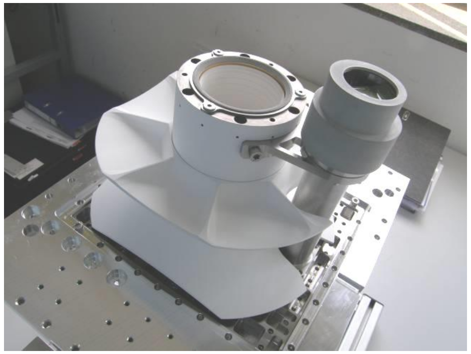
www.thalesgroup.com/germany



The HEMP-Thruster: current development and perspective

R. Heidemann, S. Weis, A. Lazurenko, H. Stalzer, A. Genovese, P. Holtmann

N. Püttmann (DLR)

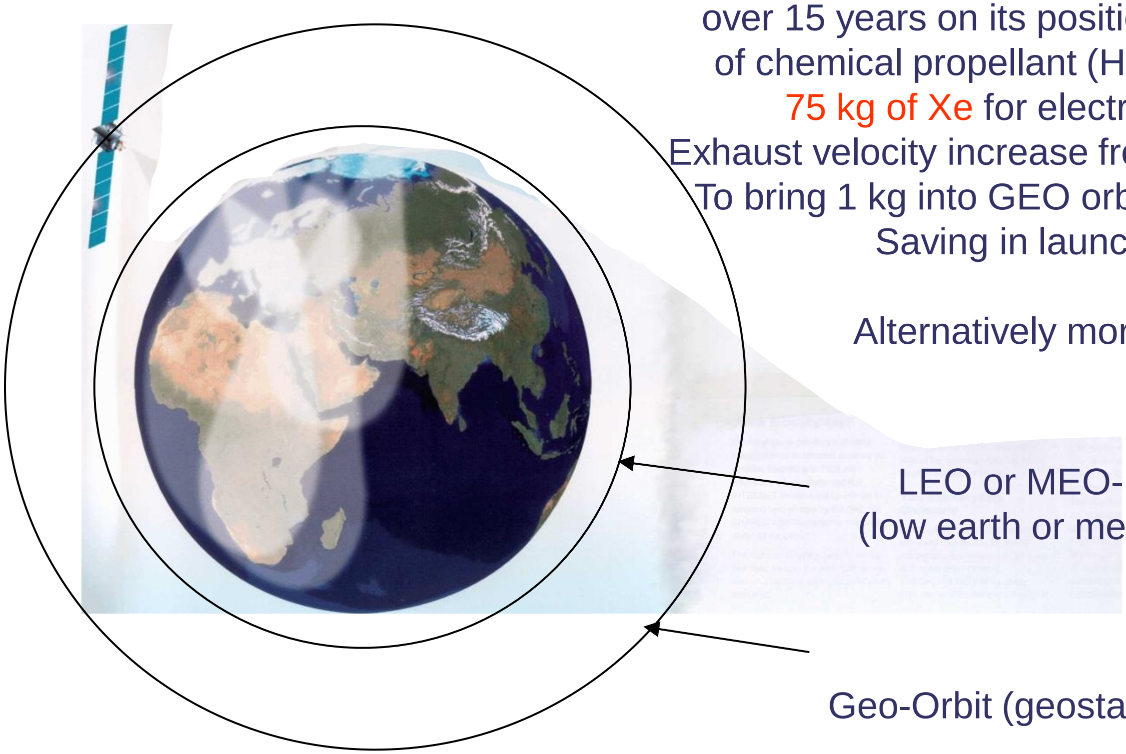
Security and mobility in a networked world.

THALES

Why ion propulsion ?

To maintain a GEO communication satellite over 15 years on its position requires 775 kg of chemical propellant (Hydrazin), but only 75 kg of Xe for electric propulsion.
Exhaust velocity increase from 3km/s to 30km/s.
To bring 1 kg into GEO orbit costs 55.000.- $
Saving in launch costs: 38.5 Mio $

Alternatively more payload channels.

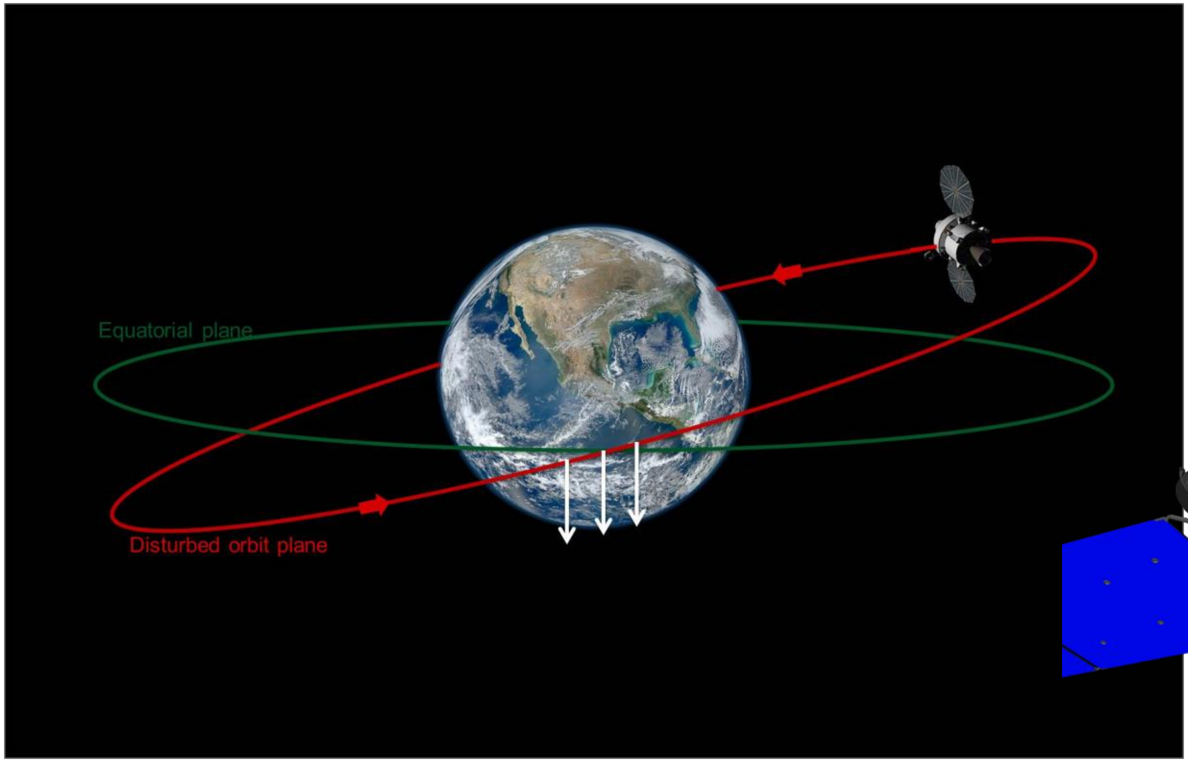


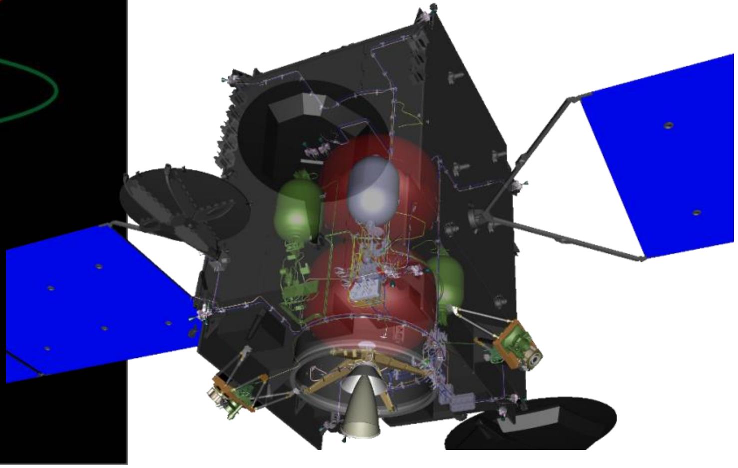
LEO or MEO- Satellite Orbit
(low earth or medium earth orbit)

Geo-Orbit (geostationary earth orbit)

H2Sat Attitude Orbit Control System (AOCS) maneuvers by EP:

