A Thrust Balance for the MINOTOR ECR Thruster

Steffen Scharmann[1], Jana Zorn[1], Jens Simon[1], Kristof Holste[1], Andreas Neumann[2], Klaus Hannemann[2], Simon Peterschmitt[3], Denis Packan[3] and Peter J. Klar[1]

[1] Justus-Liebig-University Gießen, I. Physikalisches Institut, Gießen, Germany,

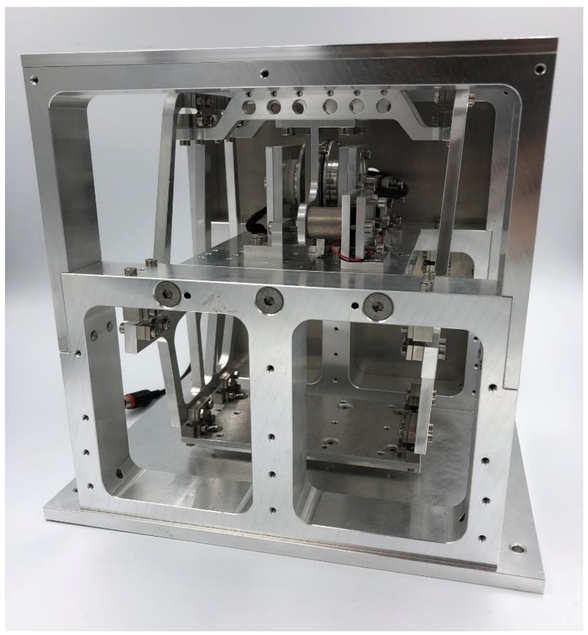
[2] German Aerospace Center Göttingen, Germany and

[3] ONERA Palaiseau, France

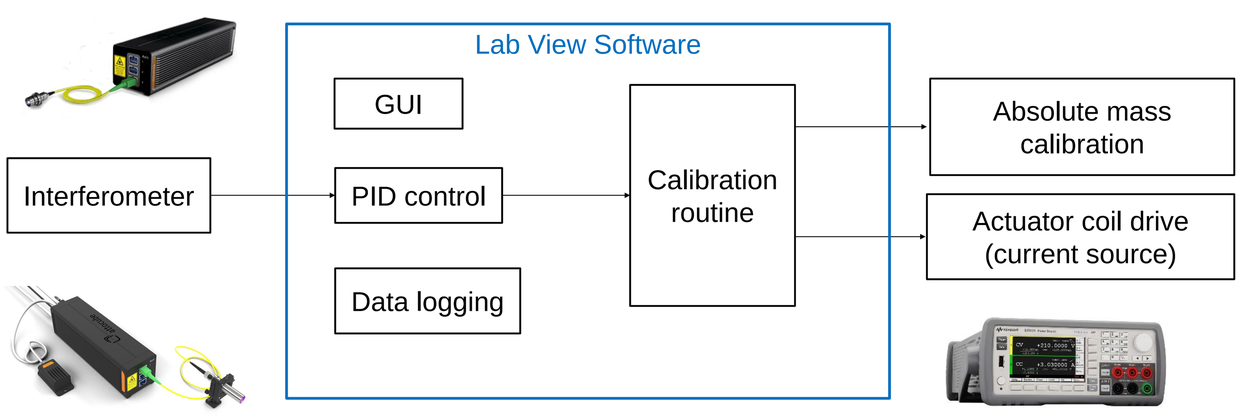
Motivation

The MINOTOR project (MagnetIc NOzzle elecTron cylcOtron Resonance thruster), funded by the European Union in frame of H2020, has the objective to demonstrate the feasibility of the ECRA (electron cyclotron resonance acceleration) technology being disruptive for electric propulsion. The ECRA technology is based on the ionization of a propellant gas by microwave heating of the plasma's electrons by utilization the electron cyclotron resonance and subsequent acceleration of the plasma with a magnetic nozzle. In frame of this project the University of Giessen developed a thrust balance for the envisaged thrust range (0.5 to 10 mN). The developed thrust balance is tested with RITs which are comparable in thrust with the ECR-thrusters used for the project.

