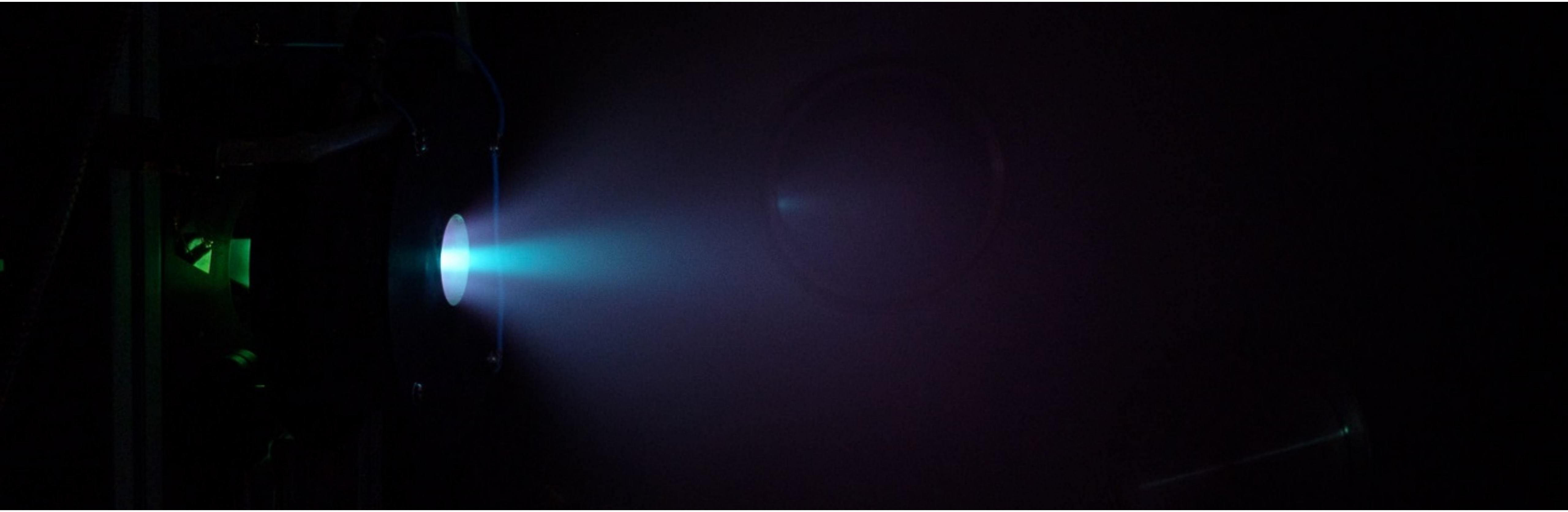
16/10/2018 EPIC Workshop. London, UK.



Experimental performances of the HPT-05M prototype in different laboratory conditions

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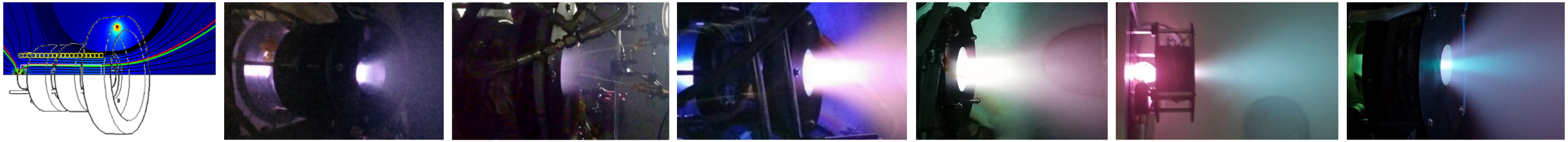
Presentation outline

- Introduction
- The HPT-05 platform
- The HPT-05M Test Campaign and Experimental Setup
- Test results
- The HPT-05M Test Campaign in ESA-EPL
- Conclusions and future work

Introduction

Background of SENER & UC3M joint collaboration on HPT development

- Collaboration between SENER and UC3M started under an ESA GSP Contract for preliminary analysis of the HPT technology capabilities.
- It continued with the agreement to design and develop a 1kW prototype → HPT-05.
- This experimental platform was firstly ignited at ESA EPL in October 2015.
- In May 2016, the prototype was tested at UC3M new EP test facility.
- Extensive test campaign on the Prototype took place in late 2016-early 2017.
- HPT-05M is an evolution of the initial prototype that is being tested in 2018.



