UPM PlasmaLab

AERnnova

Supersonic ion beam characteristics of the ALPHIE (Alternative Low Power Hybrid Ion Engine) plasma thruster

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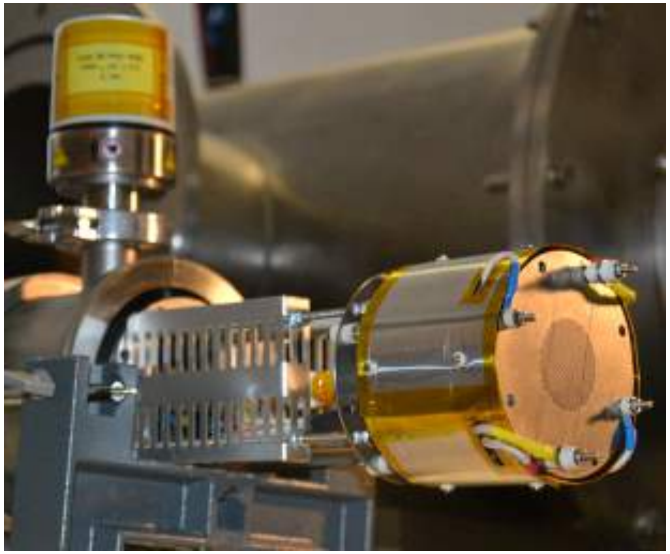
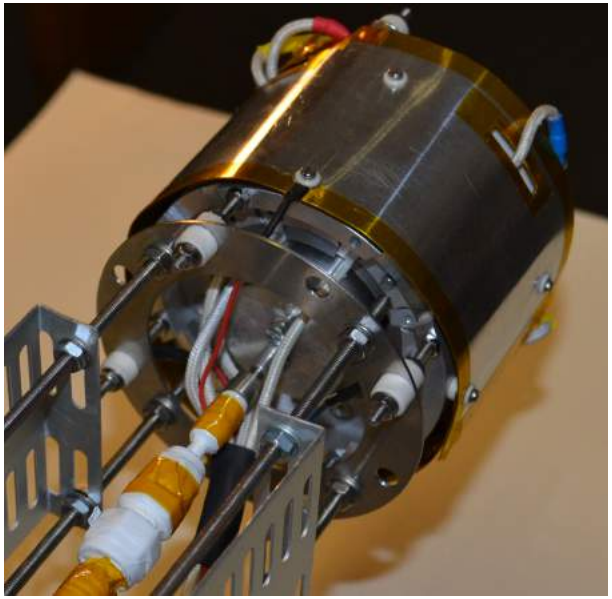
The ALPHIE plasma thruster

The ALPHIE design is a new technology of a plasma accelerator for satellite propulsion in space. Four prototypes have already been tested



This small 10 X 15 cm plasma thruster operates with less than 450 W power and is intended for small and medium sized satellites (100-200 Kg) where most commercial propulsive systems (kW range) are difficult to implement.



Our eventual commercial target is this growing LEO/MEO satellite market, ...

Envisaged applications

- Station keeping
- Orbital drag compensation in LEO/MEO
- End-of-life disposal of satellites
- Flight formation

