

Downscaling a HEMPT to micro-Newton Thrust levels: current status and latest results

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Since 2009 Airbus DS Space Systems, Friedrichshafen, has been investigating Electric Propulsion (EP) systems for high precision attitude and position control of spacecrafts. As a start, an experimental measurement campaign to demonstrate the feasibility of down scaling the High Efficiency Multistage Plasma Thruster (HEMPT), developed by Thales at Ulm in Germany, to the micro-Newton thrust level was initiated in close cooperation with university research groups. The HEMPT is potentially an attractive micro-Newton thruster concept because of the unique advantages of the HEMPT principle, e.g. nearly erosion-free operation and simple system and interface design with just one high voltage supply and one mass flow controller. We designed a next generation μ HEMPT with a thrust range between $50\ \mu\text{N}$ to $500\ \mu\text{N}$, a specific impulse of more than $2000\ \text{s}$, a divergence efficiency of more than 80% and a mass efficiency of around 70% . The proceeding will wrap up the thruster design and key parameters of the thruster and the performed measurements will be summarised.

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Nomenclature

EP	= Electric Propulsion
LISA	= Laser Interferometer Space Antenna
TRL	= Technology Readiness Level
HEMPT	= High Efficiency Multistage Plasma Thruster
AOCS	= Attitude and Orbit Control System

I. Introduction

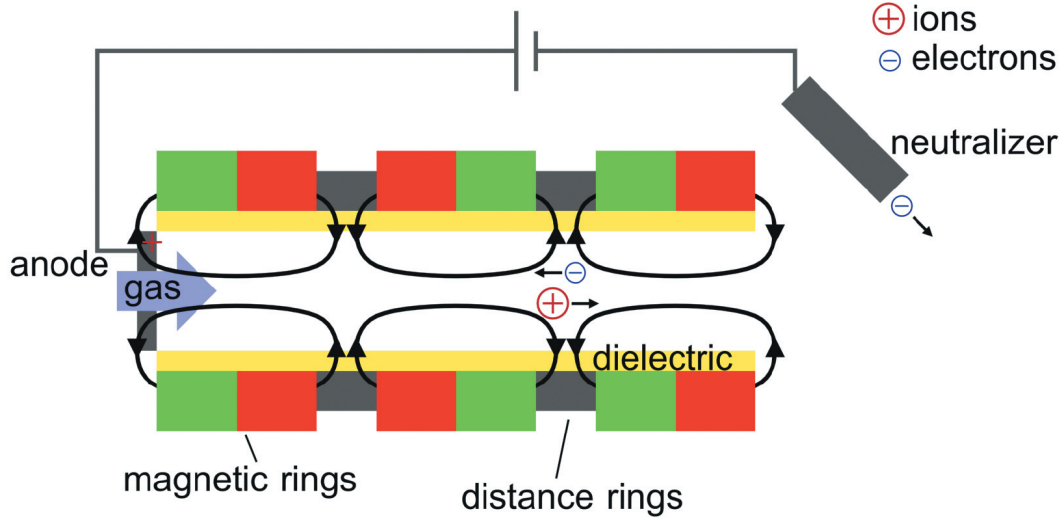


Figure 1. Schematic view of the HEMPT concept. As an example, an arrangement with a cylindrical discharge channel and three magnet rings is shown, such that 3 cusp zones with high radial magnetic field are formed in the discharge channel.

SINCE 2009 Airbus DS Space Systems, Friedrichshafen, has been investigating Electric Propulsion (EP) systems for high precision attitude and position control of spacecrafts. The motivation was twofold: firstly, the challenges encountered during the LISA-Pathfinder thruster development clearly demonstrated the need to look for viable alternative micro-Newton thruster candidates; secondly, several planned science and earth observation missions - most notably those with drag-free control such as the Laser Interferometer Space Antenna (LISA) - will require suitable μN thrusters of sufficient TRL (Technology Readiness Level) in due time to avoid technical development risks for the missions. EP remains a key enabling technology to meet that goal.

As a start, an experimental measurement campaign to demonstrate the feasibility of down scaling the High Efficiency Multistage Plasma Thruster (HEMPT), developed by Thales at Ulm in Germany [3], to the micro-Newton thrust level was initiated, in close cooperation with university research groups. The HEMPT is potentially an attractive micro-Newton thruster concept because of the unique advantages of the HEMPT principle, e.g. nearly erosion-free operation and simple system and interface design with just one high voltage supply and one mass flow controller.

