From ECRIS to Space Electrostatic Thruster

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Electrostatic Thruster

A space propulsion system uses the principle of action equals reaction to accelerate in space by ejecting propellant. This force is called **thrust** :

$$\vec{T} = \dot{m}\vec{v_e},$$

with $\dot{m}$ the mass flow rate and $\vec{v_e}$ the exhaust velocity. One kilogram of propellant allows the spacecraft to rise, in Earth's gravity g_0, for a certain amount of time called **specific impulse** :

$$I_{sp} = \frac{v_e}{g_0}.$$

An electric thruster is a type of space thruster that uses electrical energy to generate and eject its propellant mass [Goebel, 2008]. This type of propulsion reduces certain costs compared to its chemical counterpart and offers new mission opportunities. There are three categories, including **electrostatic thrusters**, which use electrical force to eject ions.

ECRIS as Electrostatic Thruster

Capable of producing intense currents of multi-charged ions, **ECRIS** would be an interesting choice for the design of a new electrostatic thruster. The high ion extraction speeds would make it possible to achieve high specific impulses or develop strong thrusts.

The objective of this research is to optimize an ECRIS from an electric propulsion perspective, prior to designing a new prototype adapted to the challenges and constraints of space travel.

Methodology

Several solutions for optimizing ECRIS are being considered, the most immediate being to adjust the parameters of the Child-Langmuir law :

$$I = \frac{4}{9}\epsilon_0 S\sqrt{\frac{2eQ_i}{M_i}}\frac{V^{3/2}}{d^2},$$

with ϵ_0 the vacuum permittivity, S the extractor open area, e the elementary charge, Q_i the ion charge state, M_i the ion mass, V the extraction voltage and d the extraction gap.

The experimental study of the influence of the parameters was carried out on a 10 GHz Microgan ECRIS, manufactured by Pantechnik (Figure 1). Its magnetic field is adjustable to produce singly charged or multiply charged, atomic or molecular particles. This source is mounted on the Tancrède test bench of the MOSAIC platform (Figure 2).

Results

By doubling the extraction voltage, the total current intensity and the argon ion flow rate are multiplied by 3, which is consistent with Child-Langmuir's law (Figure 3). The specific impulse, linked to the extraction speed, is multiplied by $\sqrt{2}$. The developed thrust increases by a factor of 4.3, the product of the previous multiples. It is therefore more affected by the ion flux.

Changing the gas from argon to xenon, while keeping the same source parameters, gives an equivalent thrust (Figure 4). The beam power is divided by a factor of $\sqrt{2}$. Xenon therefore provides a better thrust/power ratio.

Conclusions

Ion flow is the factor that needs to be addressed to produce more thrust. Future optimization efforts will therefore focus on the generation and extraction of multiply charged ions.

Xenon's superior TTPR may be a key parameter in onboard power engineering. Higher average charge states would have been expected, but the experiments were conducted at too low a power level.

The next step in this experimental study was to increase the diameters of the extraction device (Figure 5), inducing new plasma conditions. Tancrede, which was not designed to absorb such beam powers, broke down. The analysis is therefore still ongoing.