EPO Patent application PCT/EP 2015/074879

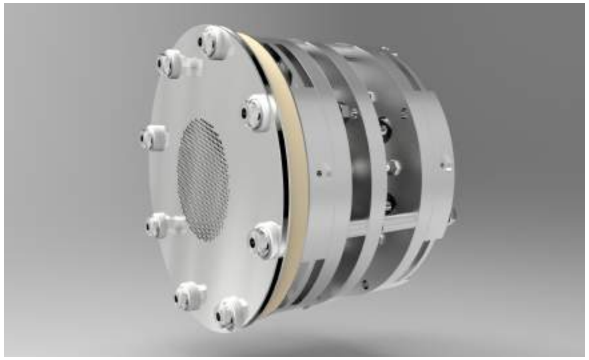
US Patent application 15/769,251

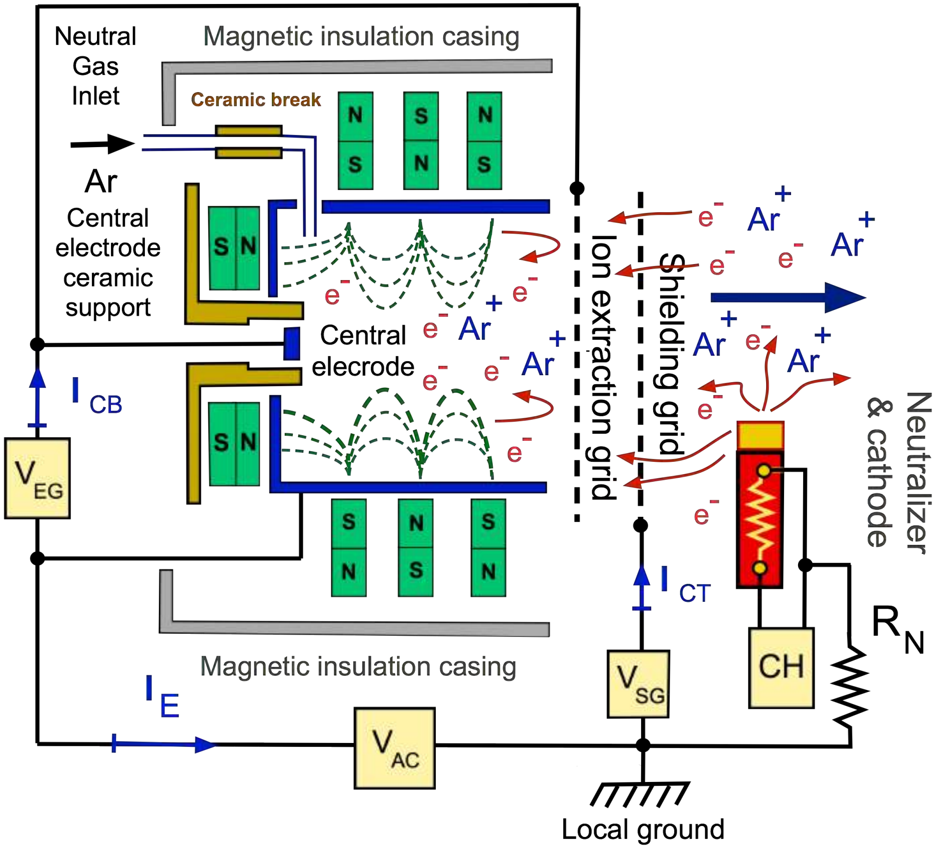
Free from ITAR restrictions

New technology for plasma acceleration

Operates with only **3** *DC power supplies* and one two are employed in normal operation. Direct electric connection with solar panels.

Only *one cathode* is employed as electron source for both plasma production and ion beam neutralization.





Grids are essential for plasma beam collimation.

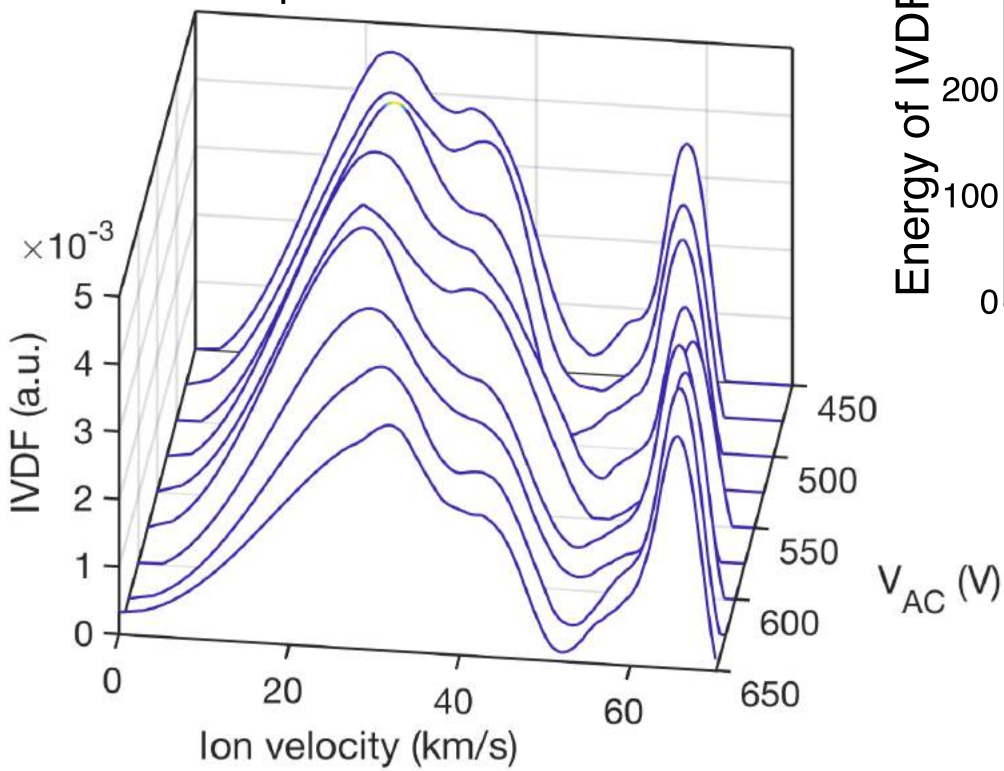
Grids are parallel and made of a drilled stainless steel plate. The electric potentials are always below kV range.

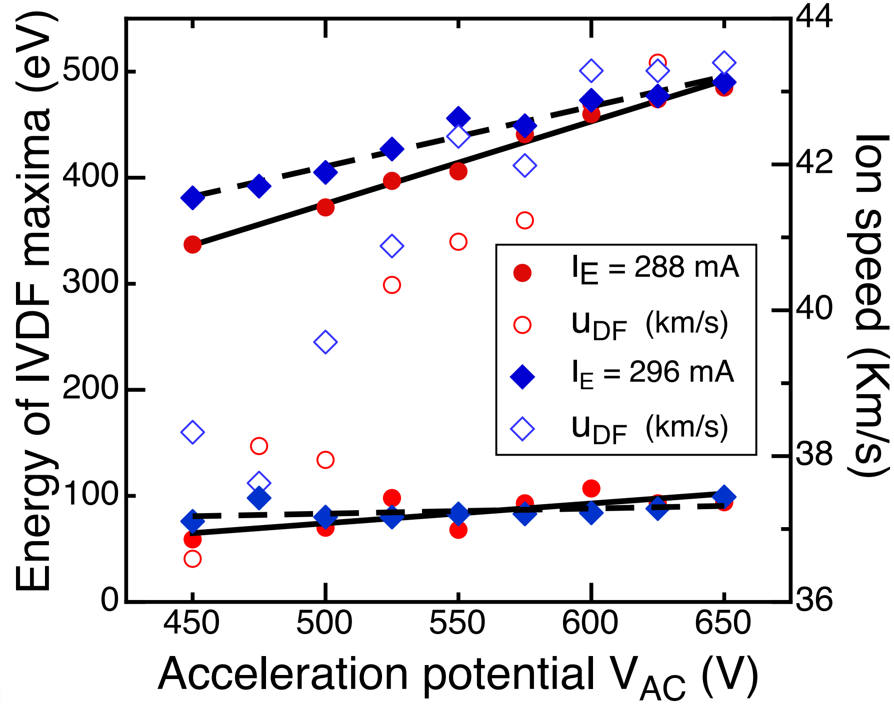
Variable throttle operation controlled by the acceleration voltage Vac.