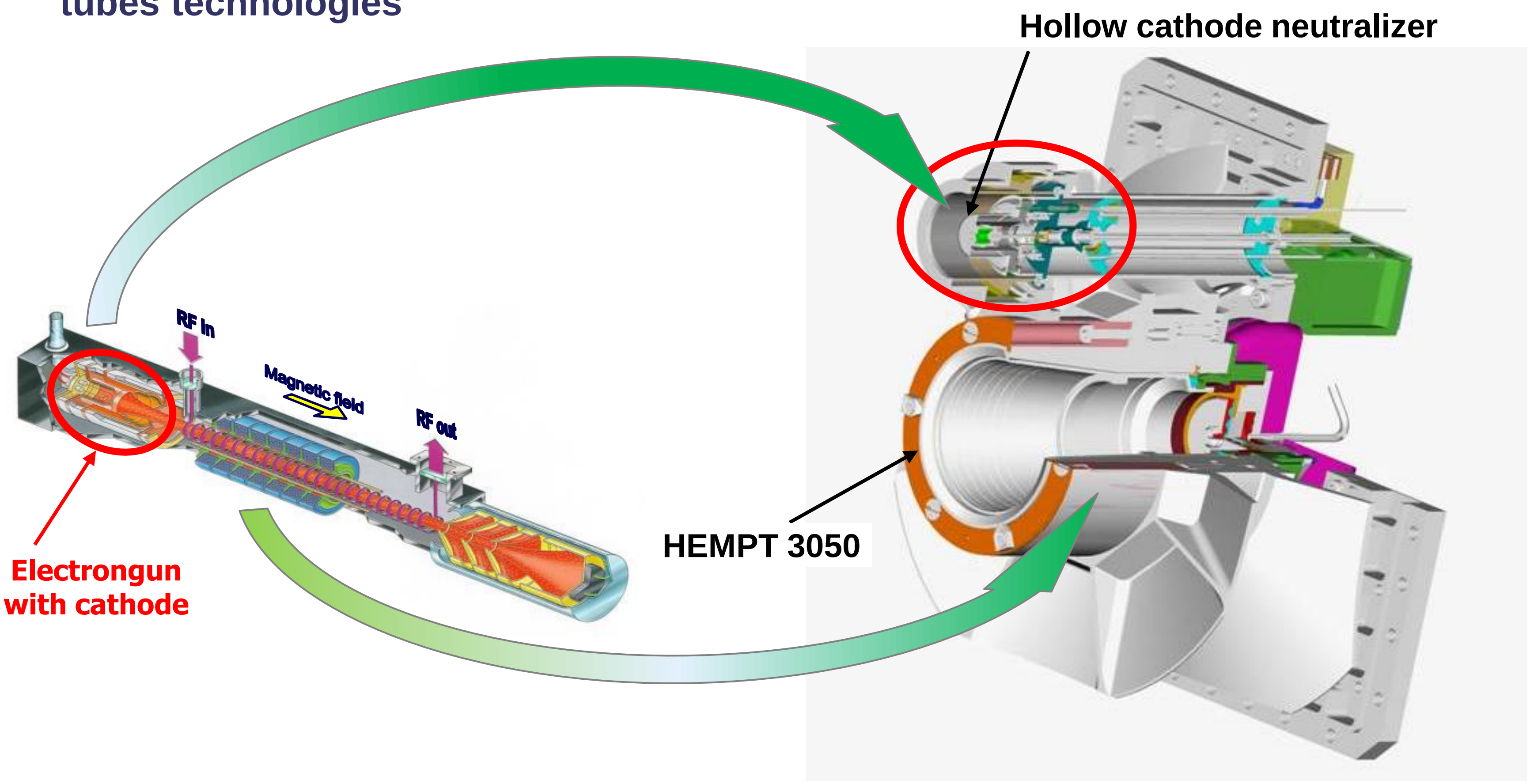
- North-South Keeping (NSSK)



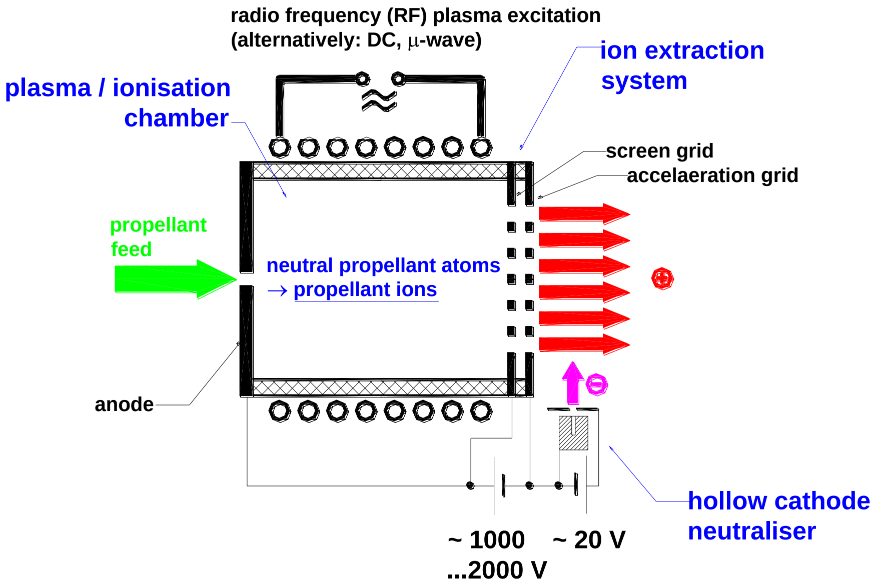


HEMPT technology

- Electric propulsion for satellite station keeping and orbit raising
- 85% of the materials and 80% of the processes for the HEMP technology is based on tubes technologies

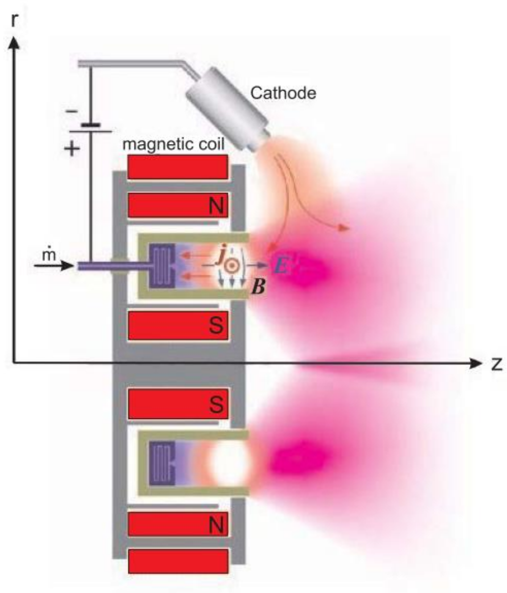


Gridded Ion Thrusters



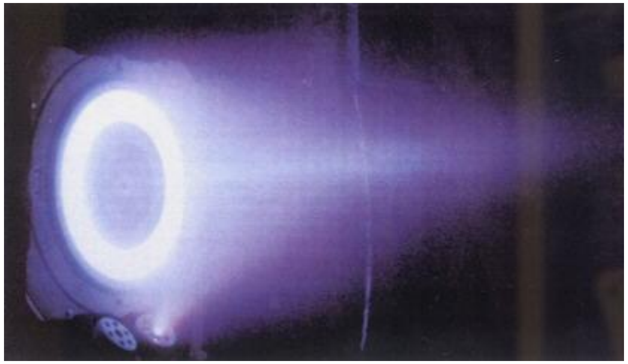
- ➢ Separate Ionization and acceleration
- ➢ Multiple grids to confine and accelerate ions
- ➢ Complicated multi-voltage power supply
- ➢ Space charge limitation on ion current density
- ➢ Plasma etching of all materials with plasma or beam contact
- ➢ Grid erosion limits lifetime

Hall-Effect Thrusters



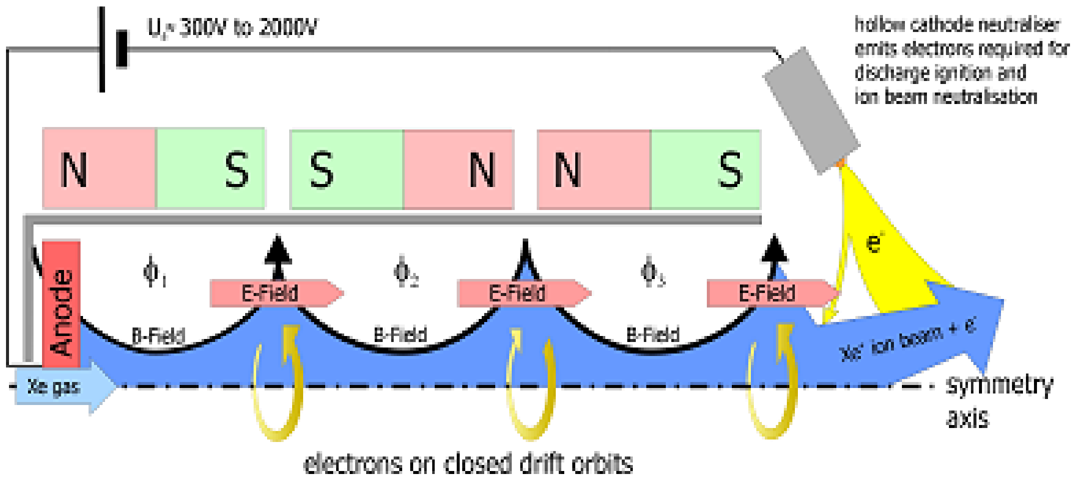
Larmor radii: $r = \frac{v \cdot M}{e \cdot B}$; $r_e << L_{channel} << r_{ion}$