January ‘15 → October ‘15 → May ‘16 → December ‘16 → February ‘17 → December ‘17 → February ‘18

The HPT-05M platform

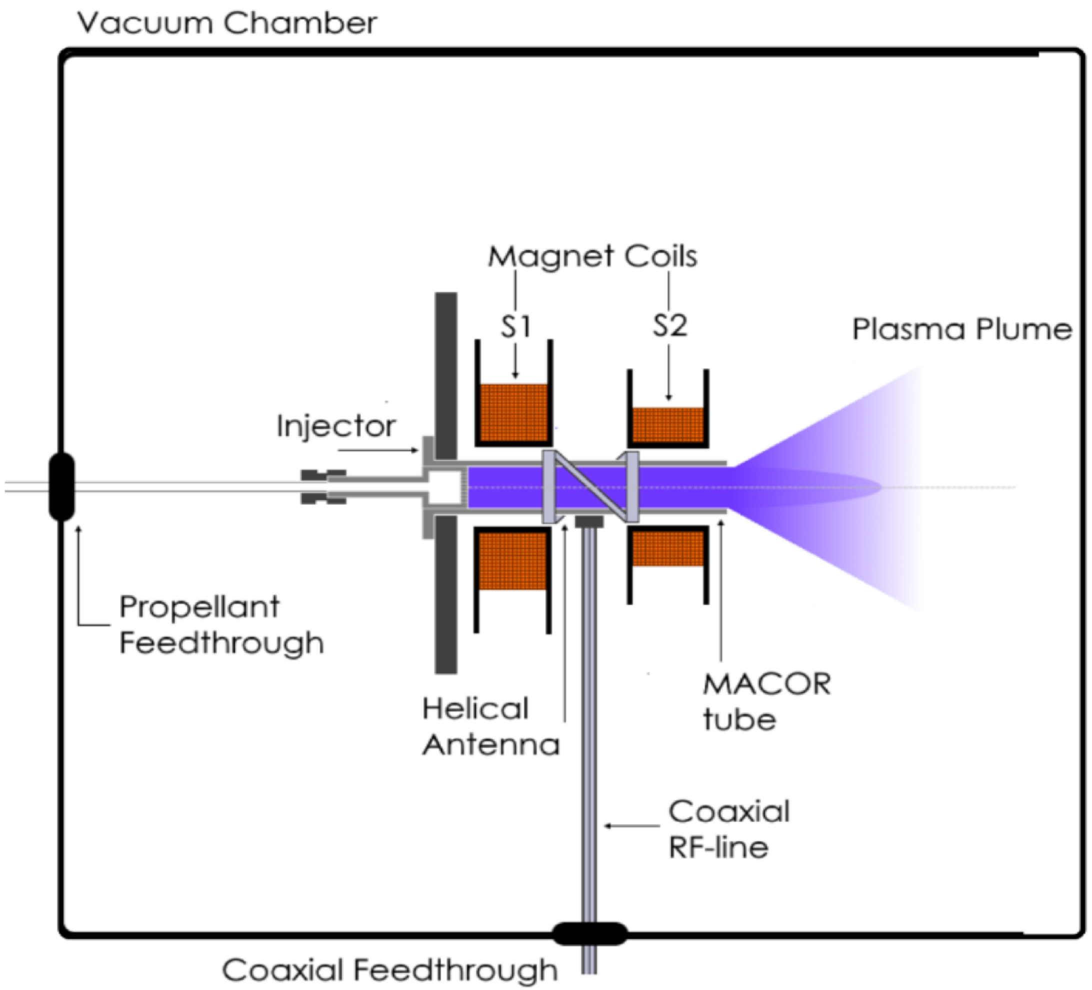
HPT-05M main physical parameters and operation range