Several units can be clustered sharing the acceleration voltage power supply.

The IVDFs measured at a fixed point

V_{CG} = 0.0 V
V_{EG} = 200 V
I_E = 296 mA
Q = 0.8 sccm
$p_a = 6.0 \times 10^{-5}$ mbar

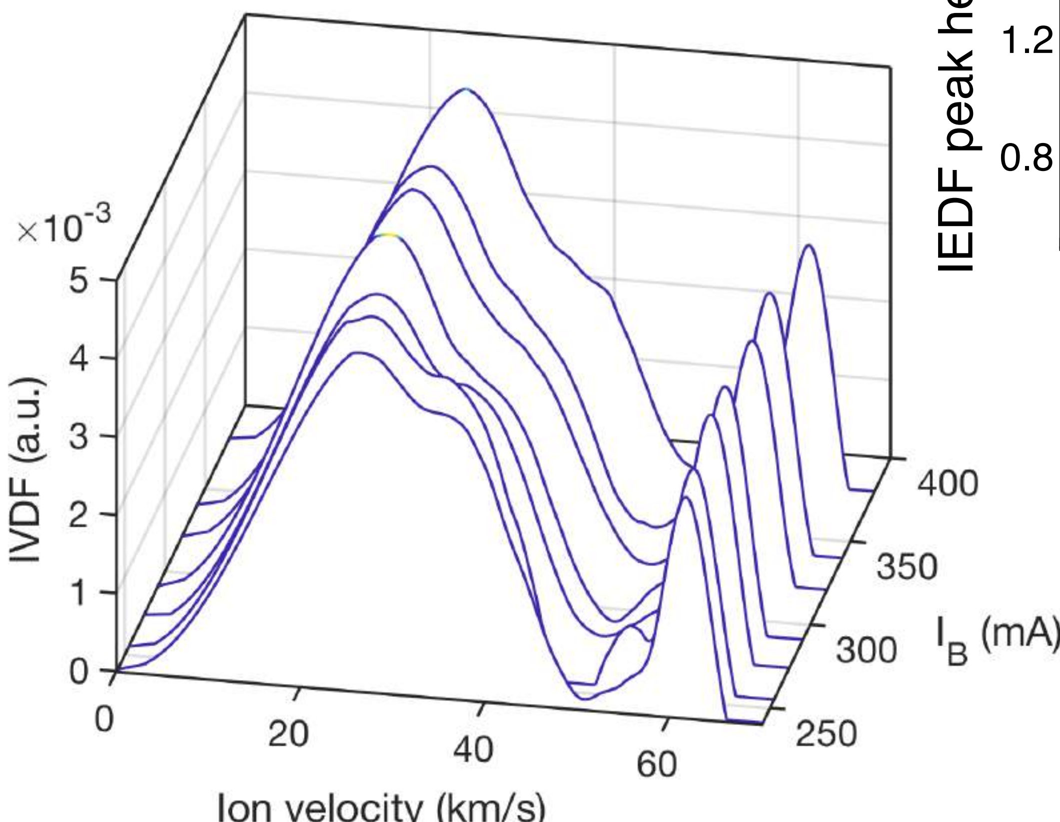


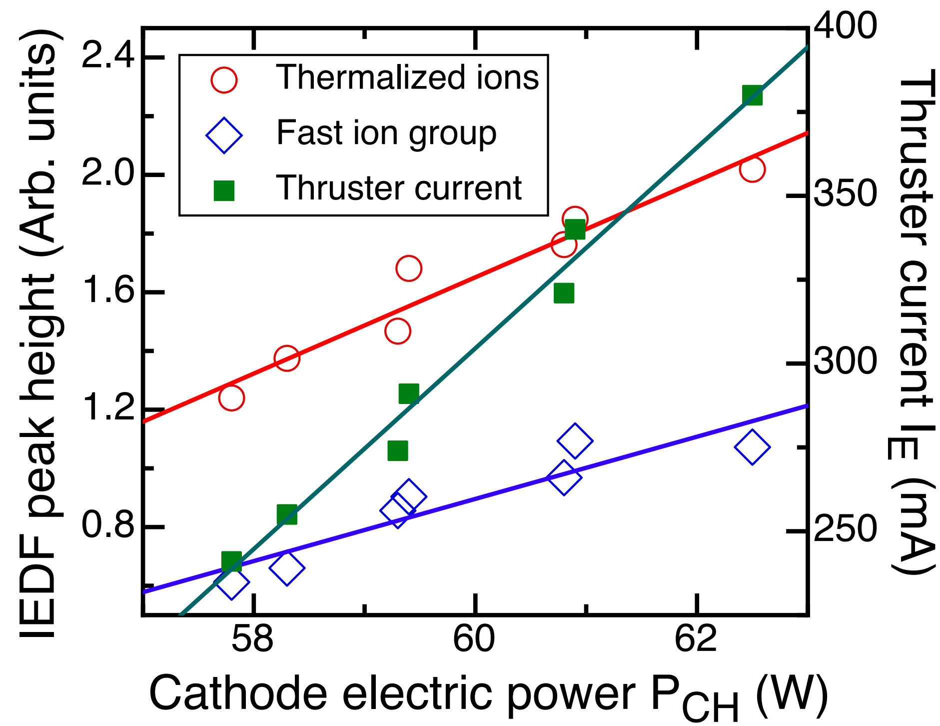


The energy of the fast ion group is governed by the acceleration voltage (throttle)

