

Numerical and experimental investigation into the performance of plasma sources for space propulsion systems

Mirko Magarotto

Centro di Ateneo di Studi e Attivita' Spaziali Giuseppe Colombo
CISAS
University of Padova

Helicon
Plasma
Sources

Mirko
Magarotto

Framework
& Statement
of the
Problem

Methodology

Results

Future
Expected
Results

- 1 Framework & Statement of the Problem
- 2 Methodology
- 3 Results
- 4 Future Expected Results

Helicon
Plasma
Sources

Mirko
Magarotto

Framework
& Statement
of the
Problem

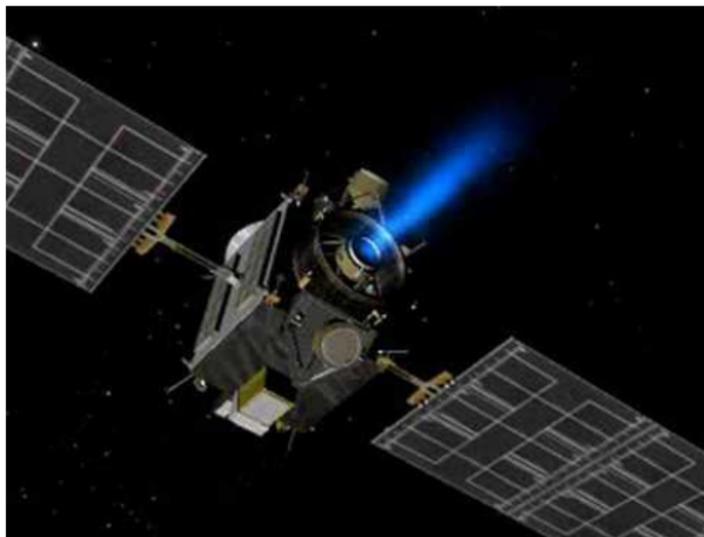
Methodology

Results

Future
Expected
Results

Main Features

- High specific impulse
- Low thrust
- High thrust efficiency



Helicon
Plasma
Sources

Mirko
Magarotto

Framework
& Statement
of the
Problem

Methodology

Results

Future
Expected
Results

Main Features

- High specific impulse
- Low thrust
- High thrust efficiency

Some applications

- Attitude control
- Interplanetary missions



Helicon
Plasma
Sources

Mirko
Magarotto

Framework
& Statement
of the
Problem

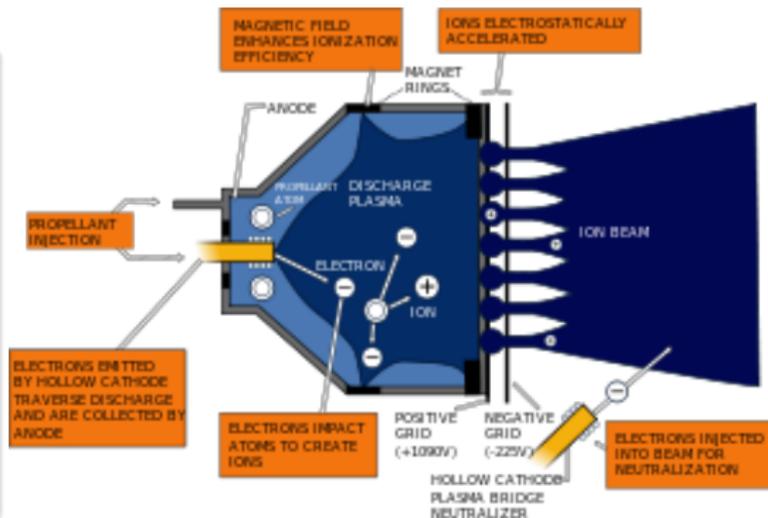
Methodology

Results

Future
Expected
Results

Ion thruster

- Polarized grids for ion acceleration
- Hollow cathode for gas ionization and beam neutralization