HPT-05M main physical parameters

Ionization chamber	Length: 150 mm (nominal); Inner diameter: 20 mm
Antenna	Half-helical antenna; 75 mm length
Internal field generator	Single copper coil on spool; 435 turns Mean coil radius: 42.5 mm

HPT-05M operating range

Propellant	Argon and Xenon
Mass flow rate (Ar)	5-50 sccm Ar 2.5-10 sccm Xe
Power input at RF generator	350-600 W
Magnetic field in chamber	0-1500 G
RF frequency	13.56 MHz

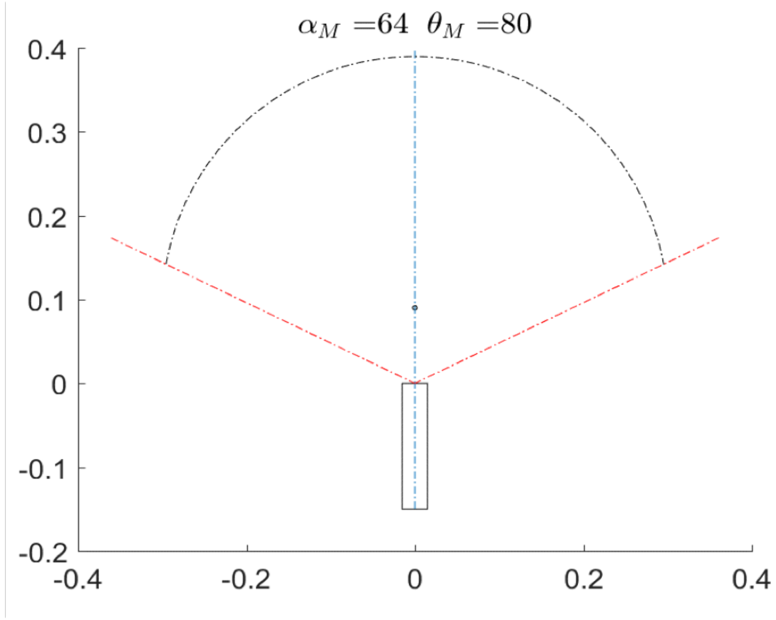


The HPT-05M Test Campaign and Experimental Setup

The UC3M-EP2 test facility and diagnostics systems

- EP2 Lab Vac Chamber was installed by Leybold on December 2015 and started operation on March 2016.
- Non-magnetic stainless-steel vessel with ∅1.5m, L=3.5m and ultimate dry pressure of 10^{-7}mbar:
  - Intrusive techniques: radio-frequency compensated Langmuir probes, Faraday probes, emissive probes, and a retarded potential analyser.
  - Non-intrusive tools such as the optical spectroscopy → paper 164 in session 62.
- Probes are hold on a rotational arm for radial-azimuthal scans at the plume expansion region.
- Estimation of, among others: η_u, n, T_e, j_i Ion Energy Distribution Function (IEDF).

Sketch of the region swept by the intrusive probes [m] during the first semester of 2018.



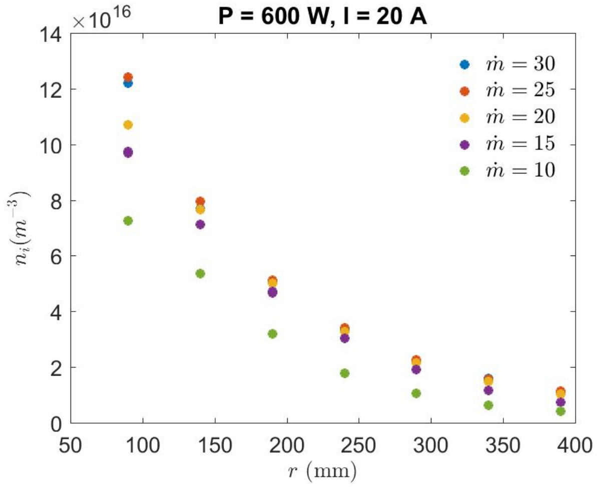
SENER uc3m Universidad Carlos III de Madrid EP2 Equipo de Propulsión Espacial y Plasmas