The IVDFs measured at a fixed point

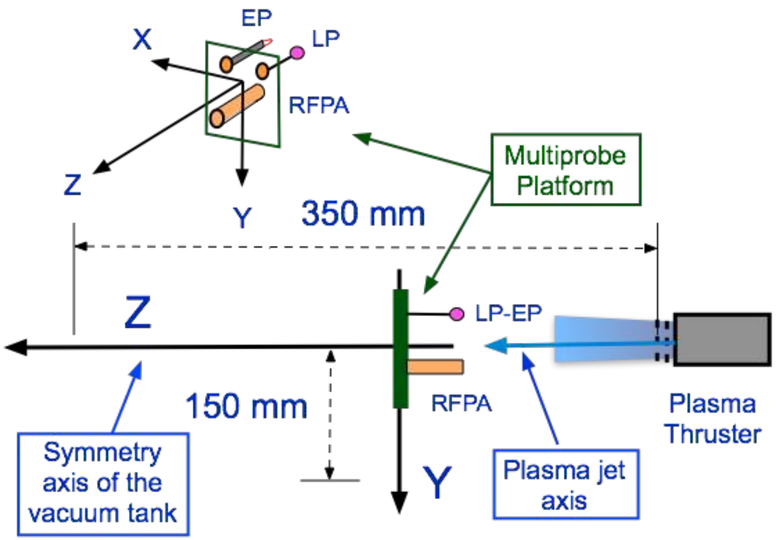
V_{CG} = 0.0 V
V_{EG} = 200 V
V_{AC} = 550 mA
Q = 0.8 sccm
pa = 6.0 × 10^{-5} mbar

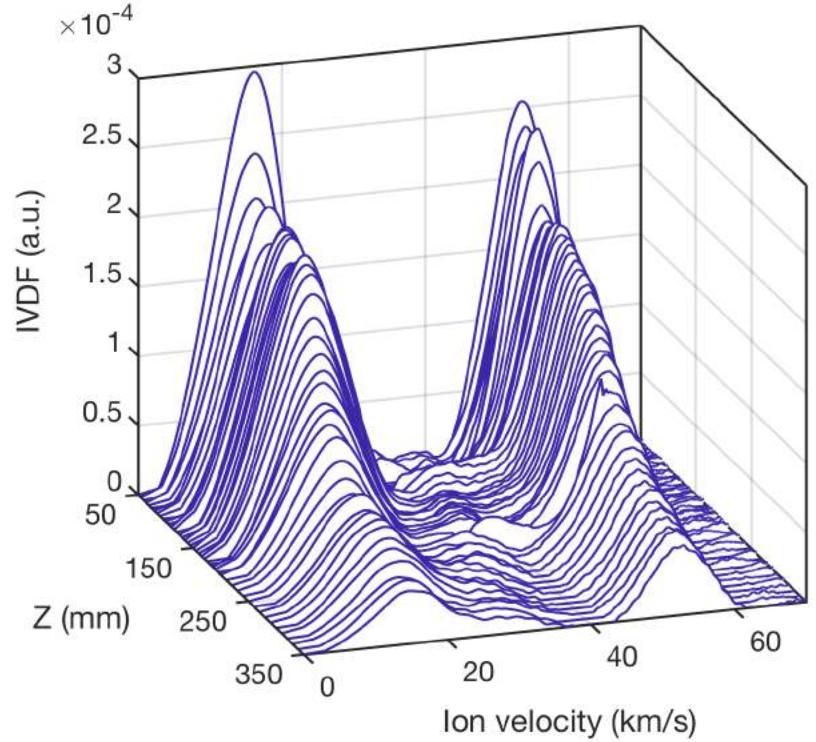


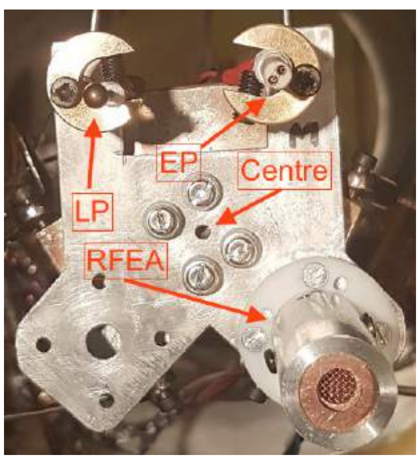


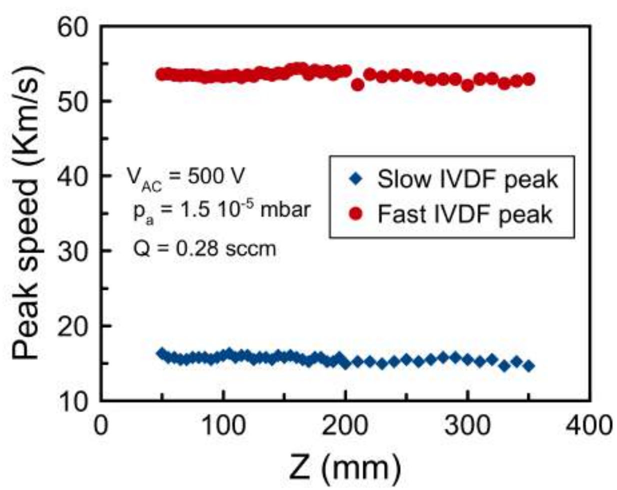
Ion production and plasma beam density essentially depend on the electron flux from the cathode governed by the electric power P_{CH}