Helicon
Plasma
Sources

Mirko
Magarotto

Framework
& Statement
of the
Problem

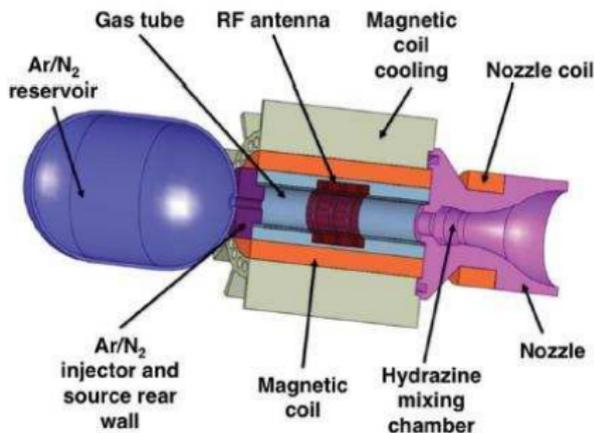
Methodology

Results

Future
Expected
Results

Main components

- cold gas tank
- plasma source
- magnetic nozzle

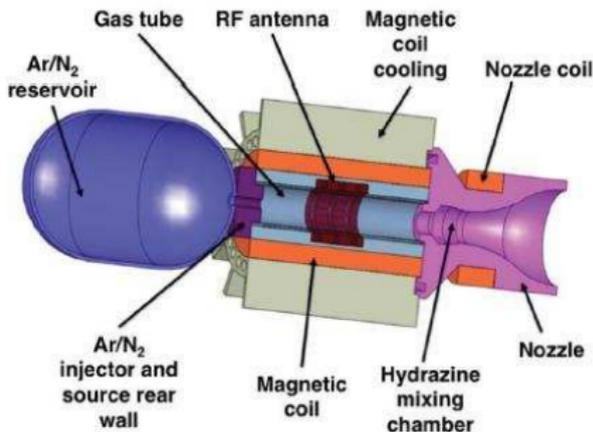


Main components

- cold gas tank
- plasma source
- magnetic nozzle

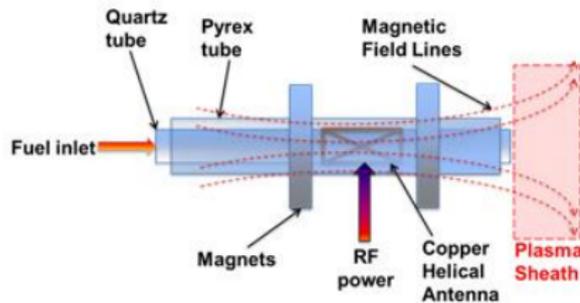
Advantages

- long life (no electrodes or grids)
- low cost (simple geometry)



Main components

- dielectric cylinder
- RF antenna
- magnetic coils



Helicon
Plasma
Sources

Mirko
Magarotto

Framework
& Statement
of the
Problem

Methodology

Results

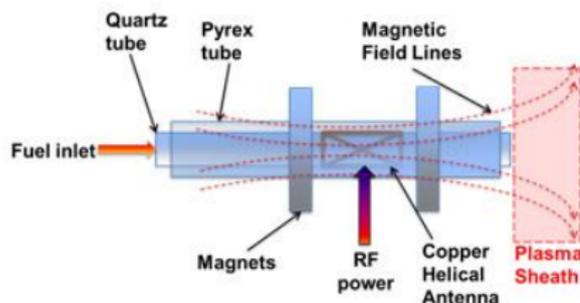
Future
Expected
Results

Main components

- dielectric cylinder
- RF antenna
- magnetic coils

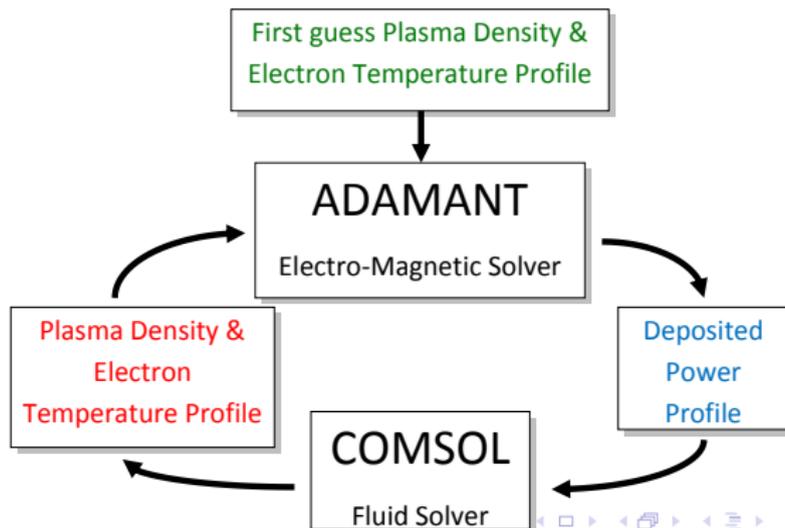
Main features

- high density plasma
 $n \geq 10^{18} \text{ m}^{-3}$
- simple antenna geometry
- low magnetic field
 $B_0 \leq 1000 \text{ G}$



