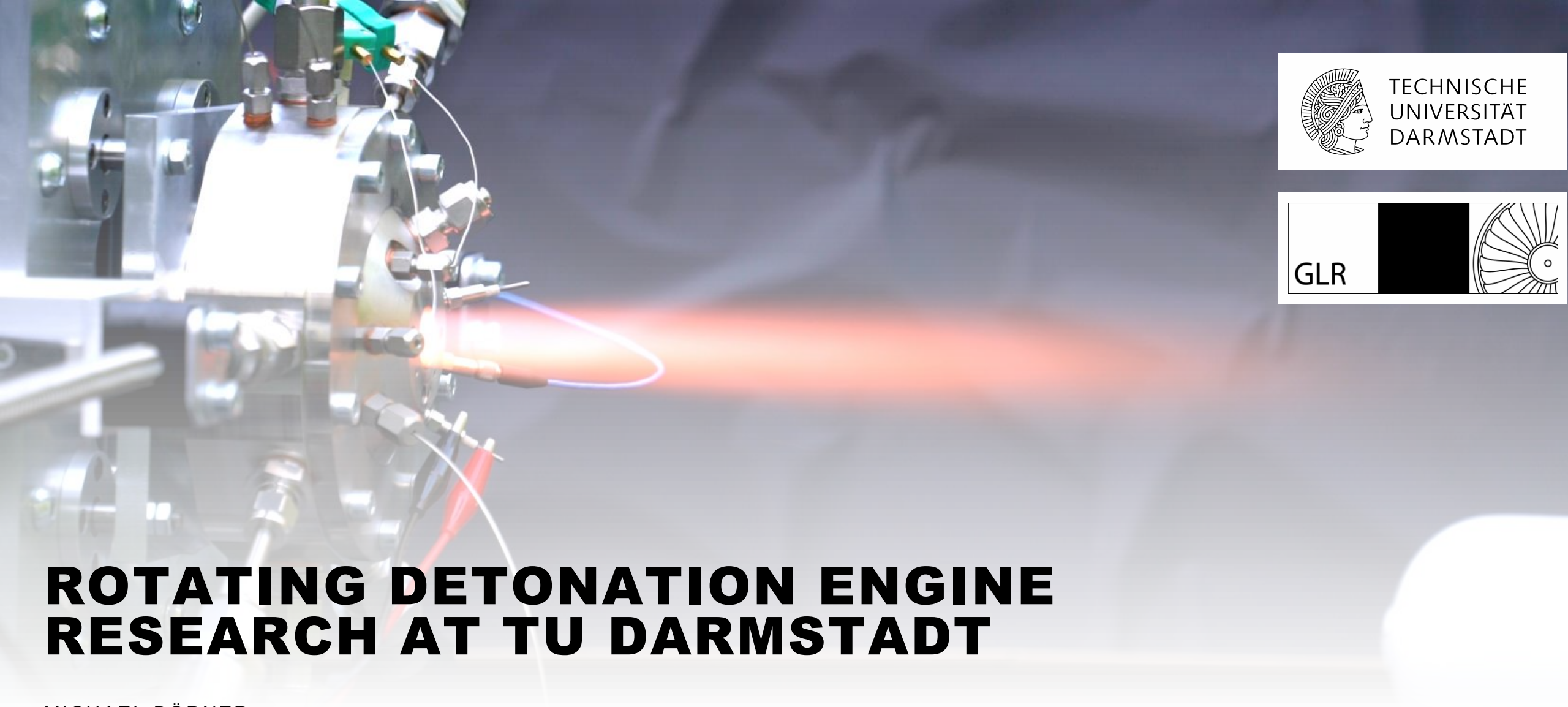
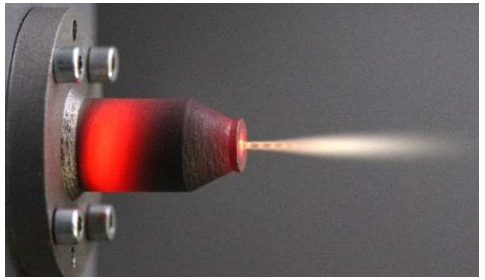