Test Results (1/4)

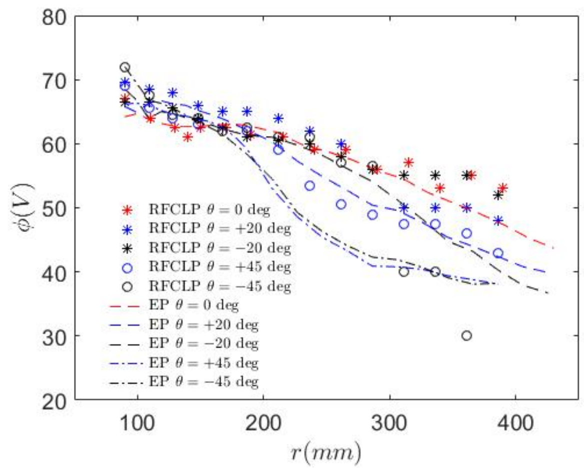
Test campaign outline

The test campaign could be split into two conceptual blocks:

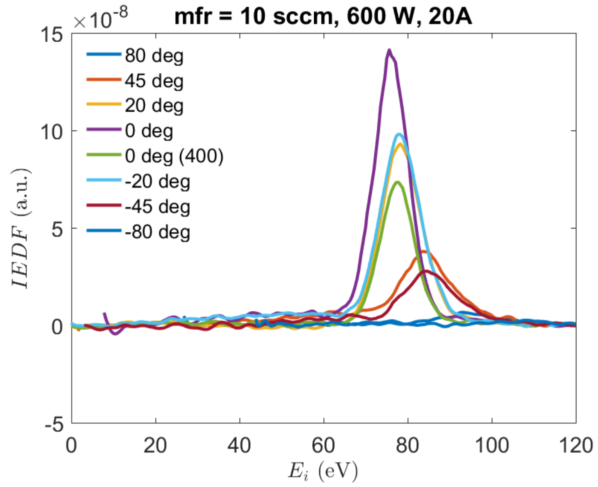
- The first one has consisted of a parametric analysis based on the optimisation of some propulsive figures such as the propellant utilisation η_u.
- The second block has been focused on the plasma plume characterisation for those cases identified as of highest interest.



Plasma Density, radial profiles measured by RFCLP. Argon MFR scan.



Plasma potential EP (direct measurements) vs RFCLP (IV postprocessed).