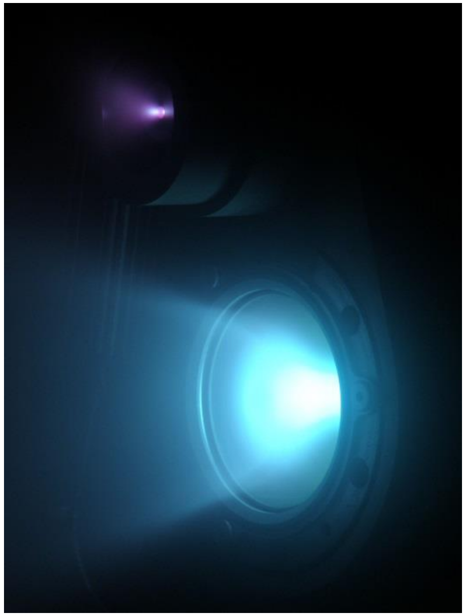
$E \times B$ – Drift $\Rightarrow$ azimuthal Hall-current



- Radial magnetic field produces Hall currents and ion acceleration
- Electrons follow magnetic field lines
- Plasma wall contact leads to high erosion and reduces lifetime
- Operation limited to low voltage and therefore low ISP

High Efficiency Multistage Plasma Thruster HEMPT: Concept





Properties:

- Minimized plasma-wall contact ➔ no channel erosion ➔ high exhaust velocities and lifetime
- Thruster and system architecture with minimum complexity ➔ cost-efficient & reliable
- Stable operation even at high voltage from 300 V…2,000 V allows high ISP

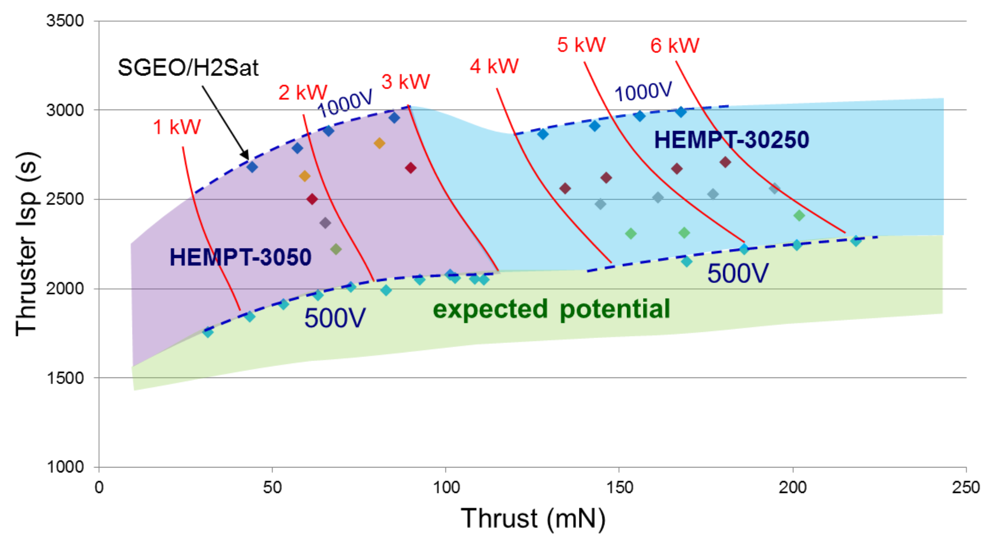
HEMPT Operational Principle:

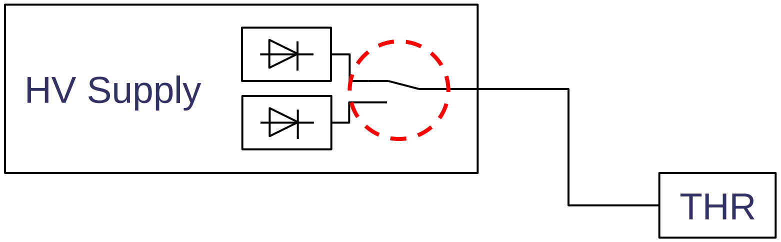
- Magnetic field confines plasma electrons and shields the discharge channel
- Axial impedance at the cusps with radial magnetic field
- Magnetic mirror and electrostatic shielding at the cusps

Dual operating Mode

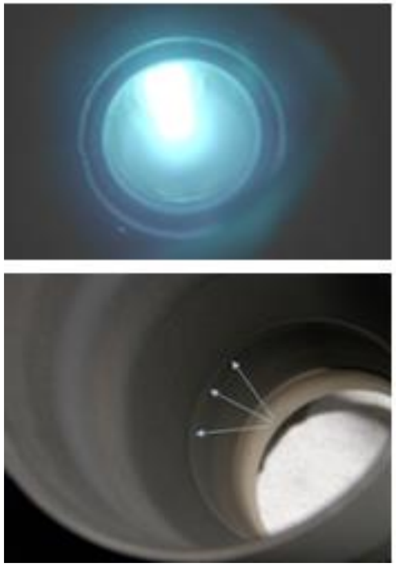
- **HEMPT Technology generally allows dynamic alteration of operating voltage**
  - No tuning / adaptation needed to change operational point
  - Dual operation allows in flight trade of between ISP and Thrust
  - x2 voltage switch requires on power supply side only one relay as typically more than one rectifier stage is used

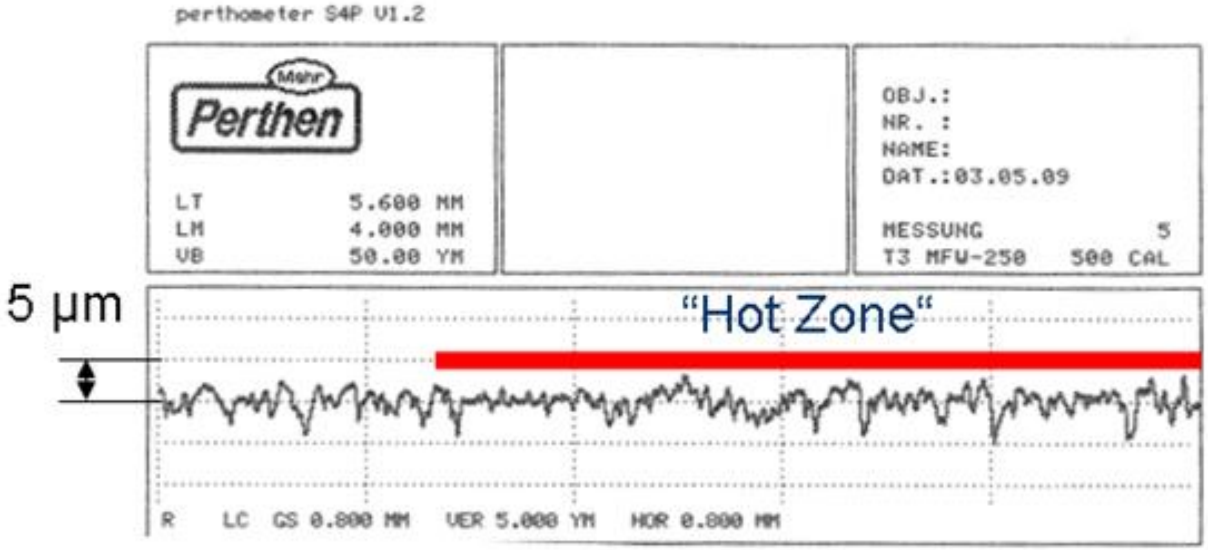
Analogue to gear shift of cars





Discharge channel analysis after 1200h nominal HEMPT operation at 1000V anode voltage for SmallGEO