A schematic thruster assembly is given in figure 1. It depicts a cut through the cylindrical HEMPT. The dielectric discharge chamber (in yellow) is surrounded by a system of periodically poled permanent magnets. This typical magnet stack forms a special magnetic field topology (black arrows) where radial magnetic field lines, so called cusps, separate the discharge chamber into several magnetic cells. On the left side of the scheme (upstream end of the discharge chamber) the anode is mounted. The anode operates as gas (typically Xenon) inlet as well. On the right side of the scheme (downstream) a neutraliser cathode is placed. Between the anode and the cathode the potential difference ranges from 300 V to 2000 V. The emitted electrons from the neutraliser are attracted by the anode, mirrored by the strong magnetic field gradient at the cusps and

thus trapped in the magnetic cells, which is necessary to enable a sufficient ionisation efficiency. Furthermore, the field confines the plasma close to the rotation axis of the thruster. Therefore, the plasma has ideally almost no interaction with the dielectric walls surrounding the discharge chamber.

However, to use the thruster in the micro-Newton regime, some development challenges must to be solved; for example the reduction of the neutral gas flow at lower thrust levels to maintain a high specific impulse or the manufacturing of the downscaled thruster geometry. The first experimental results from the downscaled HEMPT were presented at the IEPC 2011 [5] and the IEPC 2013 [6].

II. Next Generation Micro-Newton High Efficiency Multistage Thruster Design

Based on our performed experimental studies, which are summarised in A. Kellers Ph.D. Thesis [4], the gained experience, the available patents [2] and the preliminary results of the performed simulations [1], [8], we designed an optimised μ HEMPT, which could be a breakthrough of the performed downscaling.

With the next generation of our μ HEMPT (ng- μ HEMPT) we are aiming for a thrust range between $50\mu\text{N}$ to $500\mu\text{N}$, a specific inputs of more than 2000s , a divergence efficiency of more than 80% and a mass efficiency of around 70% . The estimated parameters are fortified by the simulations performed by G. Kornfeld [7], which will also be presented at the IEPC 2015.

Figure 2 presents a cross sectional snapshot of the ng- μ HEMPT. The discharge chamber is overlayed with a magnetic field line and flux density plot. The Flux density varies between 0T (in pale blue) and 1T (purple). The configuration of the magnetic field lines which are presented in figure 2 will lead to a high divergence efficiency. Notably, the flat exit plane, so called separatrix, will focus the ion beam [2], [8].

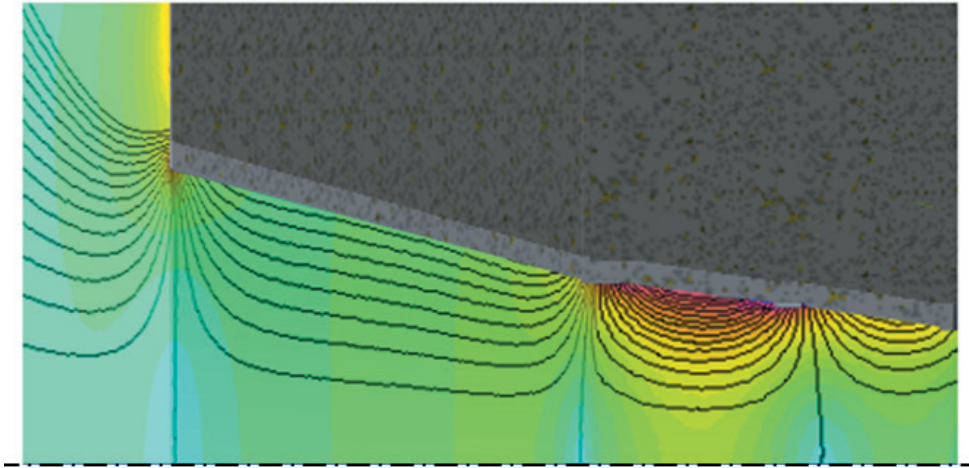


Figure 2. The Figure presents a cross sectional snapshot of the ng- μ HEMPT. The discharge chamber is overlayed with a magnetic field line and flux density plot. The Flux density varies between 0T (in pale blue) and 1T (purple).