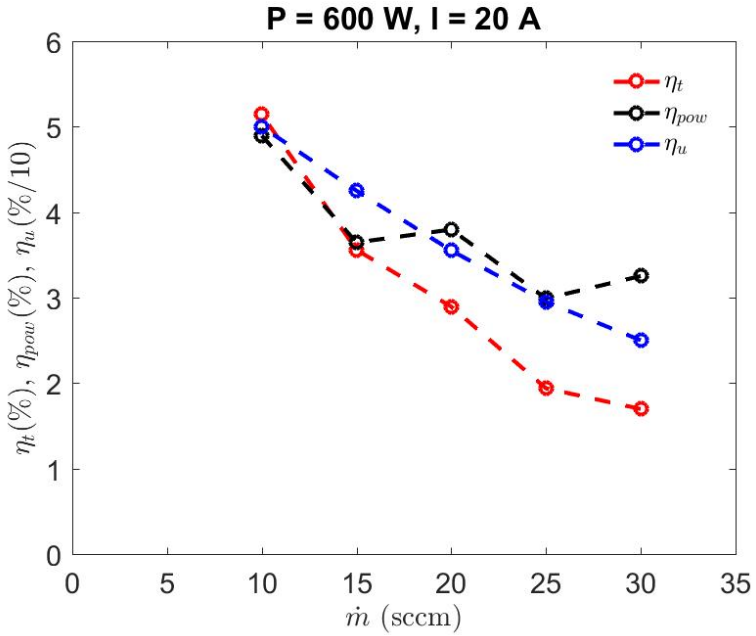


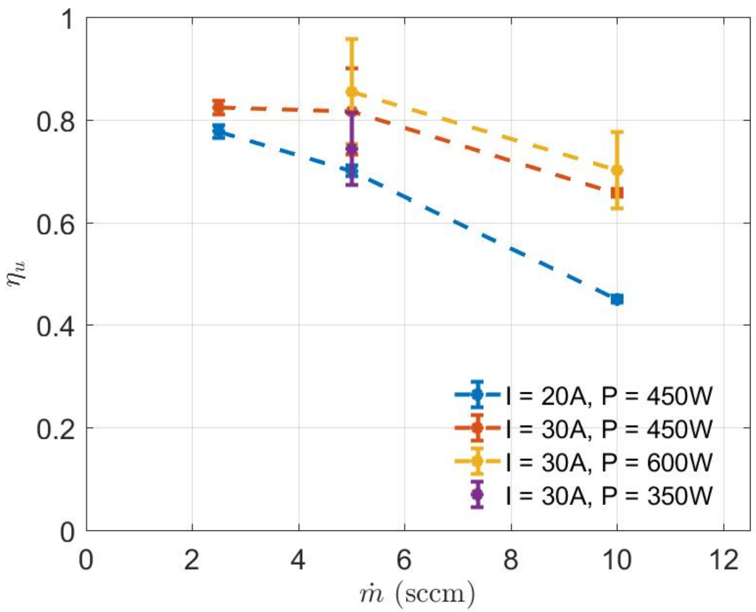
RPA measurements at different angular positions

Test Results (2/4)

Mass flow rate scan & derived performances

- Argon (left)
  - 600 W
  - 1000
- Xenon (right)
  - 350, 450, 600 W
  - 1000-1500 G



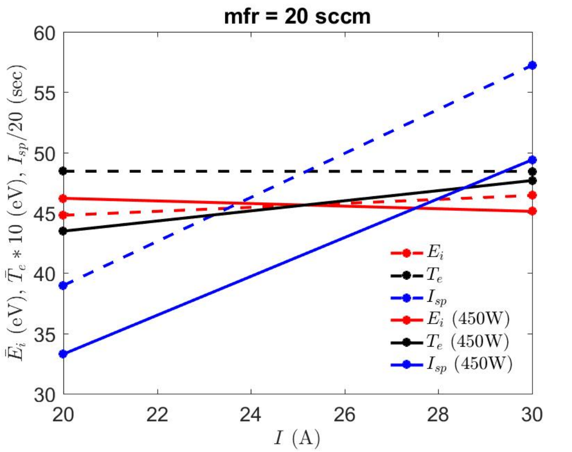


Conclusions:

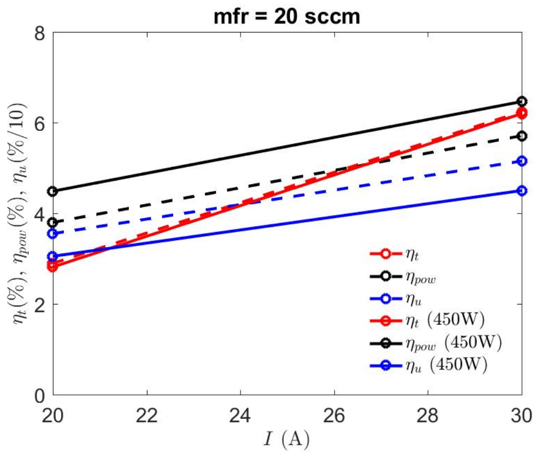
- The lower the mass flow rate is (above a certain threshold), the larger the propellant utilisation becomes.
- It exceeds 50 % for Argon and 80 % (or beyond) for Xenon.
- Thrust and power efficiencies are estimated by using a global model described in the proceeding.