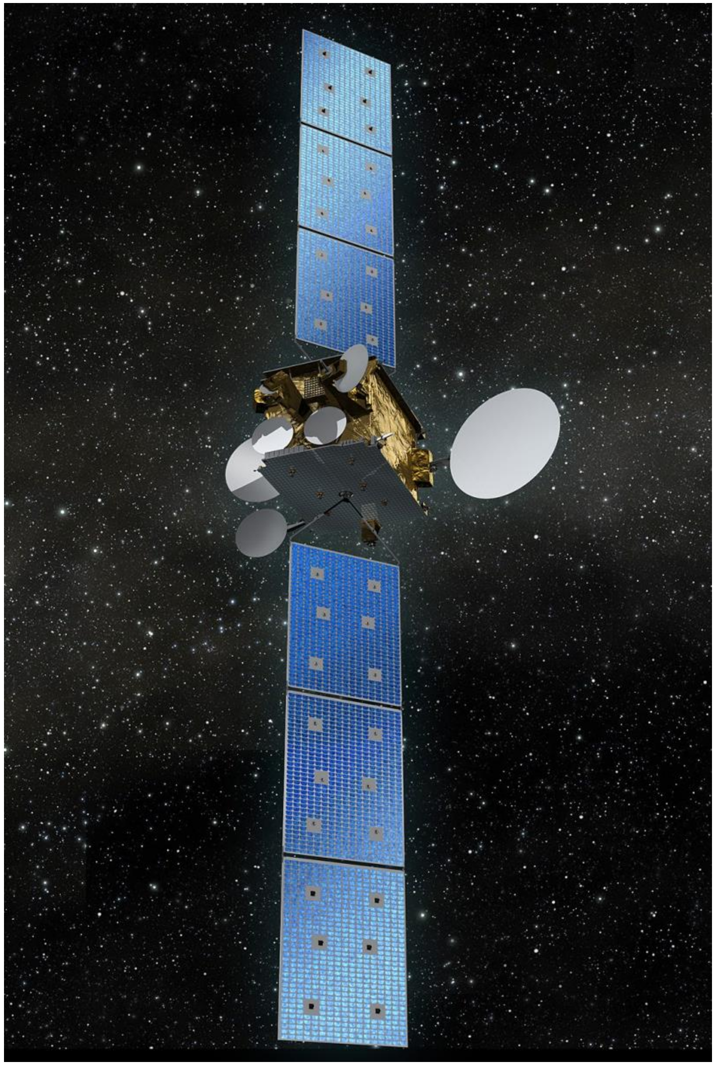


Result: < 5 microns / 1200h @ 1000V anode voltage

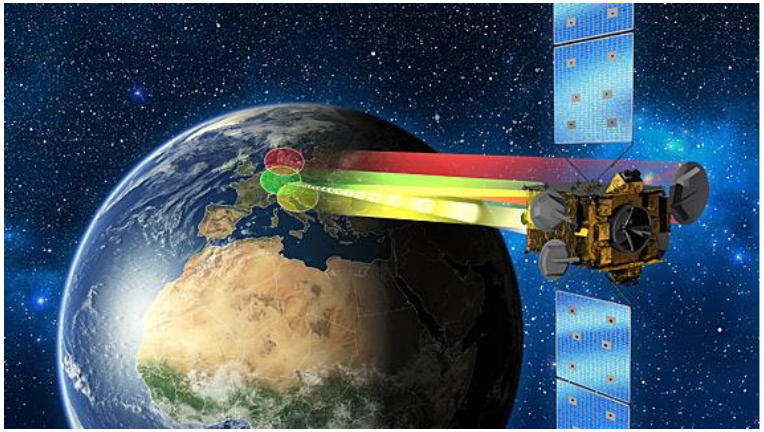
➔ **erosion is negligible!**

In orbit demonstration

HEINRICH HERTZ

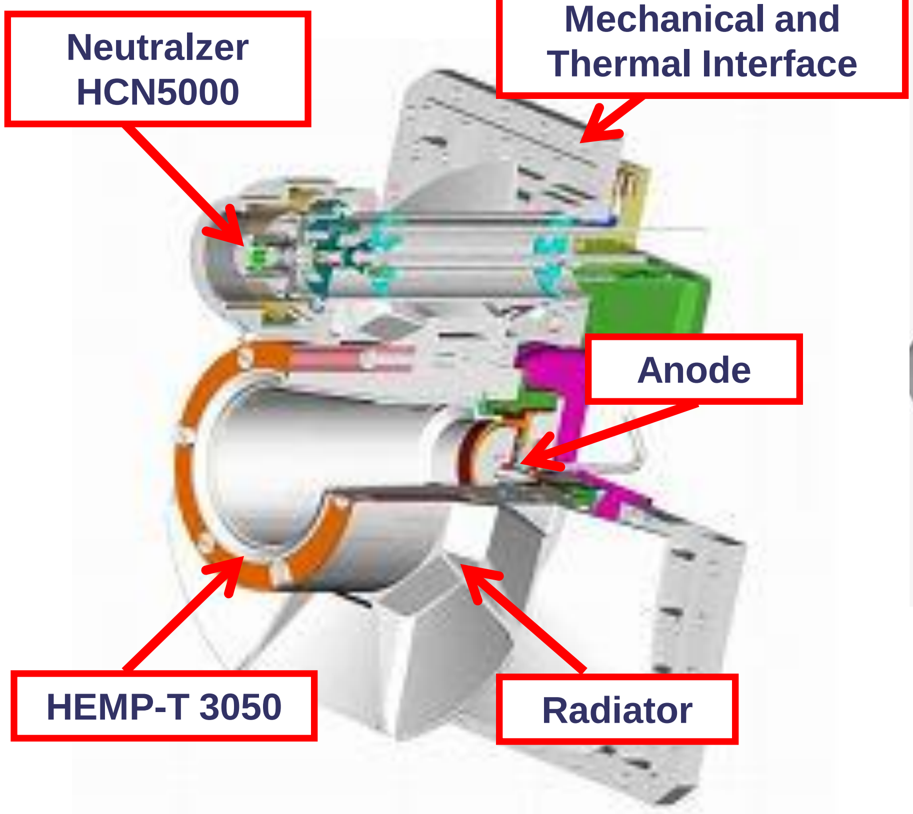


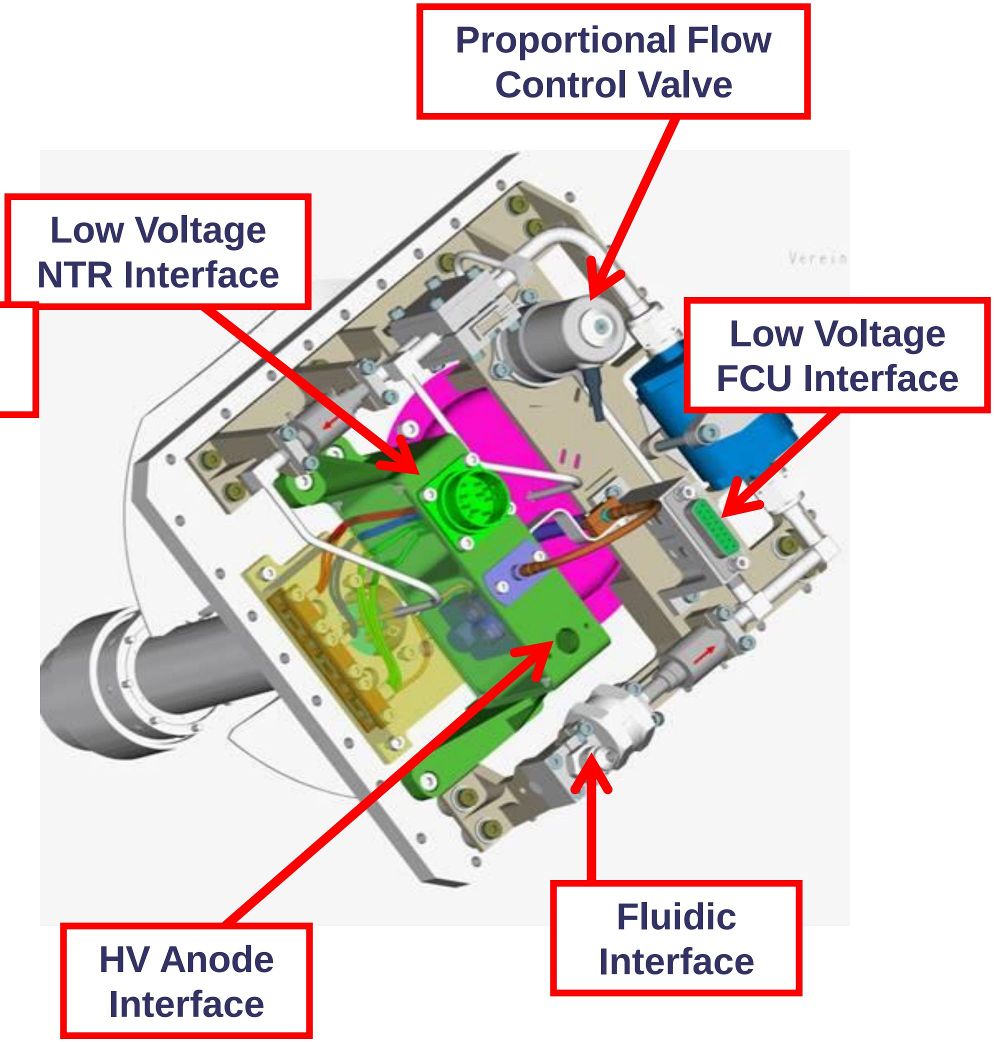
- Heinrich-Hertz (H2Sat) satellite mission
- German communication satellite
- Geo-stationary orbit in 36,000 km altitude
- 15 years service life
- Based on OHB's SmallGEO plattform
- Position control in GEO by ion thrusters
- Provides in-orbit verification of novel type satellite communication and transmission technologies
- Launch scheduled for 2019



HEMP-Thruster Module (HTM) Components:

