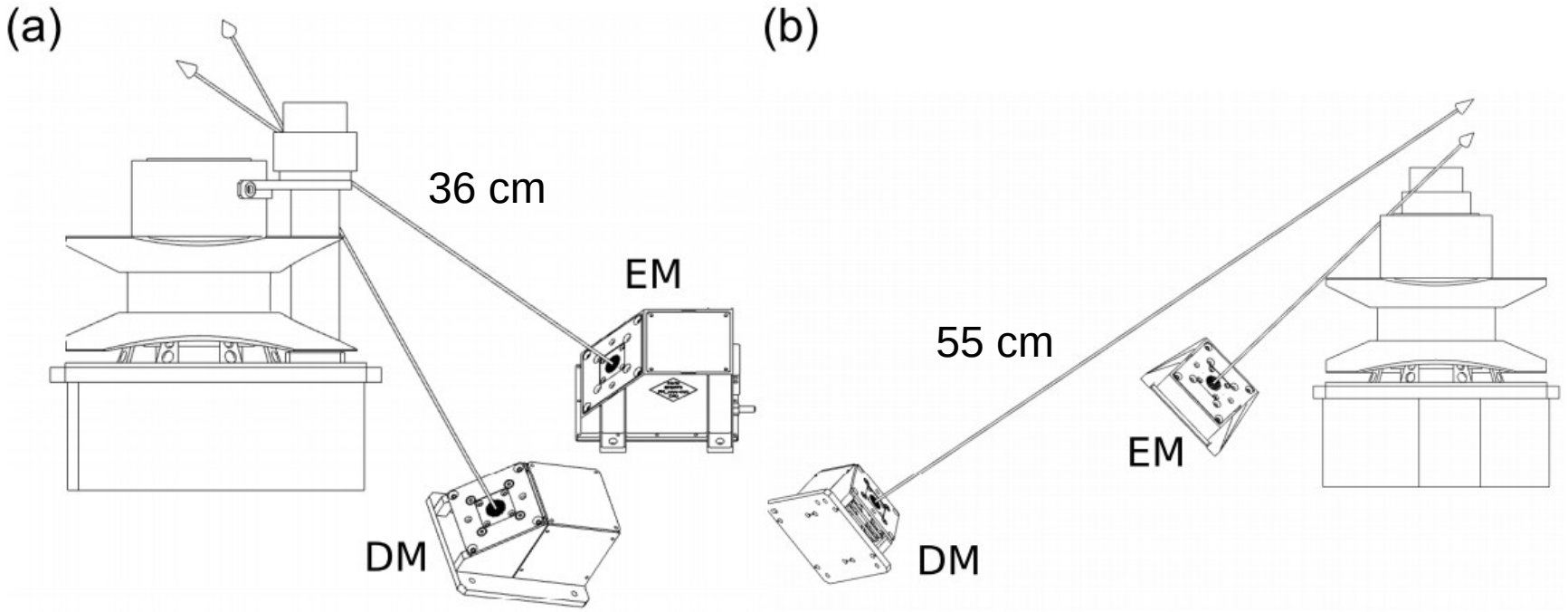


Faraday Cup



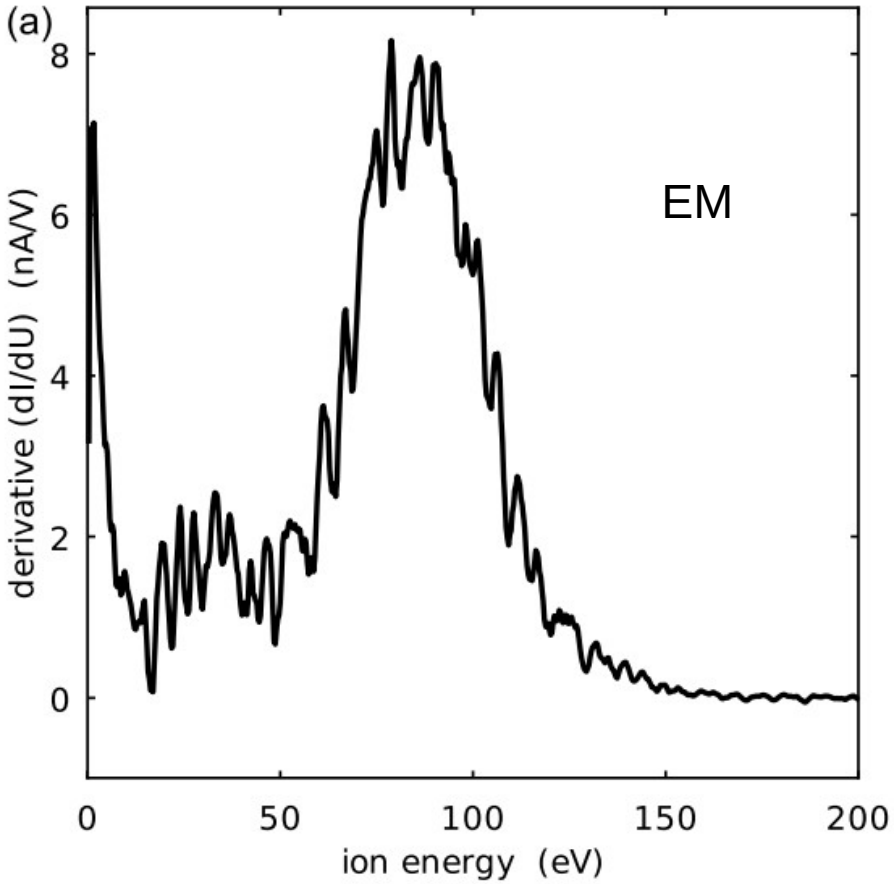
Tests in a secondary HEMPT plasma

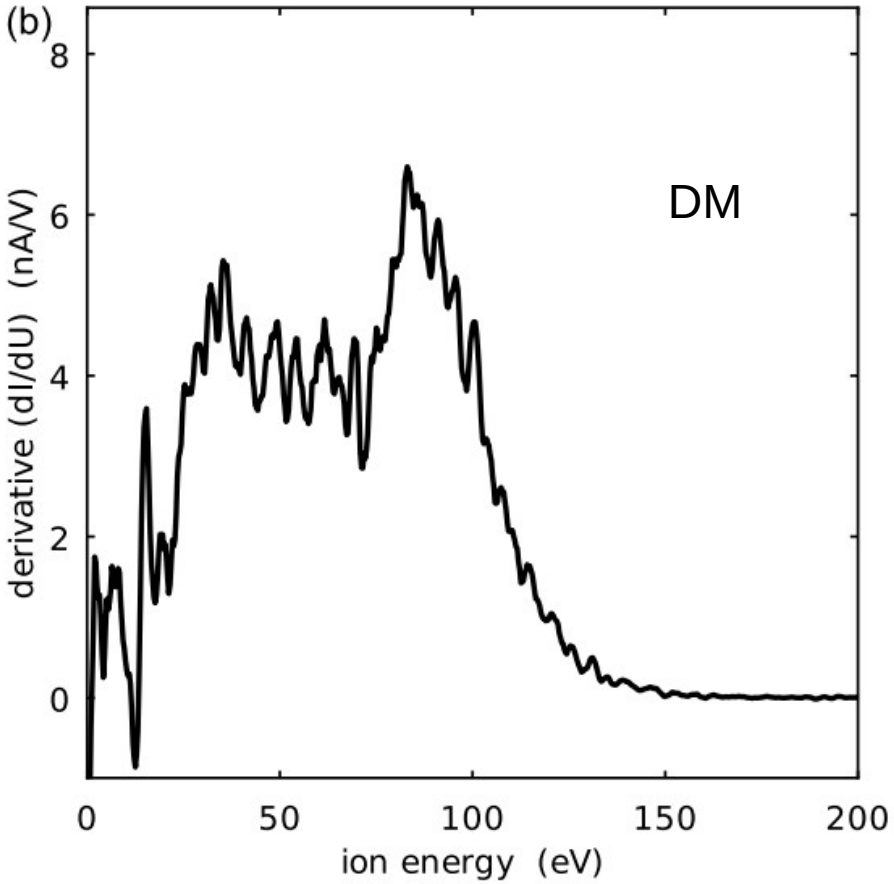
Mounting Positions in Thales Test Facility ULAN



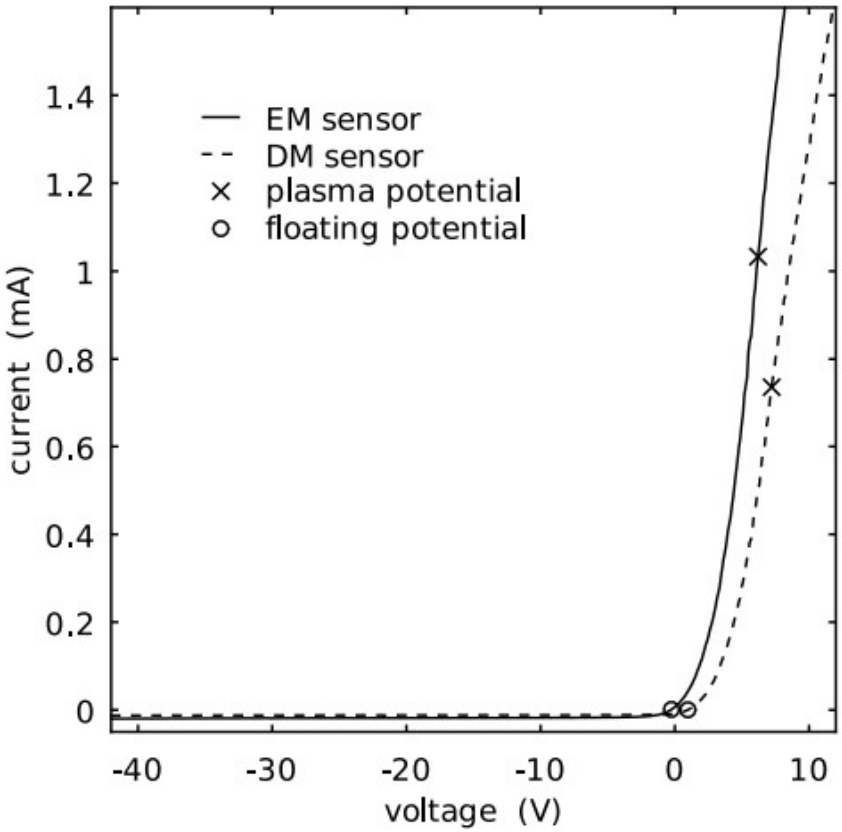
Demonstrator Model (DM) and Engeneering Model (EM) relative
To the HEMPT. (On the H2Sat: 55 cm.)

RPA Measurements in the HEMPT secondary plasma





RPA Measurements in the HEMPT secondary plasma



LP characteristics obtained from the two sensors EM and DM.

Plasma potentials: 6.2 V (EM)
7.2 V (DM)

Electron temperatures: 2.3 eV (EM)
2.2 eV (DM)

Electron densities: 8.2×10^{13} m^{-3} (EM)
5.9×10^{13} m^{-3} (DM)

Conclusions

Conclusions

- A suitable test environment for testing the EPDP and characterization of the plasma sensor has been set up
- Plasma sensor successfully tested
- Electronics tested sucessfully (not yet in vacuum and thermal tests)

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