Coupling **FLUID SOLVER** and **EM SOLVER**

- 1 Reproduction of the transport for high-density plasma
- 2 Computational cost at bay



Attained Results

- Development of a new fluid solver for plasma transport with the aid of COMSOL

$$\frac{\partial}{\partial t} n_e + \nabla \cdot \Gamma_e = R_e$$

$$\Gamma_e = -(\mu_e \cdot \mathbf{E})n_e - \mathbf{D}_e \cdot \nabla n_e$$

- Coupling the new tool with ADAMANT
- Numerical validation of the new tool

Attained Results

- Development of a new fluid solver for plasma transport with the aid of COMSOL

$$\frac{\partial}{\partial t} n_e + \nabla \cdot \Gamma_e = R_e$$

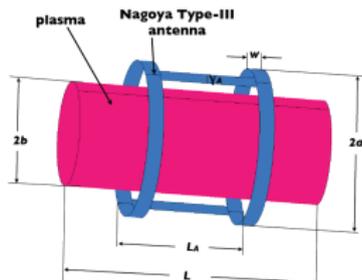
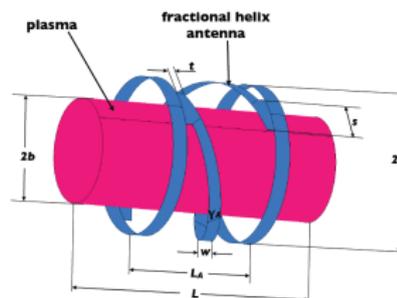
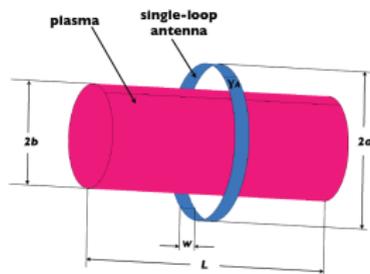
$$\Gamma_e = -(\mu_e \cdot \mathbf{E}) n_e - \mathbf{D}_e \cdot \nabla n_e$$

- Coupling the new tool with ADAMANT
- Numerical validation of the new tool

Work in Progress

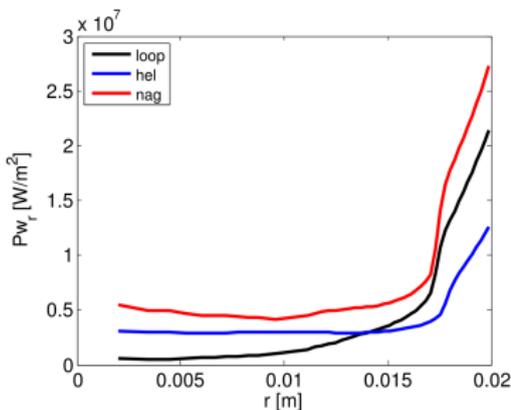
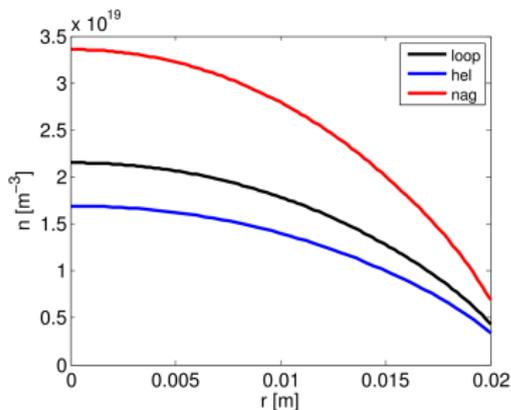
Experimental validation of the new tool

Reproduced the cylindrical geometry of the source



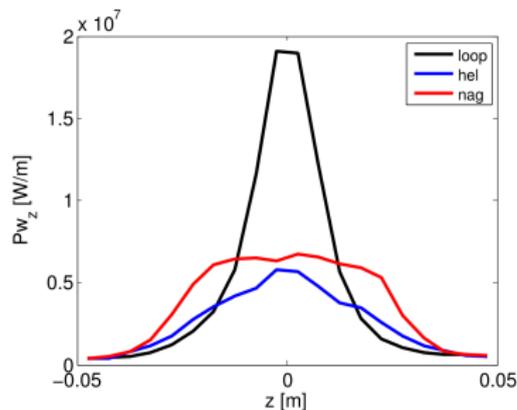
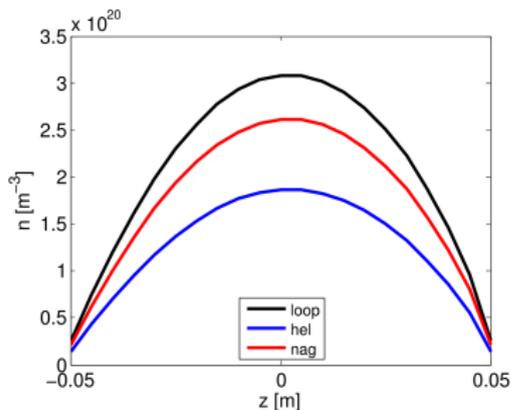
Main features