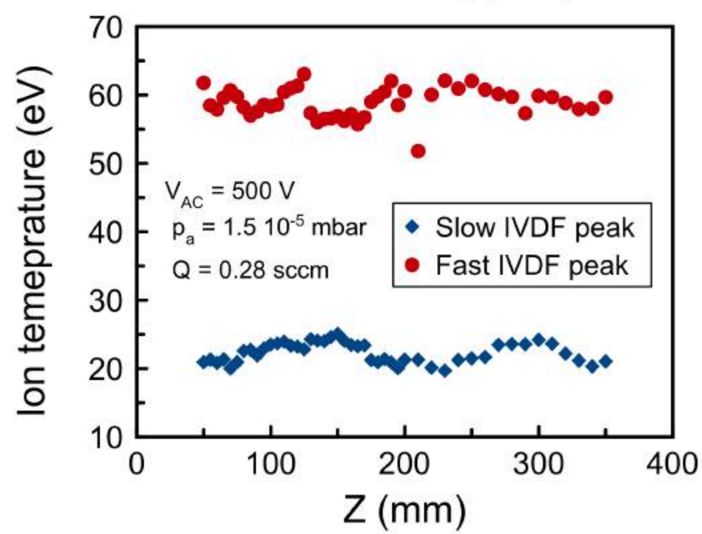
The IVDFs along the plasma stream



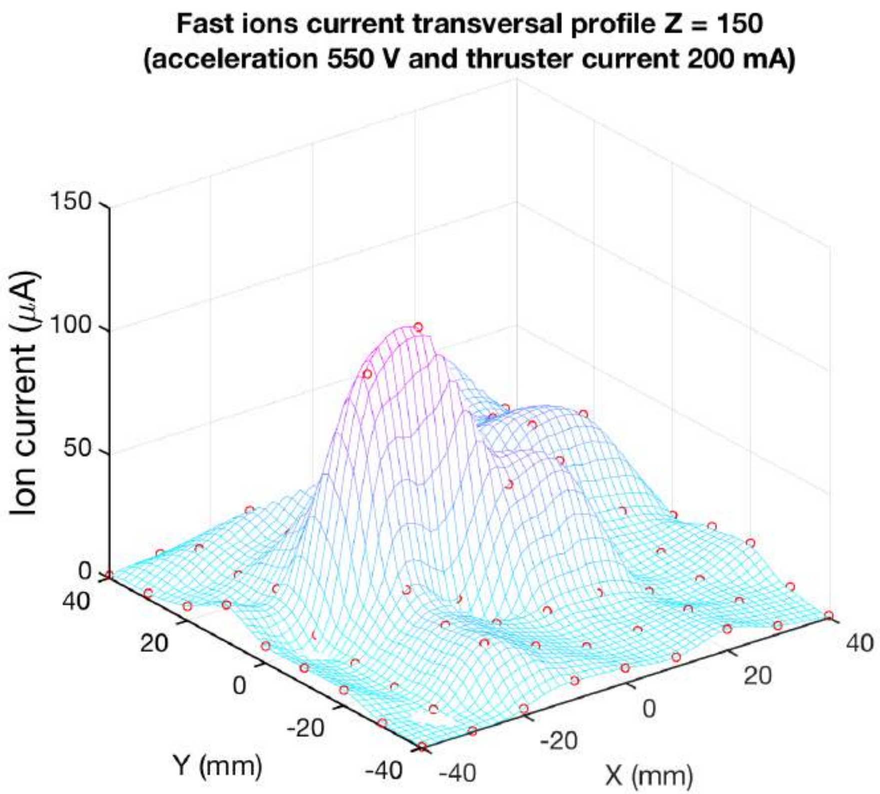


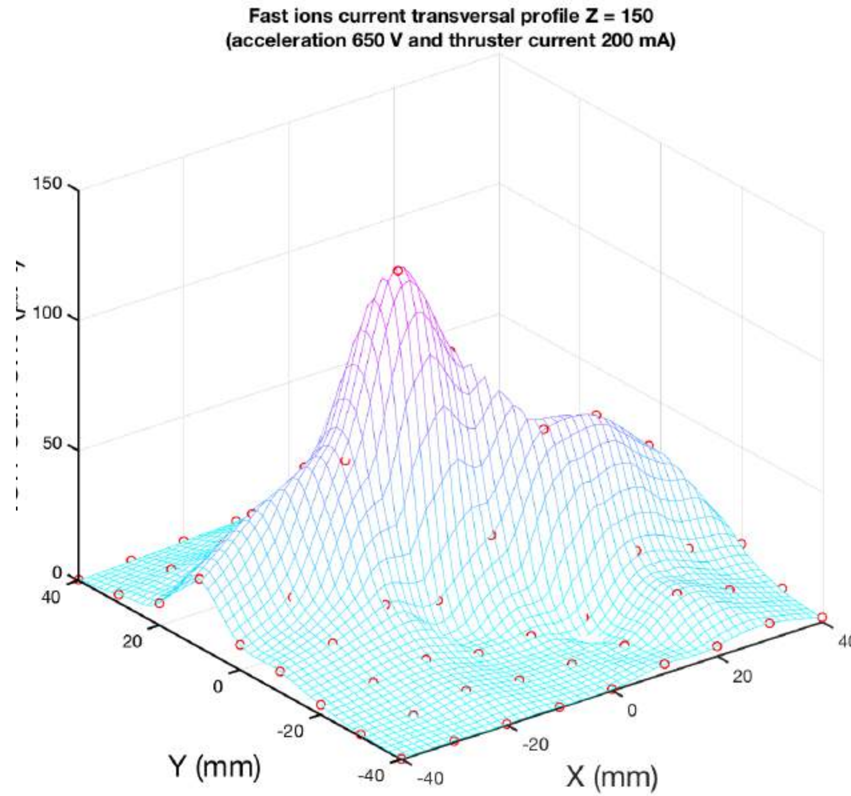






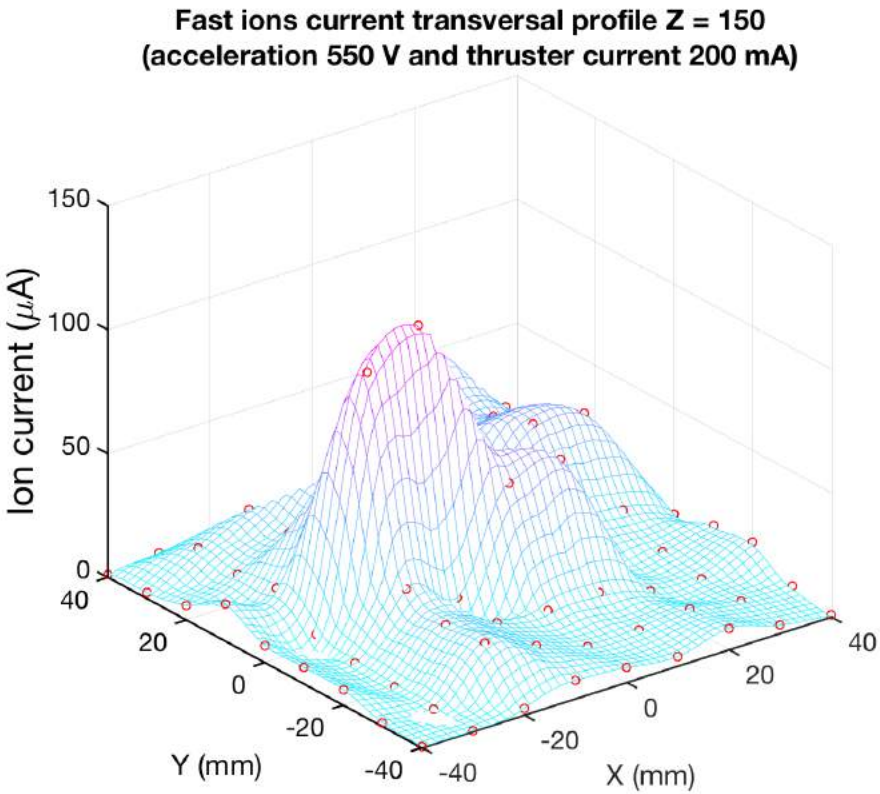