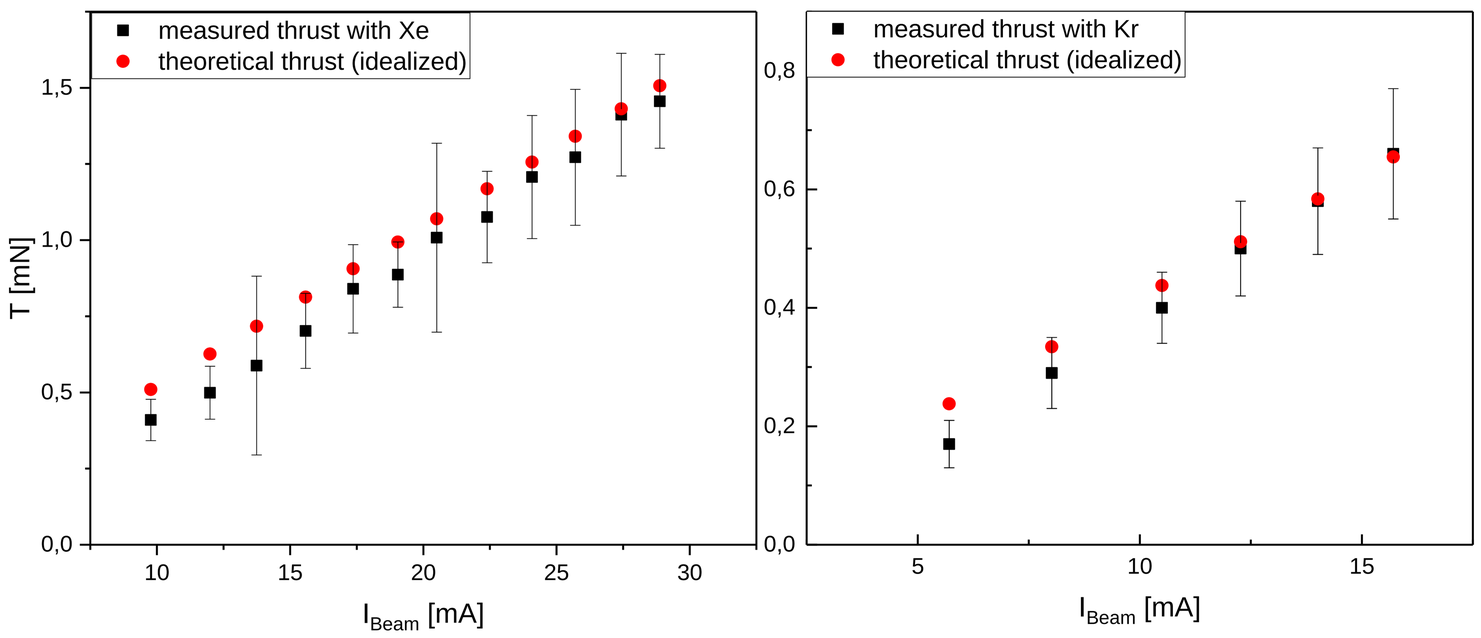
Thrust balance



- The Thrust stand consists of an aluminium frame onto which a Parallelogram-structure is attached by (bending) bearings.
- Measurement principle: Active zeroing of the balance using a voice coil together with an interferometric sensor to measure the displacement. The thrust is proportional to the voice coil current.
- The advantage of the active zeroing:
  - Perturbations by the supply lines are minimized
  - The trust balance position is nearly the same for each thrust
- Mu-metal shielding to avoid perturbations by the rf-fields of RIT
- Counterweights and magnetic vibration dampers (eddy current brake) to improve the resolution
- The achieved resolution is 50 µN and limited by the current-source