- Plasma density n peak near the axis of the source
- Radial power deposition Pw_r peak in the outer edge



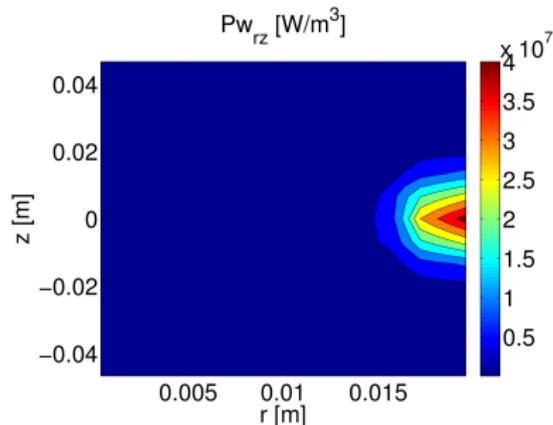
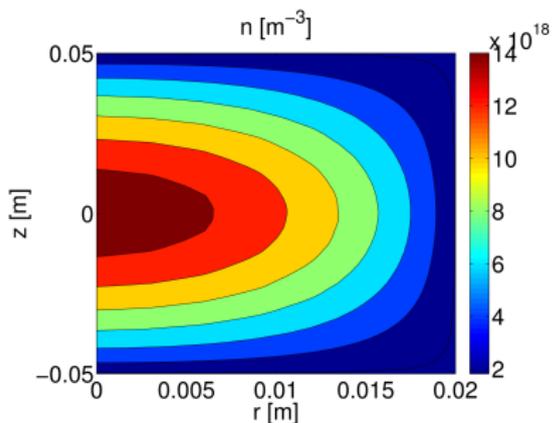
Main features

- Plasma density n peak in the center of the discharge
- Axial power deposition P_{W_z} below the antenna



Main features

- Plasma density n peak in the core of the discharge
- Radial-axial power deposition Pw_{rz} below the antenna



Plasma Diagnostic System

Fiber-optic spectrometer, Langmuir probe and MW interferometer to characterize the plasma



Helicon
Plasma
Sources

Mirko
Magarotto

Framework
& Statement
of the
Problem

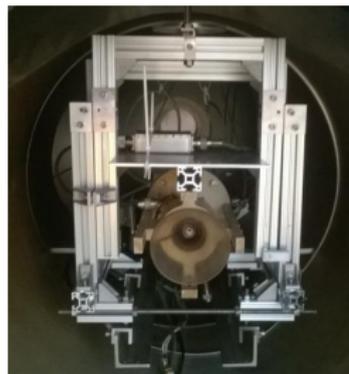
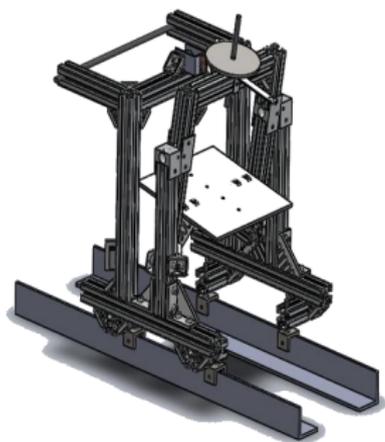
Methodology

Results

Future
Expected
Results

Thruster Diagnostic System

Faraday probe, Retarding Potential Analyzer and Thrust Balance to measure Specific Impulse and Thrust



Helicon
Plasma
Sources

Mirko
Magarotto

Framework
& Statement
of the
Problem

Methodology

Results

Future
Expected
Results

Future Expected Results

- 1 Validation of the new tool
- 2 Design, development, and testing of an high-power Helicon plasma source
- 3 Technology exploitation



Helicon
Plasma
Sources

Mirko
Magarotto

Framework
& Statement
of the
Problem

Methodology

Results

Future
Expected
Results