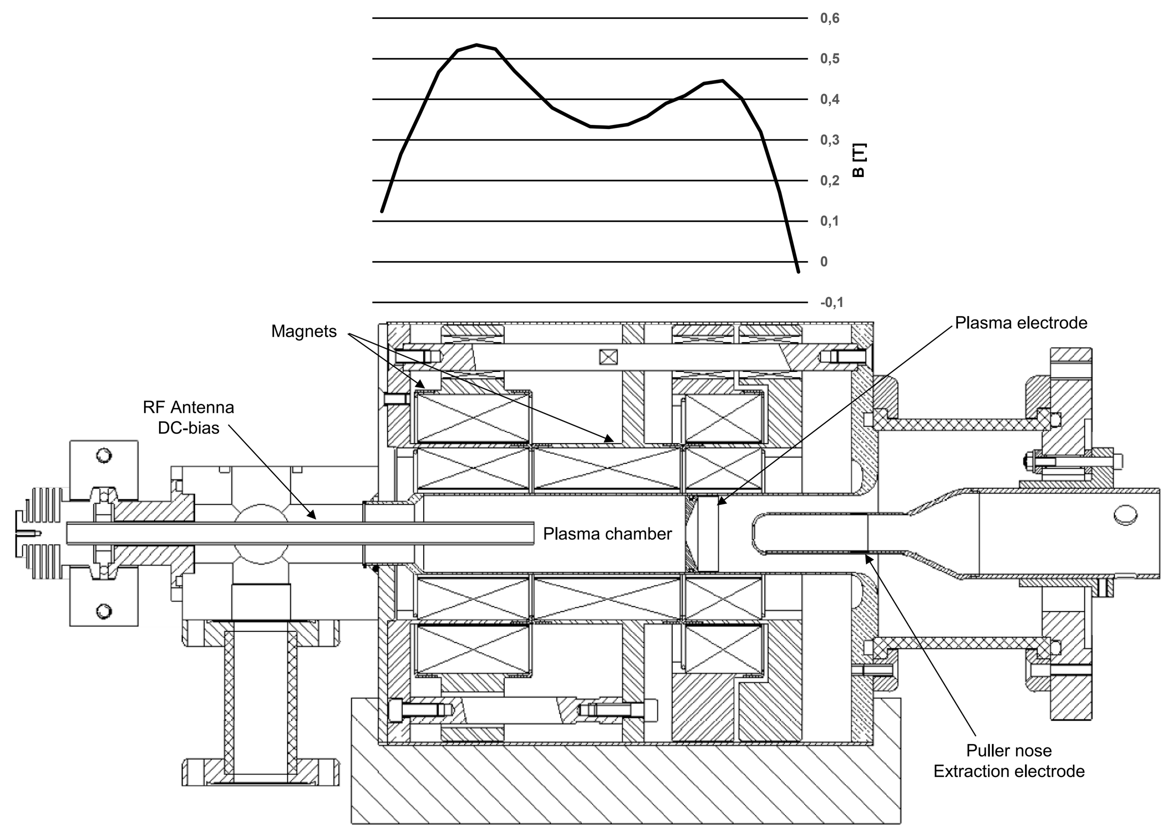

Figure 1: 10 GHz Microgan ECRIS layout and its magnetic field profile [Pantechnik]

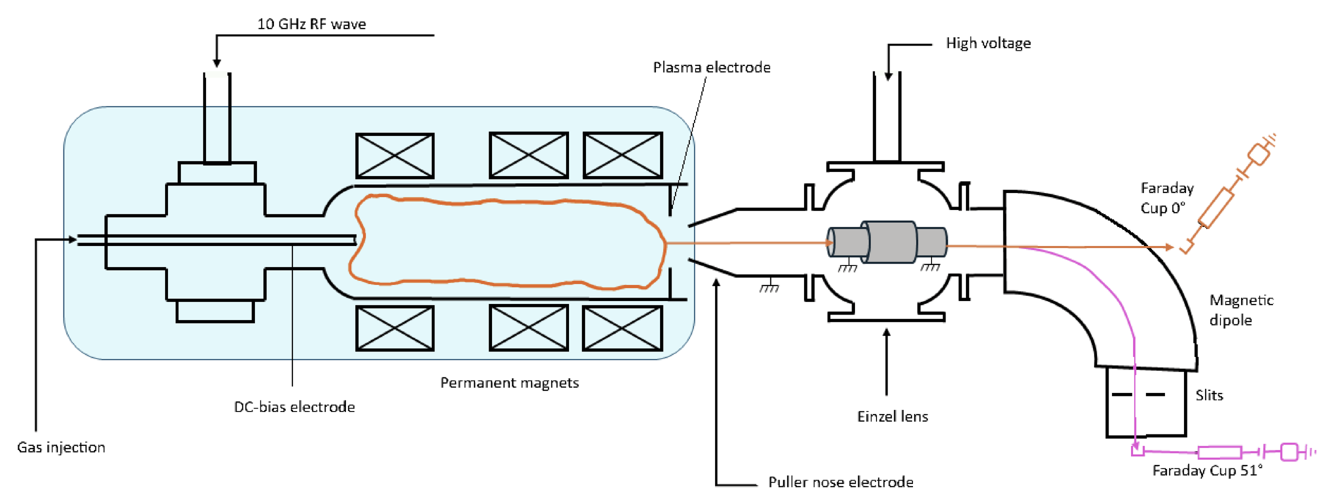

Figure 2: Diagram of the Tancrede ion source test bench

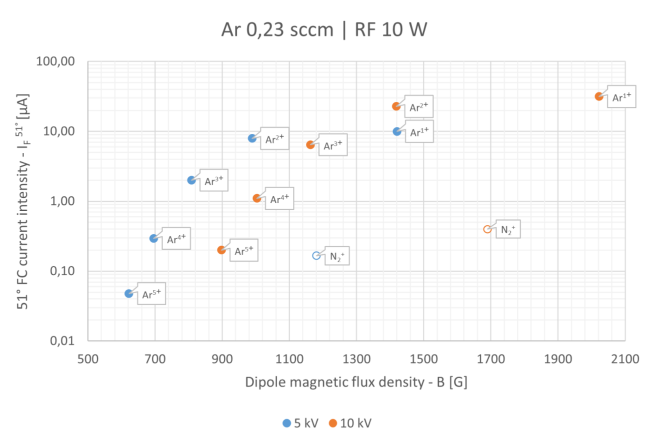

Figure 3: Distribution spectrum of argon charges for different extraction voltages

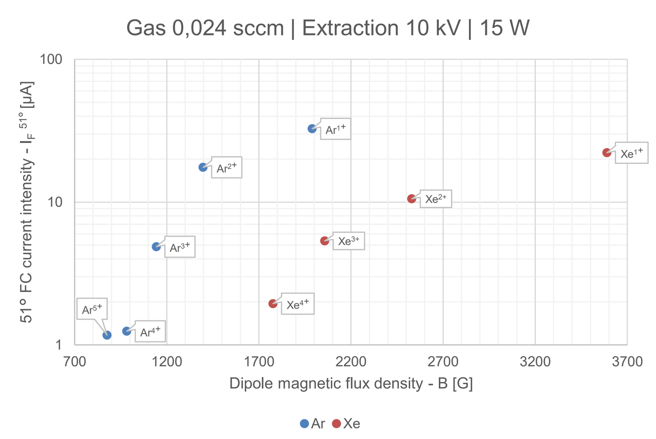

Figure 4: Charge distribution spectrum for different gases

Figure 5: Increase in plasma electrode (left) diameter from 6 to 8 mm, and extraction electrode (right) diameter from 8 to 12 mm

Acknowledgements & References

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[Goebel, 2008] Goebel, D. M. (2008). *Fundamentals of Electric Propulsion*.

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