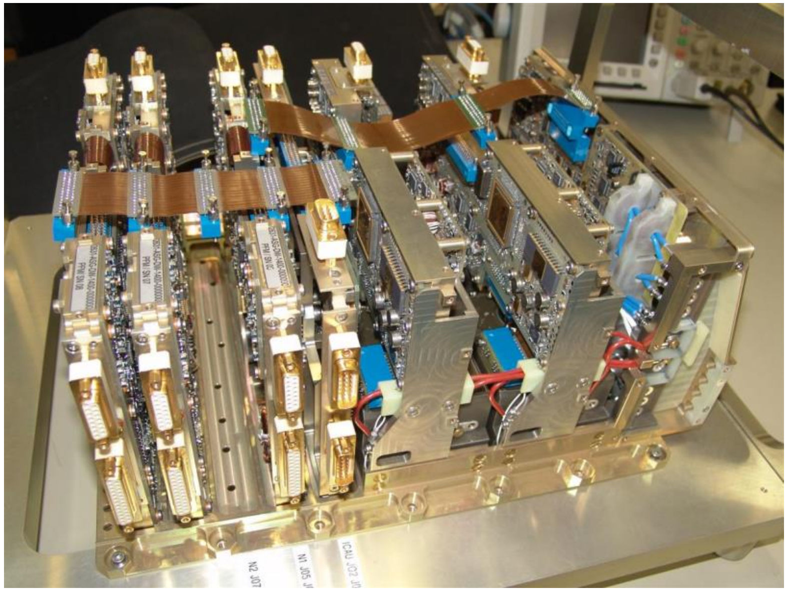
- HEMP-Thruster 3050
- Neutralizer HCN 5000
- Xenon Flow Control Unit

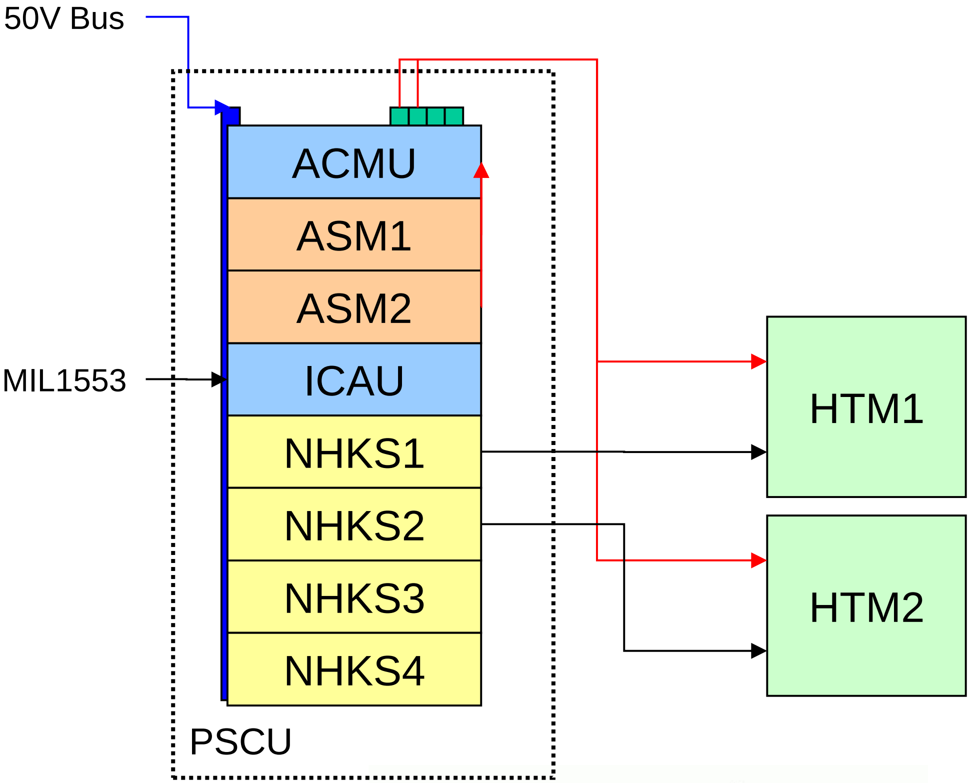




Power Supply and Control Unit - PSCU

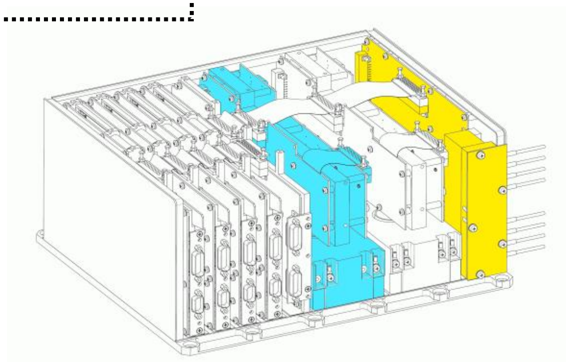
PSCU





Power Supply has a modular design:

- **ASM** to generate HV for thruster anode
- **NHKS** for supply and control of Neutralizer & propellant flow
- **ACMU** to measure HV current to thruster
- **ICAU** to control and supervise all modules



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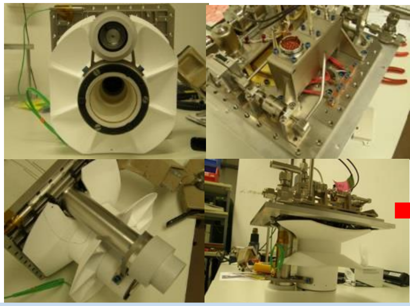
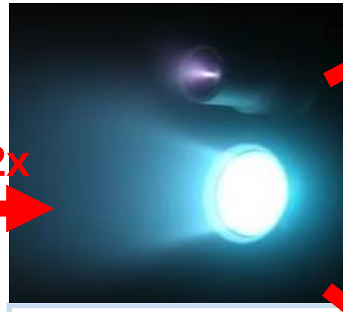
HTM-EM/EQM test campaign

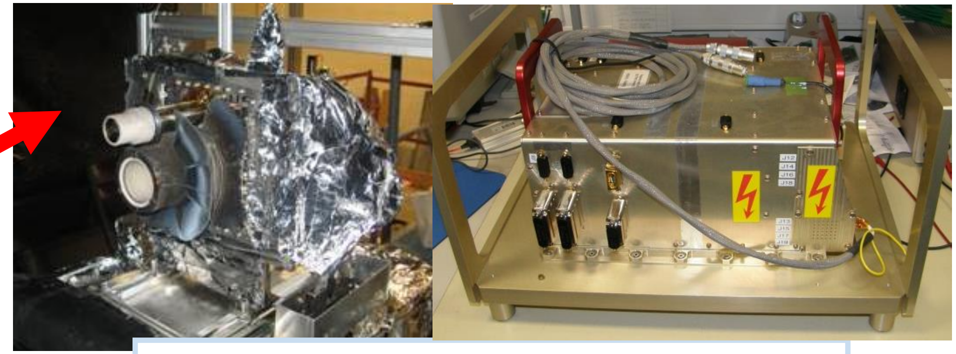


Integration

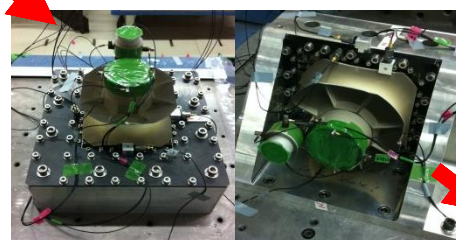
2x



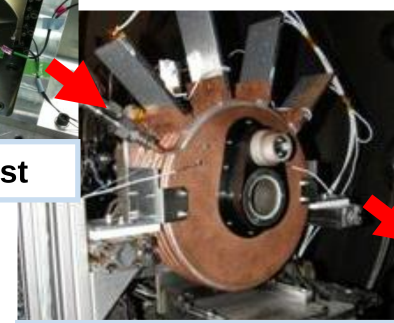
Performance Test



8,000 h Endurance Test partly w/ PSCU-EM



Vibration & Shock Test



Thermo Vacuum Test

EMI/EMC Test

Quantity/Unit	Req.	Test Value	Compl.
Thrust	≥ 44 mN	44.9 mN	Yes
Thruster power	≤ 1,380 W	1,370 W	Yes
Neutraliser discharge power	≤ 42 W	16.3 W	Yes
HTM specific impulse	≥ 2,300 s	2,474 s	Yes
Mechanical Load Sine Vibration	20 g	20 g	Yes
Mechanical Load Random	11.6 g_{RMS}	11.6 g_{RMS}	Yes
Mechanical Load Shock	2,000 g	3,500 g	Yes
Operational hours	7,200 h	8,000 h	Yes