Test Results (3/4)

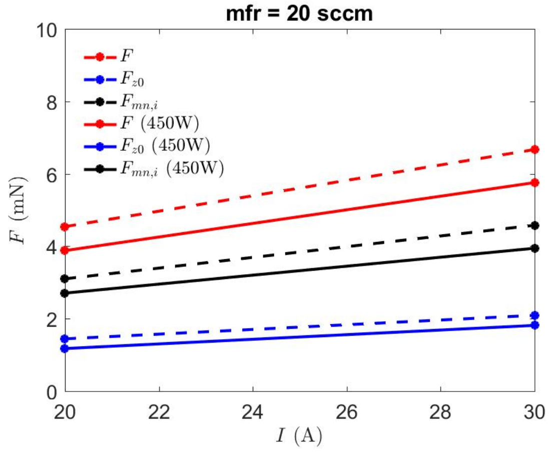
Magnetic field strength & derived performances (Argon)



Ion energy (eV), electron temperature $10 \cdot T_e$ (eV), and specific impulse $I_{sp}/20$ (sec)



Utilization, thrust and power efficiencies



Estimated total thrust and thrust contributions

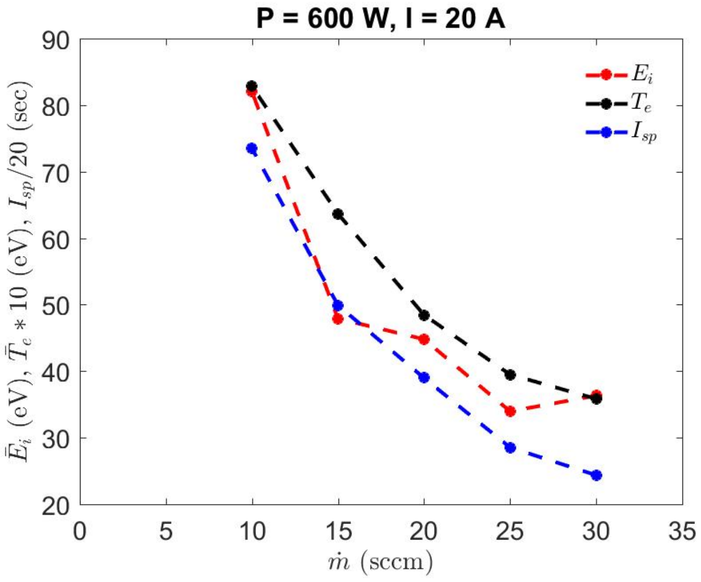
- The above figures are derived from the parametric analyses for Argon propellant.
- A similar analysis has been performed with Xenon. For the case 1500G, 450W and 5sccm:
  - $\eta_u \simeq 81$ %
  - $\eta_t \simeq 7.7$ %.
  - $\eta_{pow} \simeq 4.1$ %
  - $F_{z0} = 2{,}1$ mN, $F_{MN} = 3.9$ mN, $F_T = 6$ mN.
  - $I_{sp} = 1185$ s
  - $T_e = 10$ eV, $E_i = 63$ eV

Test Results (4/4)

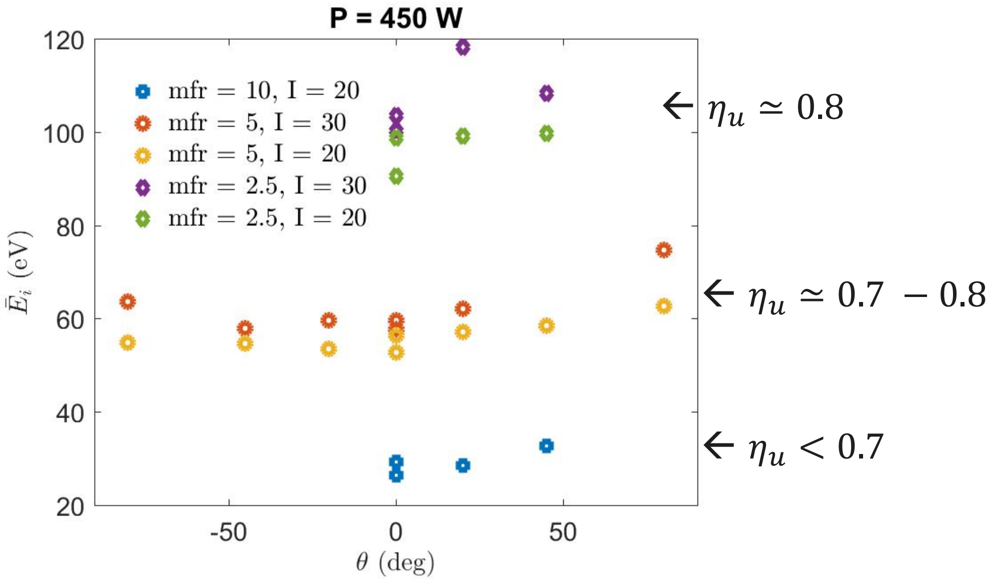
Ion energy – Electron temperature correlation

