Feasibility of a down-scaled HEMP-Thruster as possible μN-propulsion system for LISA

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Introduction

- Candidate propulsion systems for NGO are currently FEEP, Cold Gas and μRIT
- Alternative could be a down-scaled HEMP thruster due to its simplicity
- Experimental feasibility study on down-scaling HEMP thrusters in order to gain a deeper understanding of the influence of design parameters
- Goal is to comply with LISA requirements in terms of thrust level (0.1 - 150 μN) and thrust noise (0.1 μN/√Hz) in LISA measurement band (10⁻⁴ - 1 Hz)
- Thrust Measurement
  - Faraday cups measure the angular dependent ion flux
  - Ceramics and aluminium thruster shows side lobes
  - Steel thruster shows central peak
  - Plume geometry is independent of electric and dependent on magnetic properties of housing

Operation

- Operation Principle
  - Static electric field used to ionise the gas via electron bombardement as well as to accelerate the ions
  - Cupped static magnetic field increases ionisation probability, reduces erosion of the walls and focuses the ion beam
  - Simple system consisting of a high voltage power supply and a gas feed
  - Ions at 60° charge state of ion unknown which is probably created in upstream cusp

- Test facility
  - Length 1 m
  - Diameter 1.6 m
  - Turbo molecular and cryopumps with 25000 l/s throughput in total
  - Array of Faraday Cups and Retarding Potential Analyser can be rotated around thruster

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Thrust Measurement

- Direct thrust measurement with a pendulum to determine thrust and thrust noise and compare with models
- Goal: Sensitivity 0.1 - 1800 μN
- Highly symmetric setup with a reference pendulum for common mode suppression of seismic noise
- Electrostatic actuator enables closed loop operation (constant deflection of pendulum gives zero thrust and changing position and spring tuning (negative spring constant, wider measurement range possible)
- Electric connection via springs (no cables to the balance which may change spring constant)
- Optical readout with picometer heterodyne interferometer

Characterisation

- Finite Element Method (FEM) simulation of static electric field for optimisation
- SmCo ring magnets (higher operation temperature than NdFeB)
- Alumina discharge chamber
- Different housing materials (ceramics, aluminium and steel) which differs in magnetic and electric properties

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- Ion acceleration voltage
  - Retarding Potential Analyzer measures the angular dependent ion acceleration voltage
  - Charge state of ion unknown which is needed for energy determination
  - Ions at 60° passed full potential difference (probably created in upstream cusp) while ions at 0° passed only a fraction of potential difference (downstream cusp)
  - High acceleration voltages points to a high acceleration efficiencies

Conclusion and Outlook

- Principal feasibility of down-scaled HEMP thruster demonstrated
- Further optimisation necessary in order to comply with LISA requirements
- Systematic thruster test campaign planned with variation of all relevant design parameters
- Thrust balance has to be characterised without thruster operation and calibrated in open loop mode

![Characterisation Diagram](image)

![Design of Thrusters Diagram](image)

![Operation Principle Diagram](image)