Investigation of Transient Regime Transition in Inductive Plasma Generators

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Motivation

• Electrodesless EP using IPG
• Improves propellant flexibility and lifetime
• Enables new operating concepts:
  • In-situ resource utilisation (ISRU)
  • Atmosphere-breathing electric propulsion (ABEP)

Objective

• Develop an experimental technique that:
  • Investigates regime transition, to control propulsion characteristics
  • Is non-intrusive, to avoid disturbing conditions
  • Is time-resolved, to capture effects due to non-steady power supply or modulation

Theory

• Antenna current = antenna–plasma coupling
• Magnetic field strength = function of antenna current and plasma currents
• Light emission in visible range = skin depth, location of plasma current

Experiment

3 channels captured simultaneously at 5 MHz:
• HOKA probe = antenna current
• Linear stage = radially-resolved:
  • Magnetometer = axial magnetic field strength
  • Photodiode = light emission in visible range

Conditions:
• \( f_{\text{signal}} = 586 \text{ kHz} \)
• \( f_{\text{cycle}} \approx 300 \text{ Hz} \)
• \( \text{P}_{\text{tank}} = 28.5 \text{ Pa} \)
• \( \text{P}_{\text{inj}} = 5.8 \text{ kPa} \)
• \( \text{m}_{\text{gas}} = 2.7 \text{ g/s} \)
• Capacitive and inductive regimes

Gases tested:
• Nitrogen
• Argon–oxygen (2:1 by volume)

Preliminary Results

• Antenna current and characteristic frequency
• Clearly identify regime transition due to development of plasma current
• Duration of inductive coupling affected by propellant choice
• Measured and calculated axial magnetic field agree
• Plasma current has little effect, likely located downstream far from probe
• Argon–oxygen: ring and central emission appear at different times

Conclusions

• Identification of regime transition, and plasma current behaviour, possible at time-scale of discharge cycle
• Plasma current appears to be localised in small, downstream region
• Numerical models may need to consider transient behaviour

IPG7 and Experimental Setup

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