There is a good correlation between propellant utilisation, electron temperature, and ion energy.

- Higher η_u → higher T_e. Firstly, being efficient ionising. Then, the excess of power seems to be easily converted into electron thermal energy.
- Higher T_e → higher E_i. The electron thermal energy is converted to ion kinetic energy.



Argon MFR scan. Ion mean energy, electron temperature and specific impulse.



Xenon mfr and magnetic field scan. Ion mean energy.

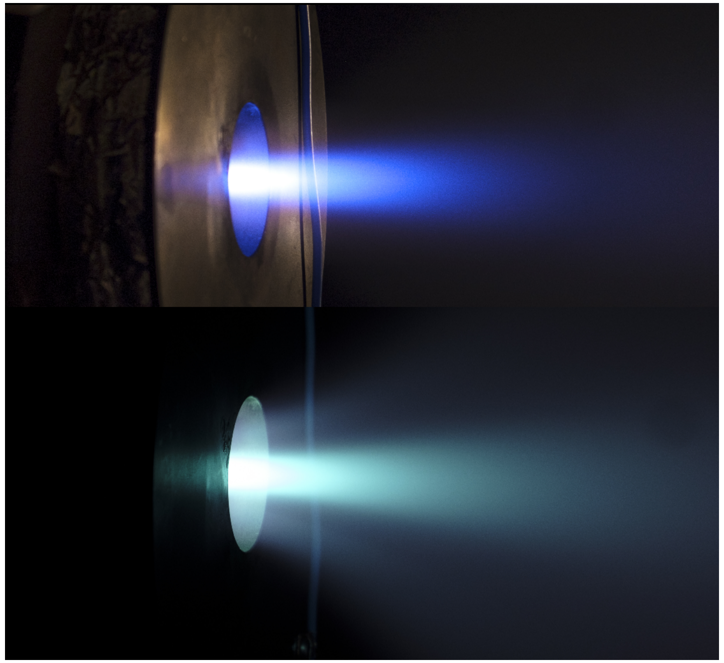
The HPT-05M Test Campaign in ESA-EPL

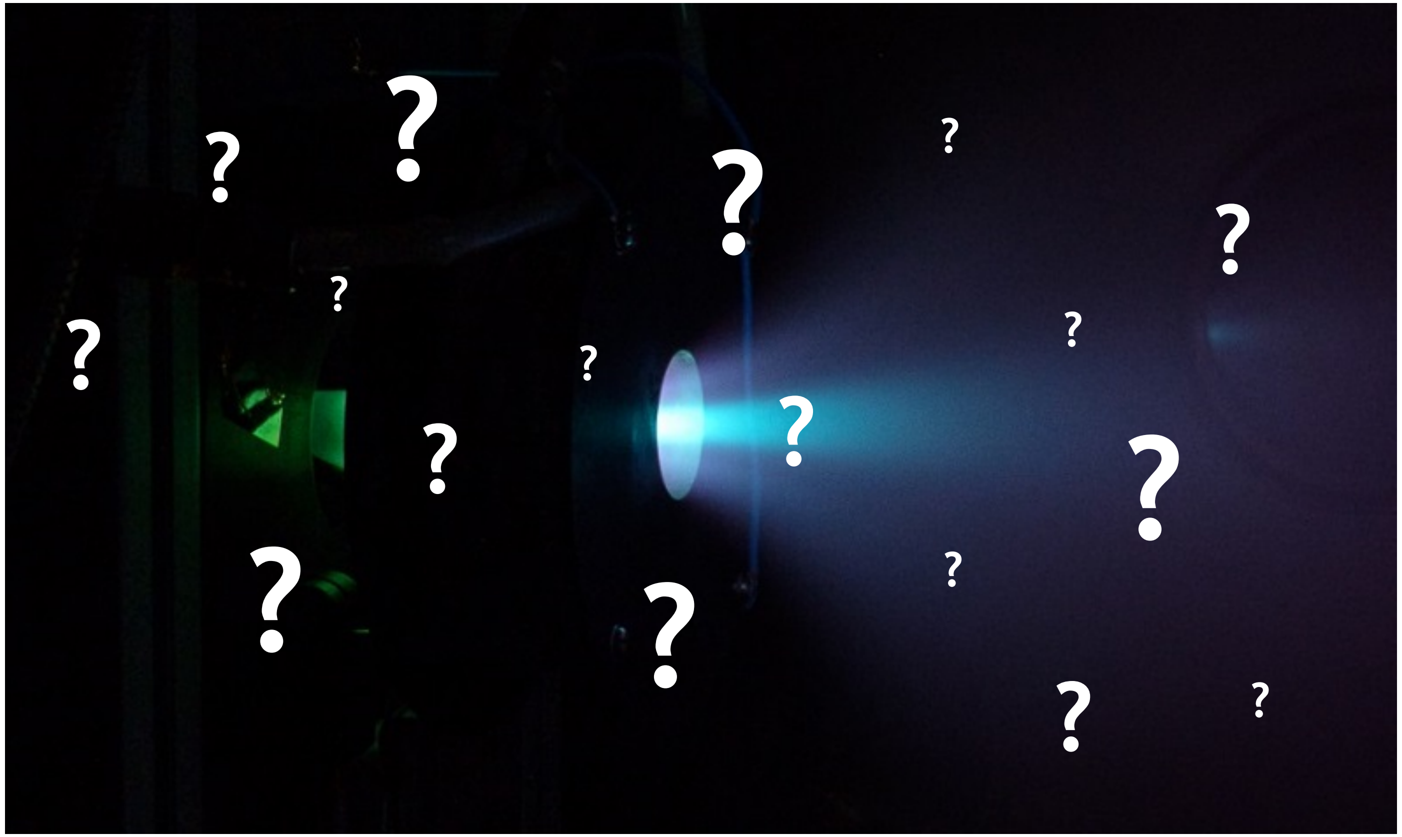
Direct thrust measurement attempt

- In June 2018, an attempt was made to directly measure the thrust of HPT-05M at ESA-EPL.
- SPF Vacuum chamber and ALTA 1-Axis Optical thrust balance were used for the test.
- Additionally, one UC3M manufactured Faraday Probe was installed on the chamber's rotary arm.
- Results:
  - The noise and the random response of the thrust balance are in the same order or even larger than the measured/assessed thrust.
  - There was a clear lack of repeatability in the measurements.
  - The largest drifting effect was due to the thermal heating of the wires supplying power to the coil.
  - FP was too far downstream for its measurements to be considered valid.
- Conclusions:
  - After analysing the post-processed thrust data, and because of the high uncertainty inherent to these measurements, a reliable value of the HPT05M thrust cannot be declared.
  - The new HPT-03 BB will include modifications in the IFs to improve its integration on a balance.

Conclusions and future work
Towards TRL5

- Achievements in these test campaigns:
  - Characterisation of the plasma plume.
  - Preliminary estimation of propulsive performances vs mfr, Ar/Xe, P, B.
  - Estimation that this prototype has reached the same efficiencies of other prototypes.
- Next steps:
  - A new PA is currently being integrated within the RFGPU. Coupling tests to the TU are expected by the end of 2018.
  - Direct T measures at UC3M Laboratory in early 2019.
  - Currently developing a HPT-03 TU engineering model under a recently signed GSTP Project with ESA.
  - By the end of 2019, the expected TRL will be 5.
  - We will aply for a H2020 Grant to continue to higher TRLs.





THANK YOU

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