- Excellent basis for lifetime testing

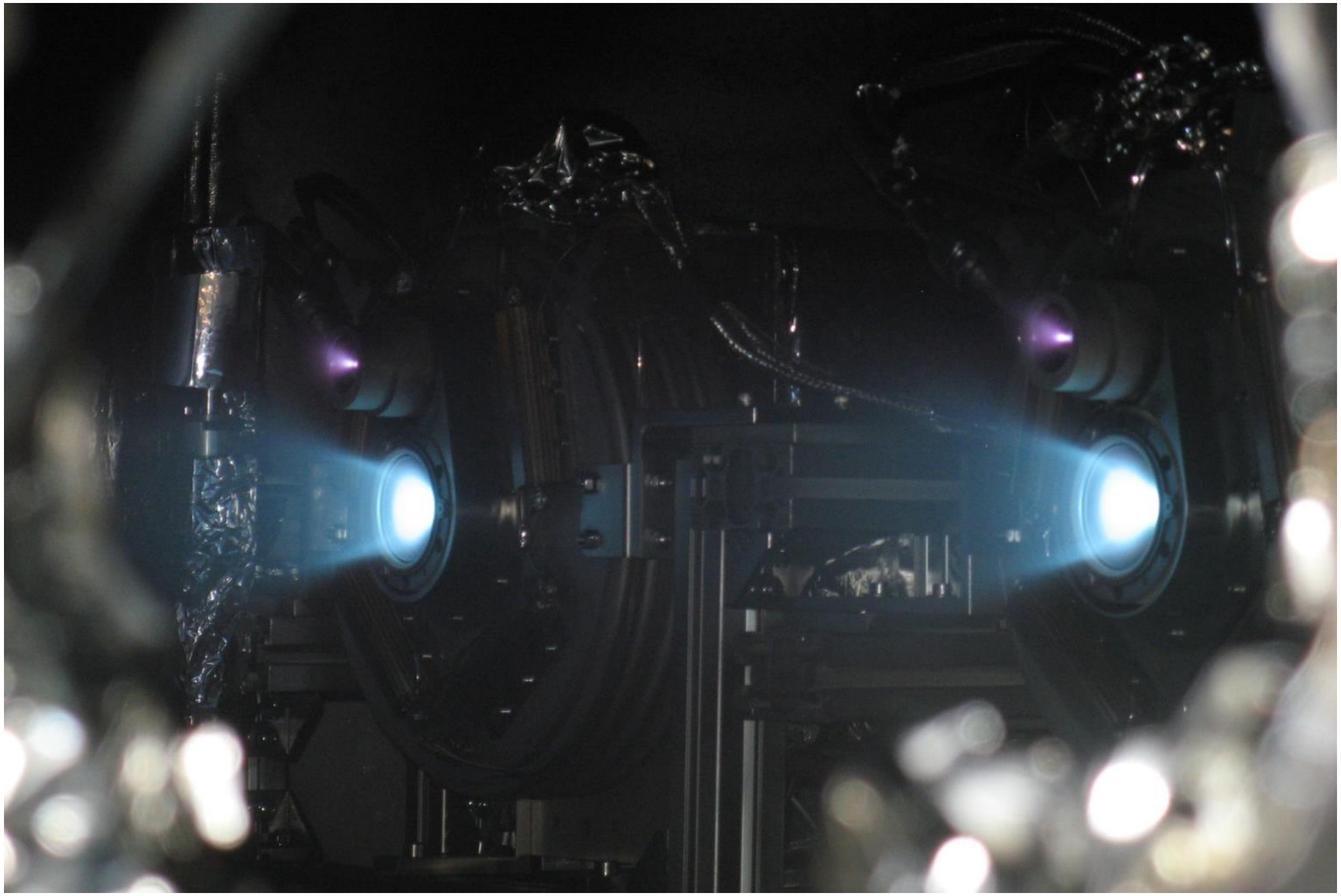
HTA 3050 QM lifetime testing

HTM-QM1+PSCU-EQM:
Gesamt-Betriebsstunden: 2913 Std (von 8583)
Qual-Zyklen: 3455 (von 10200)
33.9%

HTM-QM2:
Gesamt-Betriebsstunden: 1890 Std (von 4932)
Qual-Zyklen: 1150 (von 3000)
38%

HEMP-TIS Lifetime Test – results – simultaneous operation

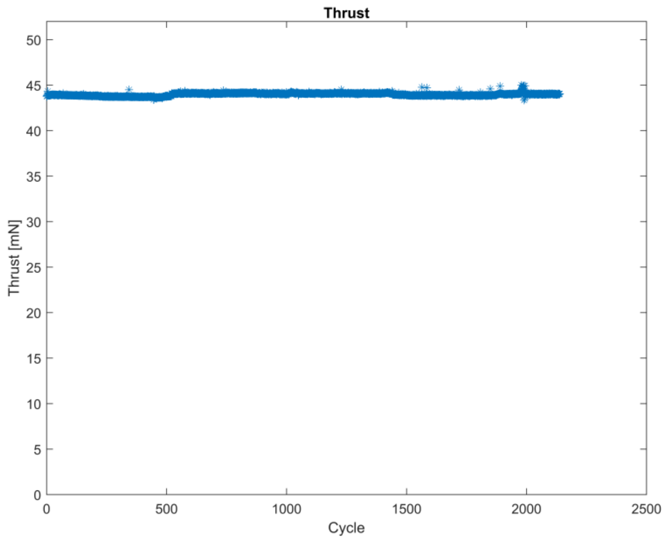
- **HTM-QM1 and HTM-QM2 test sequences overlap**
  - **Stable start-up, operation and shut-down at the presence of the second operating HTM**

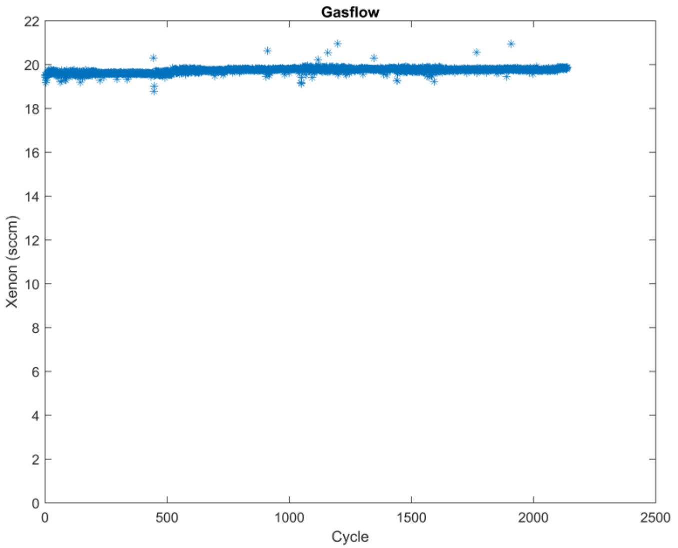


HTM-QM2 (left) and HTM-QM1 (right) operating during the Lifetime Test

HEMP-TIS Lifetime Test – results – HTM-QM1 performance

- **HTM-QM1: 1900 h and 2200 cycles**
- **Stable performance, within specifications**

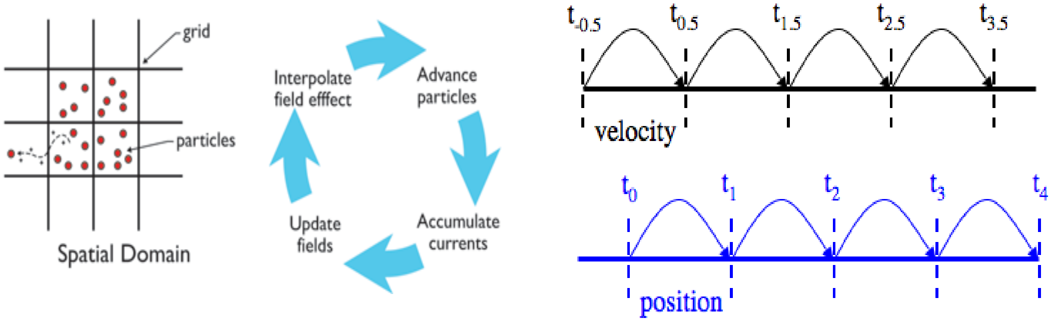




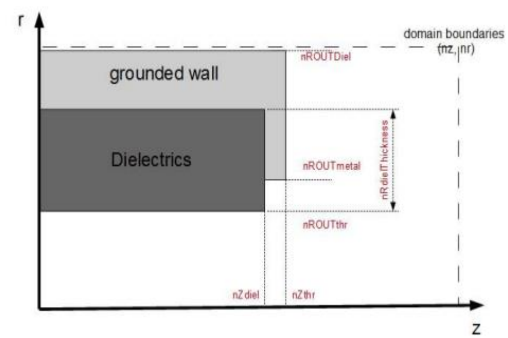
Particle in cell simulation

- Kinetic plasma simulation of the HEMP Thruster
- FEM simulation not possible at low densities
- Code is developed by the University Greifswald
- Problem with regions of high density difference

