## Vacuum Facilities

Two high-vacuum facilities are used for the (V)LEO tests. A 10000 l/s cryo pump is connected to each vacuum chamber (large: 1.2 m x 1.4 m x 2.5 m; small: ø 0,5 m, length = 1 m) which generates a base pressure of $5 \cdot 10^{-8}$ mbar. Additionally, a 2300 l/s trubo pump is attached to the larger chamber.

Fig.: Large (left) and small (right) cryo chamber.

**About us**

Our development team with expertise plasma physics and aerospace engineering has many years of experience in the development and operation of electric propulsion systems and thrust balances. Ranging from electrothermal-, electrostatic-, electromagnetic thrusters to photonic force measurements with steady-state lasers in solar-sail applications. In our laboratories at the Institute of Aerospace Engineering at Technische Universität Dresden in Germany we continuously improve our devices in space-like environments.

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GWT Gesellschaft für Wissens- und Technologietransfer

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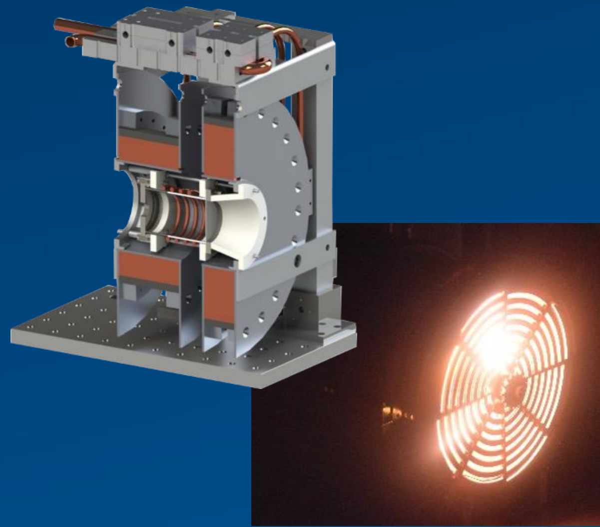

# (V)LEO Particle Simulators

Replication of the (V)LEO particle flow environment

ilr

Institute of Aerospace Engineering

# VLEO Particle Simulator

Simulating the Very Low Earth Orbit (VLEO) particle flow in a vacuum chamber is essential for on-ground testing of Air Breathing Electric Propulsion (ABEP) systems and special materials as well as estimating drag coefficients. The results can be used to optimize ABEP systems, improve numerical simulations and for more precise mission design.

The current design generates a particle beam with a diameter of about 17 - 36 mm (at the outlet) which is used for material research [1, 2]. Bigger versions are planned to test ABEP systems.

### VLEO Particle Simulator Features

- ✓ Vacuum compatible
- ✓ Tested gases: Ar, $O_2$, $N_2$, Soon: Mixtures ($O_2$ + $N_2$)
- ✓ High velocity neutral particle beam (including a small portion of charged particles)
- ✓ Simulated altitude range: 160 – 300 km
- ✓ Continuous operating time > 10 min

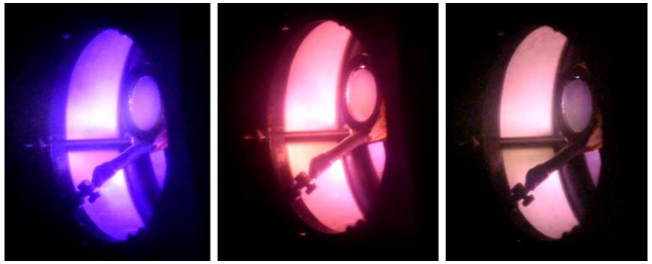

Fig.: VLEO Particle simulator operating with different gasses: left: Ar, middle: $N_2$, right: $O_2$.

Various diagnostics were developed to characterize the particle beam such as a combination of a catalytic and force probe that can estimate the particle flux density, particle velocity and ratio of atomic to molecular particle composition [1]. A high-resolution thrust balance including a titanium collector is also used to estimate the particle velocity.


Fig.: Particle beam diagnostics: left: combination of catalytic and force probe, right: collector thrust balance.

# LEO Plasma Simulator

The Low Earth Orbit (LEO) Plasma Simulator is used to determine interactions between the LEO space environment and spacecrafts, like degradation of materials, damages due to radiation, collisions with micro meteorites or space debris as well as build-up of electric charges which can damage sensitive electronics. The latter is based on interaction of the spacecraft with the LEO plasma environment. Furthermore, the expected properties of the surroundings can have a significant influence on the performance characteristic of the discharge. Testing electric devices such as hollow cathodes or electric thrusters in a LEO-similar plasma can improve confidence in the performance as well as reliability of these components.

The LEO consists of a thin plasma with particle energies of about 5 eV (atomic oxygen ion) and 0.1 eV (electron) in reference to a spacecraft. Atmospheric conditions are varying drastically due to various influences such as sunset or eclipse phase, sun inclination, sun cycle, sun eruptions, latitude, longitude, altitude, etc. The plasma density is also influenced by these factors and varying roughly between $10^{10}$ – $10^{13}$ $\text{particles/m}^3$. [3]

### LEO Plasma Simualor Features

- ✓ Vacuum compatible
- ✓ Tested gases: Ar, $N_2$
- ✓ Ion energy: ~3 eV
- ✓ Electron energy: 0.2 – 1.5 eV
- ✓ Plasma density: $2 \cdot 10^{10}$ – $7 \cdot 10^{12}$ $\text{particles/m}^3$
- ✓ Continouus operating time > 6 h

Various plasma diagnostics such as ExB probe, Langmuir probe and emissive probe were developed at the ILR to characterize the plasma.

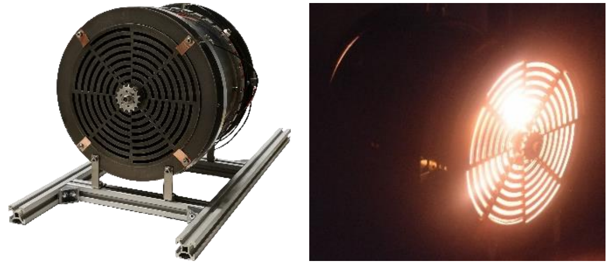

Fig.: LEO Plasma Simulator.

### Exemplary References:

[1] F. Prochnow *et al.*, "Investigation on the Ionization Probability of Coated Intakes used for a Novel Passively Ionizing Air-Breathing Electric Propulsion Concept for Very Low Earth Orbits," in *74th International Astronautical Congress (IAC)*, IAC-23,C4,5,3,x76605, Baku, Azerbaijan, 2023.

[2] F. Prochnow *et al.*, "Development of a Novel Passively Ionizing Air-Breathing Electric Propulsion Concept for Low Earth Orbits," in *37th International Electric Propulsion Conference*, IEPC-2022-420, 2022.

[3] F. Prochnow, C. Peter, J.-P. Wulfkühler, C. Drobny, Tajmar, and M, "Development of a low earth orbit plasma simulator," in 37th International Electric Propulsion Conference, IEPC-2022-589, 2022