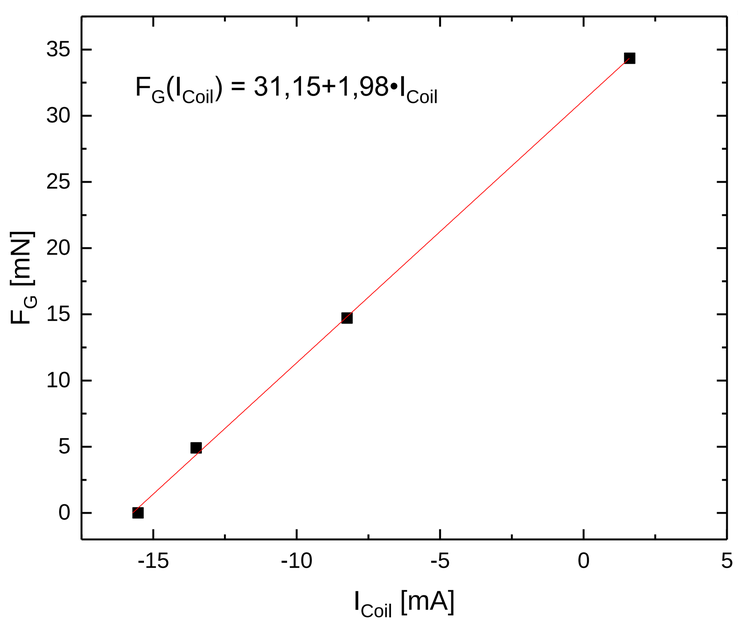
Measurement of a RIT 4



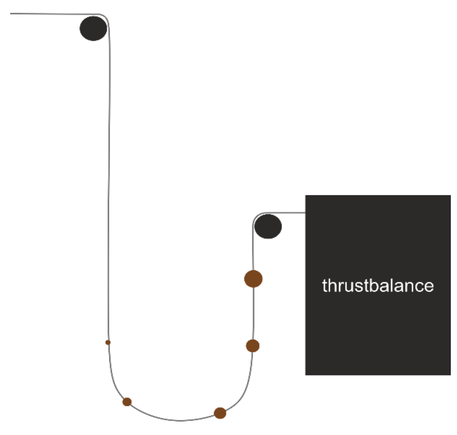
Characteristic parameters of the RIT 4:

- Mass: 0.5 kg
- Acceleration voltage 1000 V
- Thrust range: 50 µN – 2 mN (xenon)
- Mass flow xenon: 24-78 µg/s
- Thrust range: 40 µN – 1.7 mN (krypton)
- Thrust to weight: < 1:2500
- Mass flow krypton: 25 - 62 µg/s
- $T = I \cdot \sqrt{\frac{2mU}{Q}}$ with, Q=1e

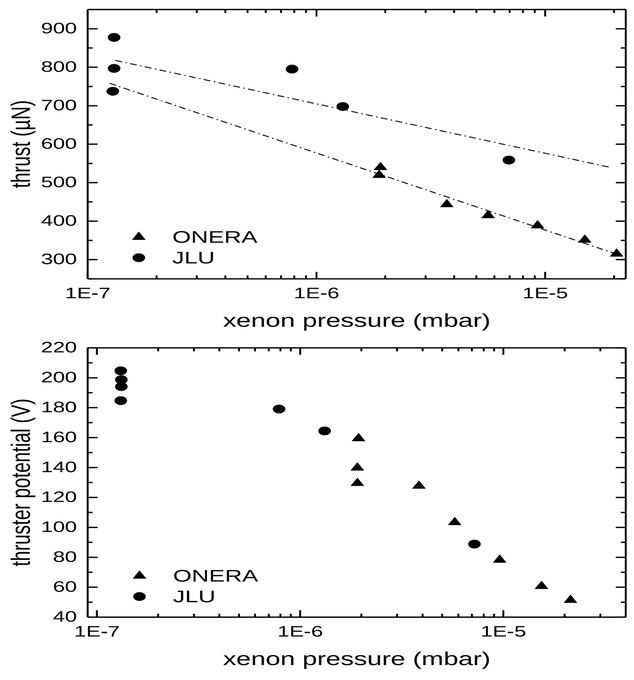
Calibration



- In situ calibration
- Absolute weights attached to the thrust balance by a pulley (relative error of the calibration weights < 0,24 %)



Test results with an ECR-Thruster



Characteristic parameter of the ECR-Thruster:

- Mass: 1.2 kg
- Thrust: 0.3 mN – 1.0 mN
- Thrust to weight ratio < 1:12000
- Mass flow: 0.1 mg/s
- Microwave frequency: 2,45 GHz
- Magnetic field: 87,5 mT
- Power consumption: 10-50 W
- Discharge channel 2-3 cm

Outlook

- Measurement of further thrusters and thruster types (HEMP, other RITs, other ECRs
- Comparison with other diagnostics (faraday array, PPA, indirect thrust measurement)
- Temperature control and monitoring

References

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Acknowledgement

This work has funding frobeen supported by the MINOTOR project that has received m the European Union's Horizon 2020 research and innovation program under grant agreement No 730028-

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MINOTOR
Magnetic nozzle thruster with electron cyclotron resonance