Cross sections of plasma stream

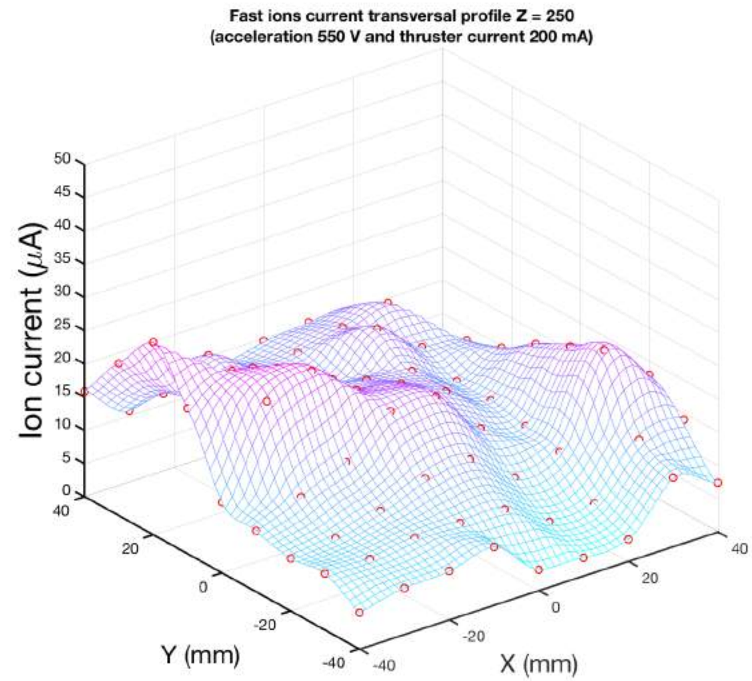




- The transversal ion beam current at a fixed point increases with the acceleration voltage V_{AC}, which governs the throttle.