The radius of the thruster is 13mm , which is 2.45 times wider as the largest configuration of the previously performed experiments [6]. An extrapolation of the measurement data leads to a bigger dimension to reduce electron losses and side effects. To isolate the plasma from the magnets and the other structure, a discharge chamber made of boron nitride is used. In figure 2 the discharge chamber is illustrated in bright grey, all other structures are presented in dark grey. Furthermore, as baseline NdFeB Magnets will be used instead of SmCo Magnets, which were used before. The higher flux density of the NdFeB magnets should lead to an improvement of the electron confinement and thus to an improved ionisation efficiency at low neutral gas densities. For an experimental evaluation of this effect, the new thruster configuration will also be tested with SmCo Magnets.

Figure 3 illustrates the mechanical design of the ng- μ HEMPT. Due to the current development state the thruster is designed as a laboratory model. This includes the easy access to all components and the possibility to change single parts. The design allows a systematic test of different design features like magnet

material and geometry, as already mentioned. But also the test of different discharge channel materials, anode concepts, etc. can be realised. The experimental tests will be compared with the performed particle in cell simulations of our cooperation partners from the DLR Bremen and the Kornfeld, Plasma & Microwave Consulting.

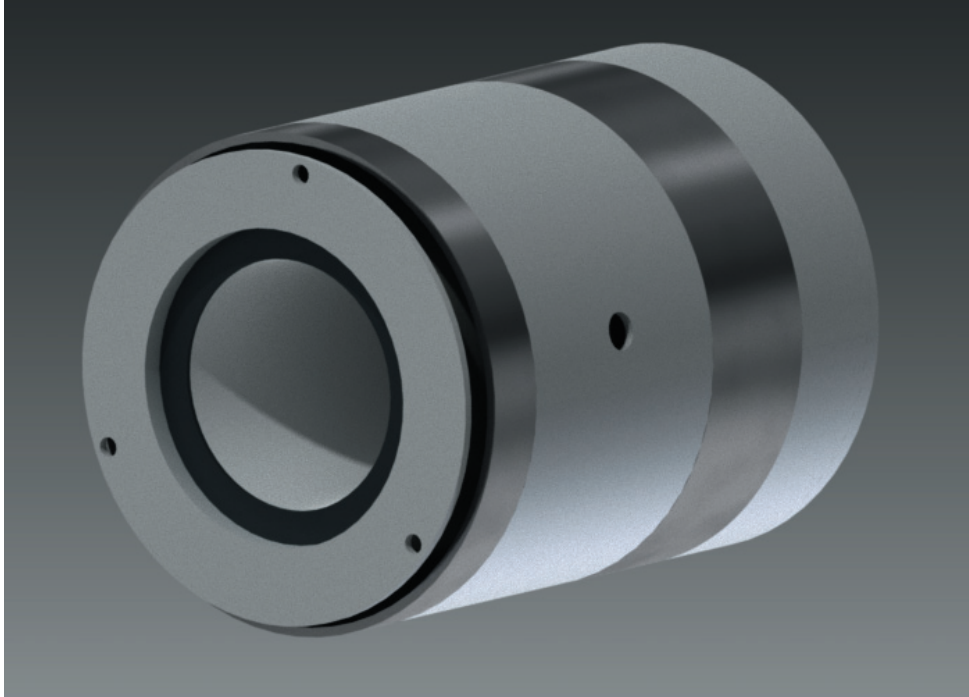


Figure 3. The rendered illustration of the mechanical the ng- μ HEMPT design illustrates the current development state of the thruster as a laboratory model. This includes the easy access to all components and the possibility to change single parts. The design allows a systematic test of different design features like magnet material and geometry.

III. Measurement Result and Analysis

In this chapter the performed measurements result should be presented. But unfortunately, not any measurement were performed up to now (May 2015). But we are optimistic that the first results can be presented at the IEPC 2015. Moreover, this proceeding will be updated as soon as possible.

IV. Conclusion and Outlook

We designed a next generation of our miniaturised HEMPT to demonstrate that the technology has the capabilities which are required for highly precise AOCS. The new thruster follows a generic design concepts which allows the simple modification of single components. It will be operating in a thrust range between $50\mu\text{N}$ to $500\mu\text{N}$, with a specific impulse of more than 2000s . This estimations were verified by the particle in cell simulations of G. Kornfeld.

Unfortunately, we were not able to perform any measurement up to now (Mai 2015). The proceeding will be updated when the measurement data is available.

References

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