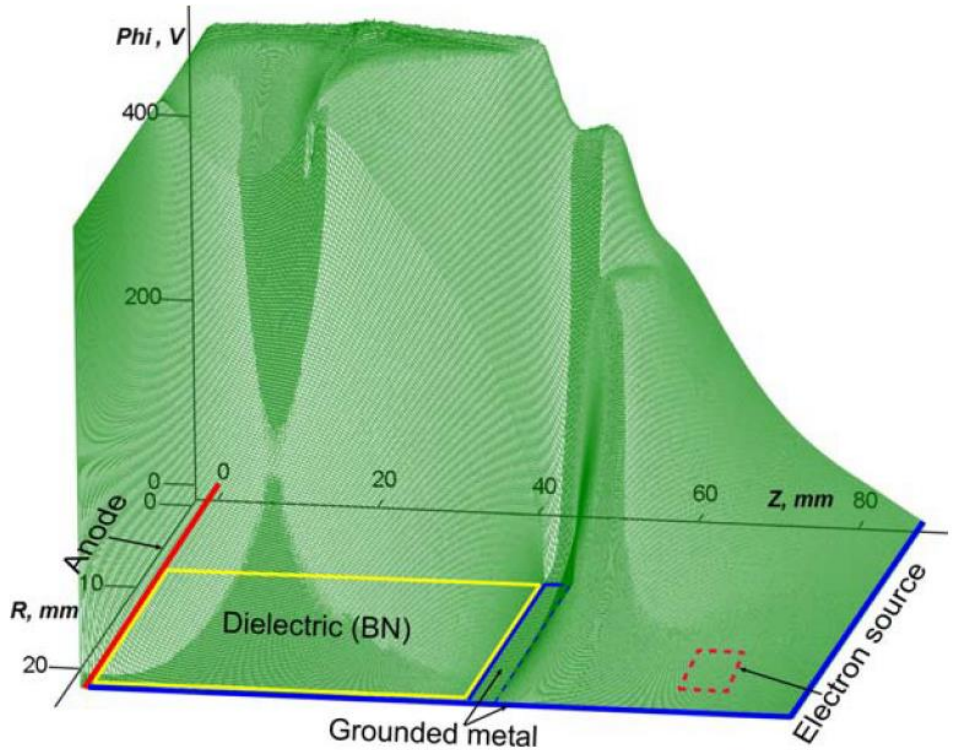
Simulation auf atomarem Niveau



Geometrie DM3a

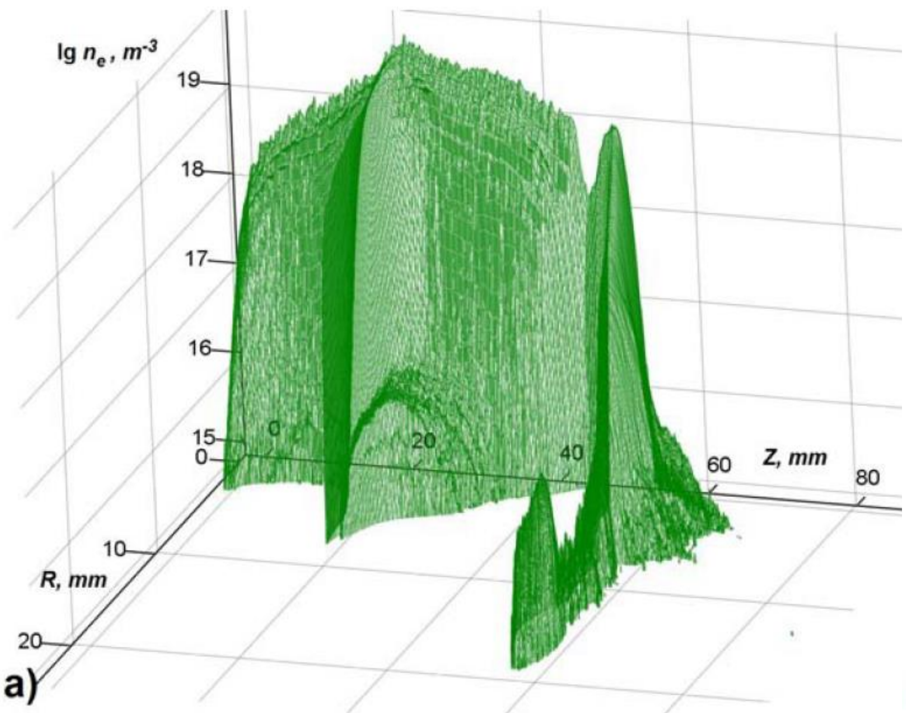


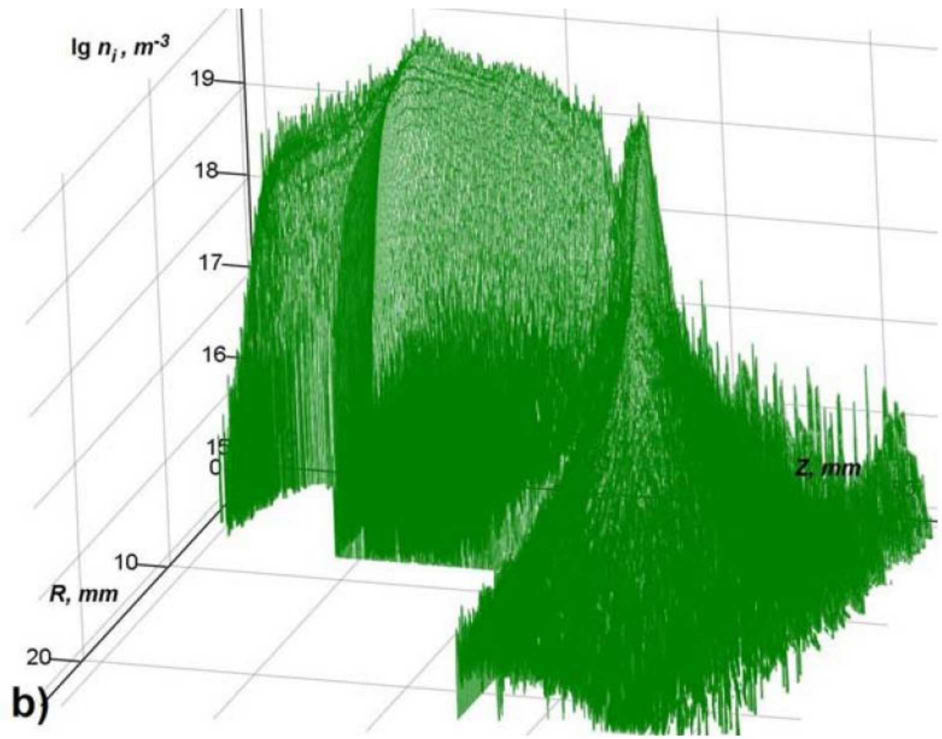
Particle in Cell (PIC) Simulation of the Ernst Moritz Arndt University Greifswald

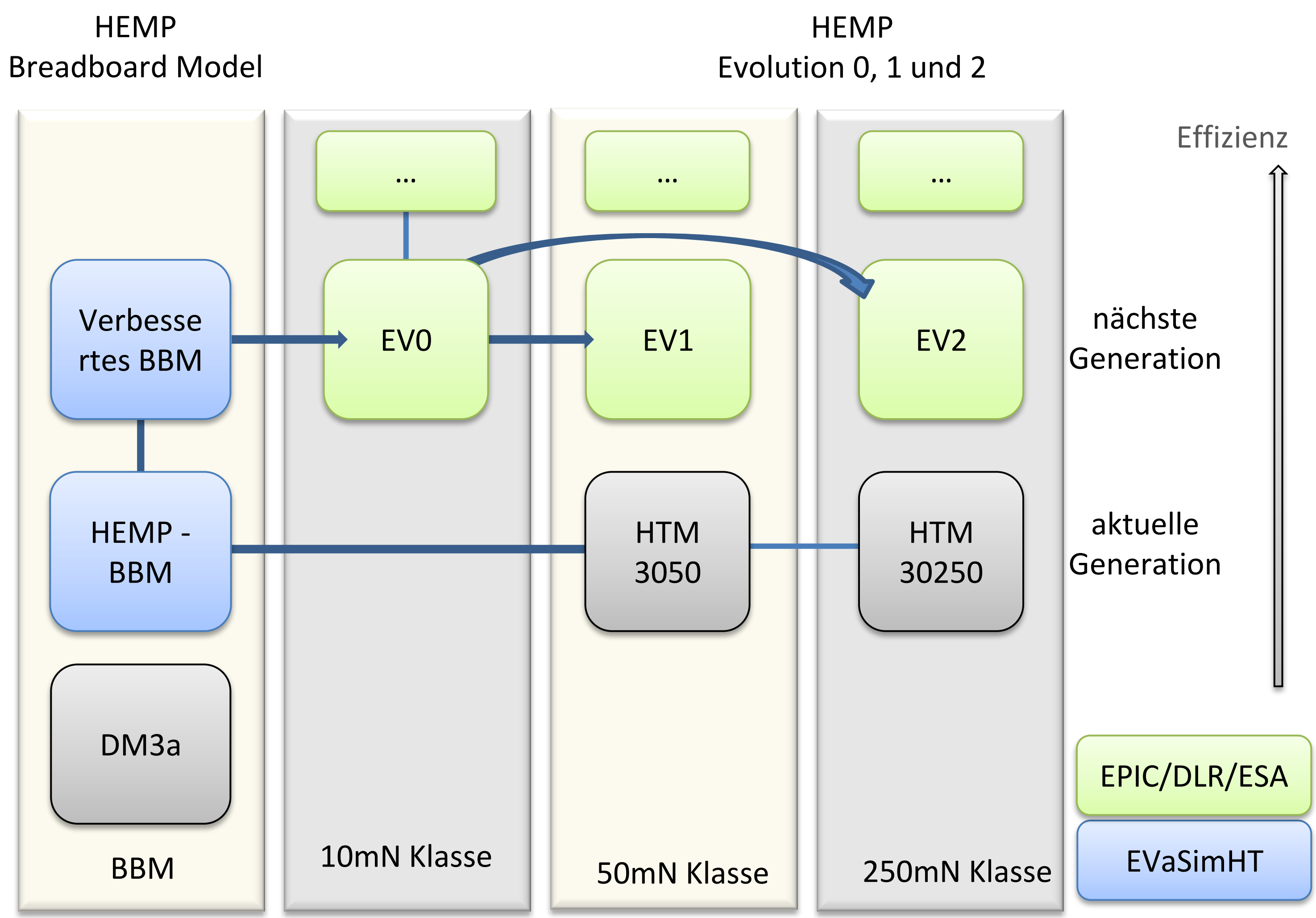


Computational domain for the simulation of the HEMP DM3a thruster with a calculated potential profile.