Cross sections of plasma stream

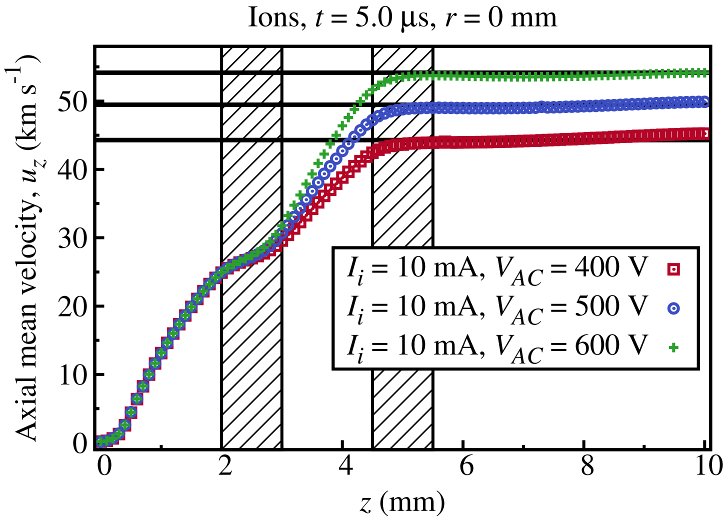


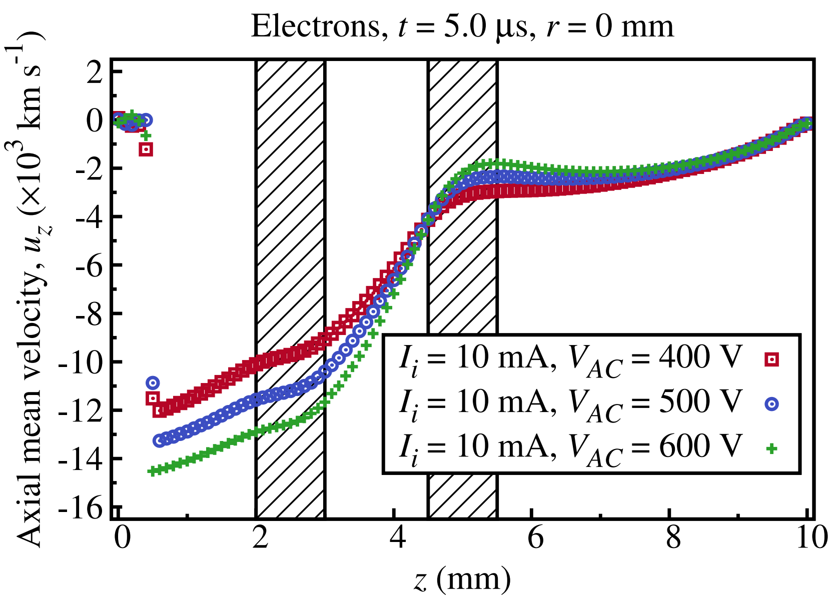


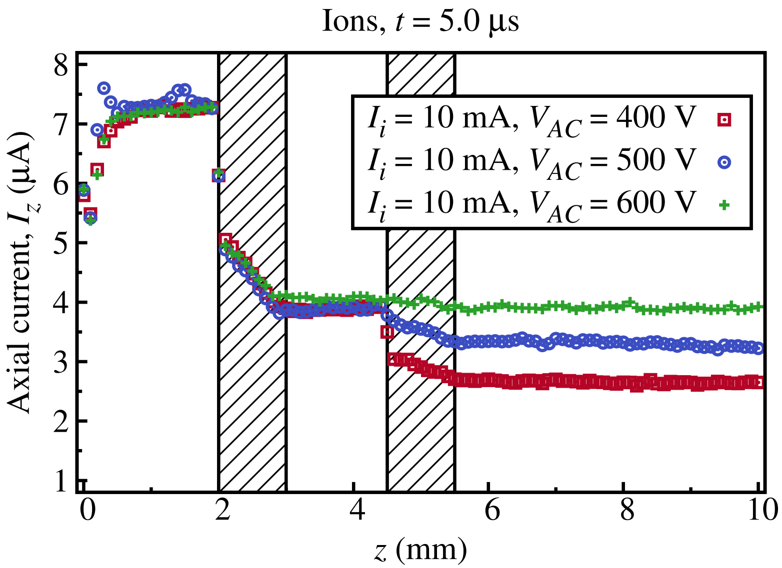
- The ion beam current decreases with the distance from the exit section of the ALPHIE plasma thusrter for a fixed acceleration voltage V_{AC}

PIC simulations of charge transport through the grid system

- Grids are indicated by shadow regions.
- The numerical simulations confirm the charge transport processes.
- The strong ion collimation compensates the loss of particles at the grids.





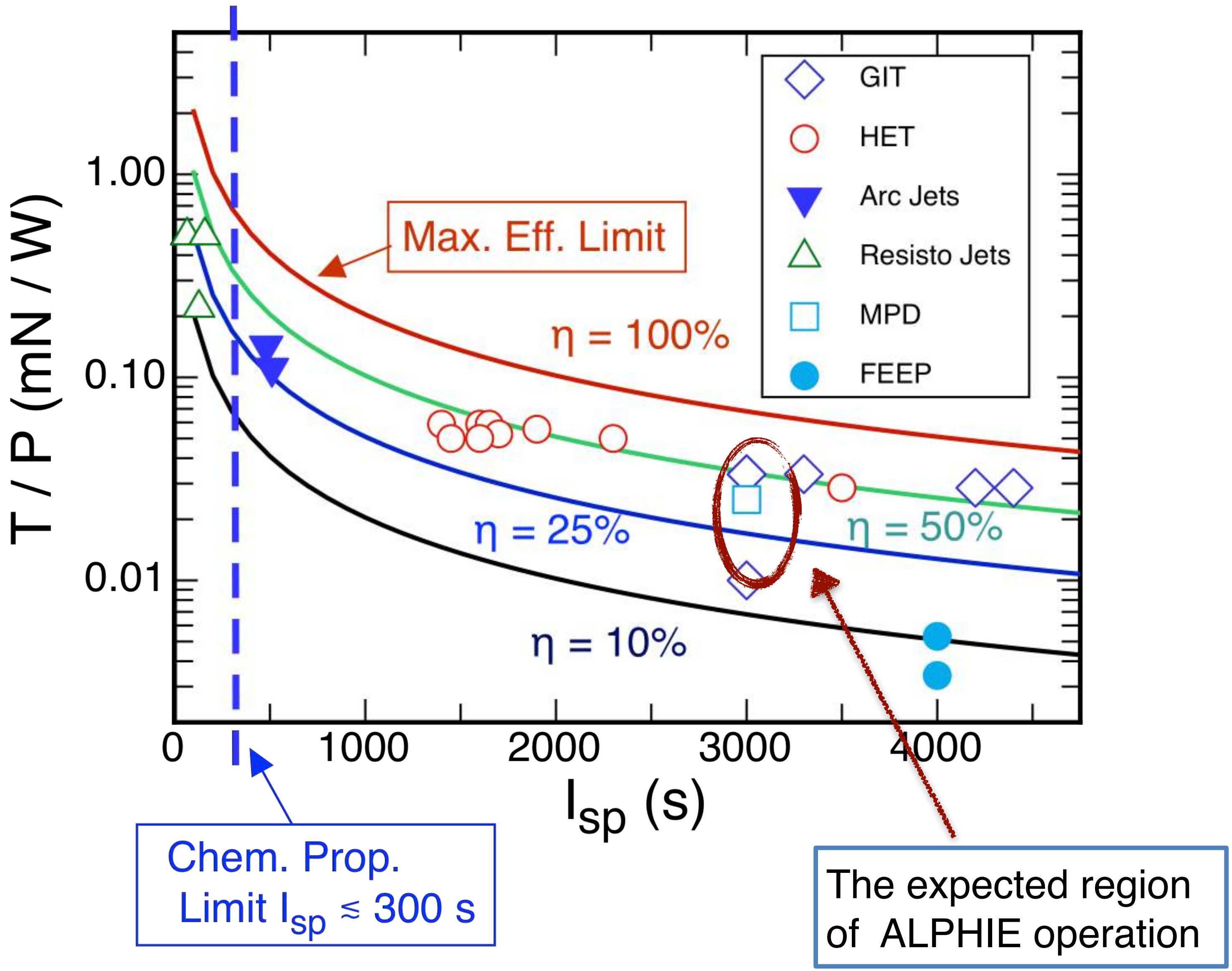


ALPHIE performance

- **Throttleable operation:** The ion outflow could be controlled by either the acceleration potential, the neutral gas injection or by the flow of neutralizing electrons.
- **Variable specific impulse:** Up to the order of $I_{SP} \simeq 3000$ s with (estimated) thrusts in the range of 1.0-0.5 mN and trust-to-power ratios of about $T/p \simeq 0.05$ mN/W.
- **Clustering:** Few units can share the electric circuit for higher trust and/or spin
- **Low DC electric power consumption:** The system operates using DC power supplies and involved voltages are always below 900 volts. This fact simplifies the PPU design and reduces the electric power to the range 200-300 W.
- **No high voltages for ion acceleration:** The grids are electrically biased below the kV range and essentially control the ion outflow. This reduces the wear caused by ion bombardment, eliminates grid sparking and simplifies the PPU design.
- **Adaptable:** Operates with either Xenon or Argon which reduces the budget for qualification tests.
- **Low gas flow rates:** The ionization of the neutral gas is produced by the highly efficient magnetic trapping of ionizing electrons. Therefore, the required neutral mass flow rates of Argon or Xenon could be as low as a few sccm(*)

(*) sccm: standard cubic centimeters per minute or STP ml per minute.

ALPHIE compares to …



ALPHIE development status

	Description	Status	TRL
1	Basic concept of the ALPHIE plasma accelerator	Validated in the laboratory. Ion acceleration and throttle control validated in the laboratory.	Level **4** (laboratory)
2	Analysis of ALPHIE operation modes	Operation modes validated in the laboratory. The different options for throttle control have been determined.	Level **4** (laboratory)
3	The grids and the ion optics.	Design and concepts are validated in the laboratory. Advanced concepts under study.	Level **4** (laboratory)
4	Valve and gas feed system	Validated in the laboratory. Commercial solutions are available.	Level **4-9** (laboratory)
5	Electron sources for plasma production and ion beam neutralization	Validated in the laboratory. Commercial solutions are available.	Level **4-9** (laboratory)
6	Magnetic isolation of the thruster body.	Design of the external insulation casing validated in the laboratory.	Level **4** (laboratory)
7	Determination of the levels of thrust for the different operation modes	Laboratory estimations based on the measured ion currents. Determination of realistic levels of thrust from measurements of the ion energy spectrum.	Level **3** (laboratory)
8	Power processing unit (PPU)	Design requisites have been determined.	Level **2**

Relevant issues not yet fully addressed

	Description	Status
1	PPU design	The requisites are determined in the laboratory at breadboard level. Design would be simpler than other technologies and free from ITAR restrictions.
2	Measurements of the delivered thrust in a microbalance	We have a first design (thrust along one dimension) in collaboration with the UPM School of Mechanical engineering.

We are flexible in the terms of collaboration with partners with complementary experience interested in the technical development and the commercial exploitation of ALPHIE conception in the perspective of commercial and/or scientific missions.

For further information,

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Thank you for your time and interest

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