Electron (a) and ion (b) density profiles of the HEMP DM3a thruster.





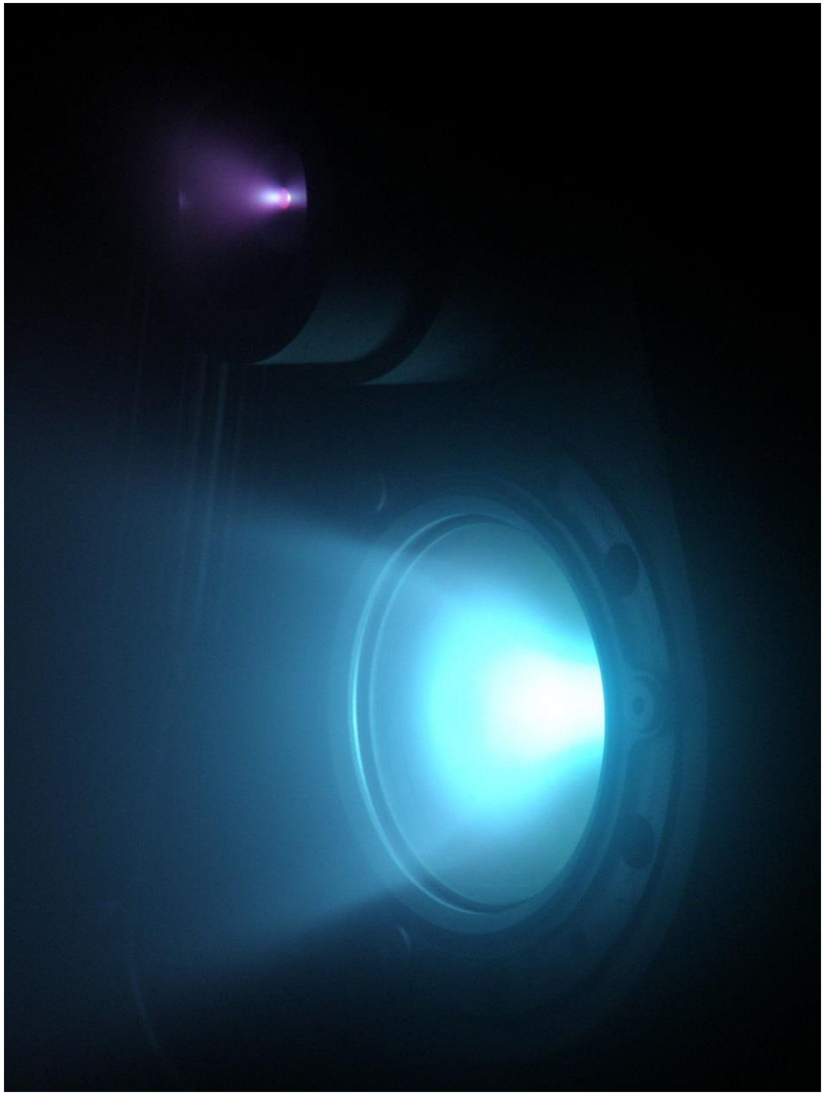

HEMP
Breadboard Model
HEMP
Evolution 0, 1 und 2
Effizienz
...
...
...
Verbesserte BBM
EV0
EV1
EV2
nächste Generation
HEMP - BBM
HTM 3050
HTM 30250
aktuelle Generation
DM3a
EPIC/DLR/ESA
EVaSimHT
BBM
10mN Klasse
50mN Klasse
250mN Klasse

HEMP in operation

Photography of the HEMP 3050 in operation

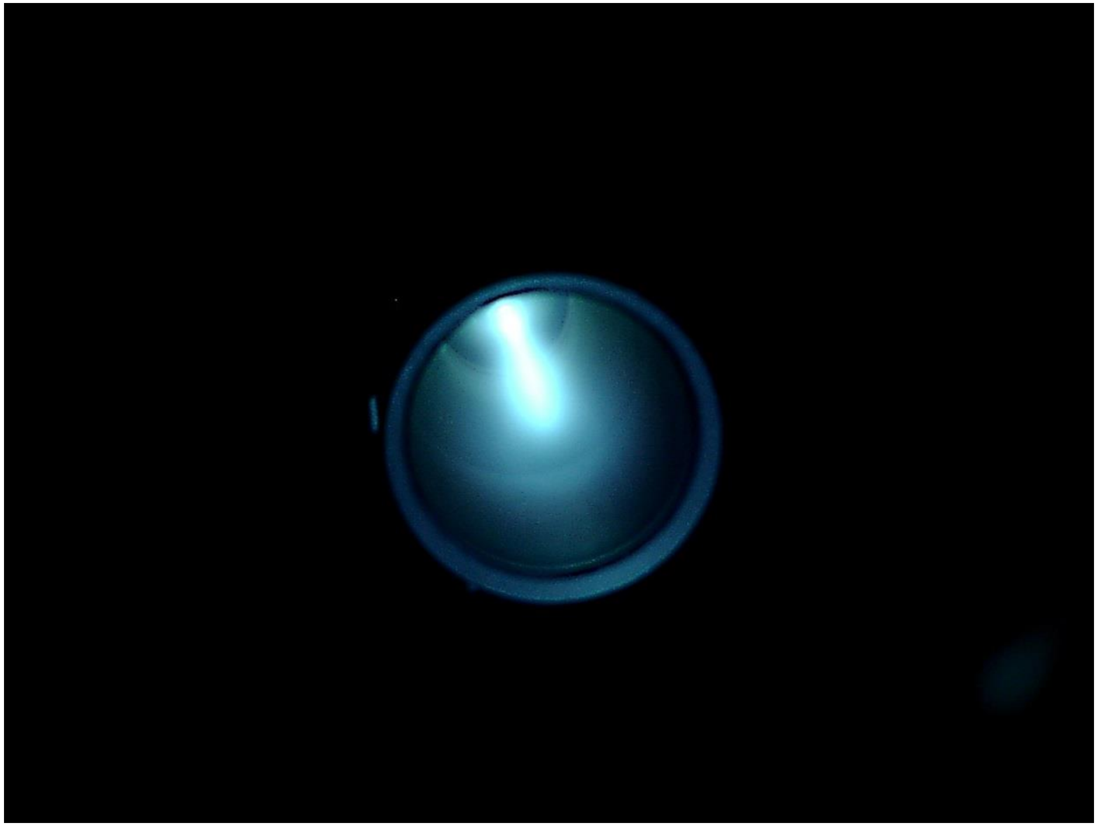
Purple glow: Hollow cathode neutraliser

Blue: Plasma, Plume and Beam

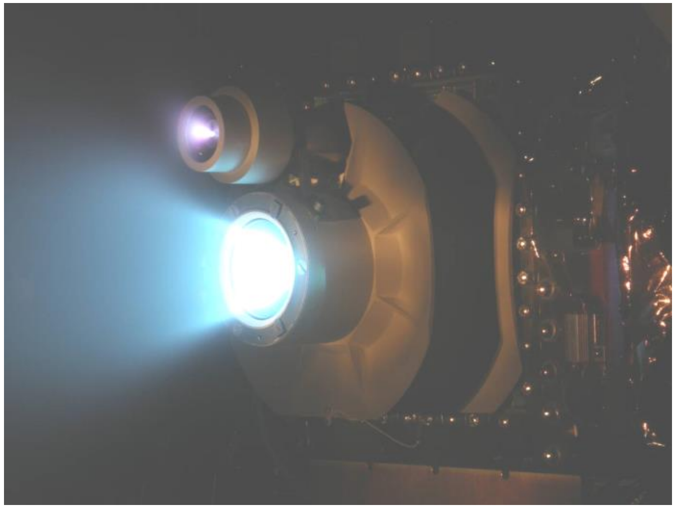


4 New Results: HEMP thruster DM7, Focused Plasma beam

Look into channel of DM 7_14_2 (BB HEMP 3050)
No plasma wall contact nor wall erosion



Thank you for your attention!



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