ROTATING DETONATION ENGINE RESEARCH AT TU DARMSTADT

MICHAEL BÖRNER
YONGHUN LEE
JUSTUS ALBERT
ALEXANDER KLINGEBERG

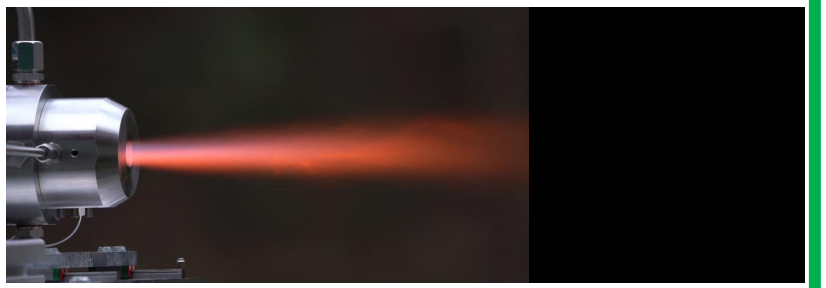
GLR SPACE PROPULSION RESEARCH
OVERVIEW

TECHNISCHE UNIVERSITÄT DARMSTADT



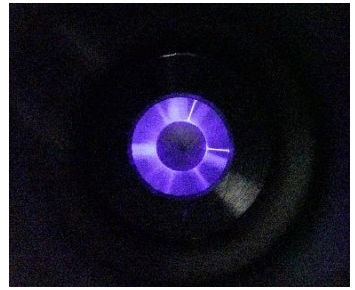
1. **Water Electrolysis Propulsion (WEP)**
   - Ban on hydrazine (EU REACH regulation) creates demand for alternative propellants
   - Address demand for compact propulsion systems in small satellites & space probes

2. **Small-Scale Rotating Detonation Engine**
   - Compact and potentially high-efficiency engine beneficial for air breathing & space applications
   - Reaction Control Systems on space transportation systems or deorbiting applications
   - Potential combination with WEP



Featured in AEROSPACE AMERICA Year in review 2024

3. **Ignition Methods for Space Propulsion**
   - Demand for alternative ignition methods using passive or active systems
   - Aim to minimize ignition delay, for more efficient use of propellant



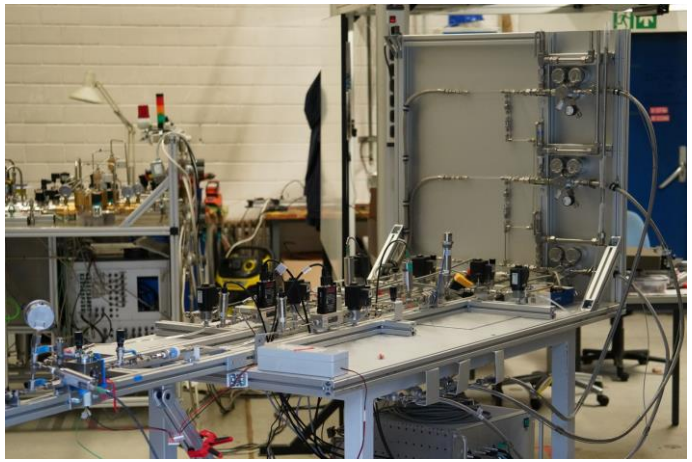
GLR SPACE PROPULSION RESEARCH

OUR EXPERIMENTAL INFRASTRUCTURE

TECHNISCHE UNIVERSITÄT DARMSTADT

PICO

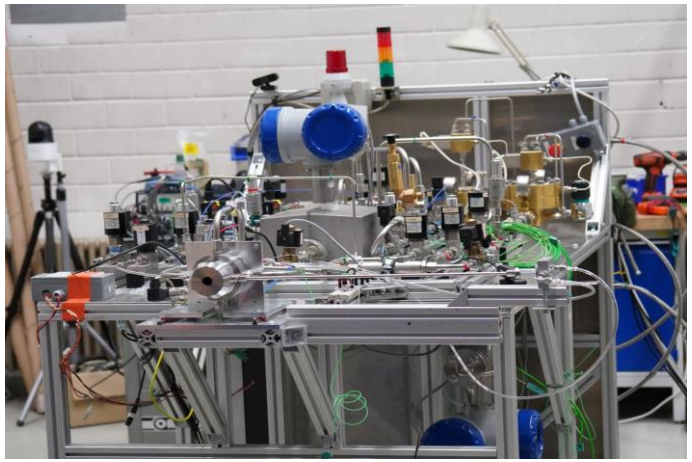
Propulsion Infrastructure for CubeSat Operation



Propellant:	O2 & H2
Mass flow:	0.77 g/s
Pressure:	20 bar
Thrust range:	~ 1 N

LOTUS

Liquid Oxygen Test Unit for Space

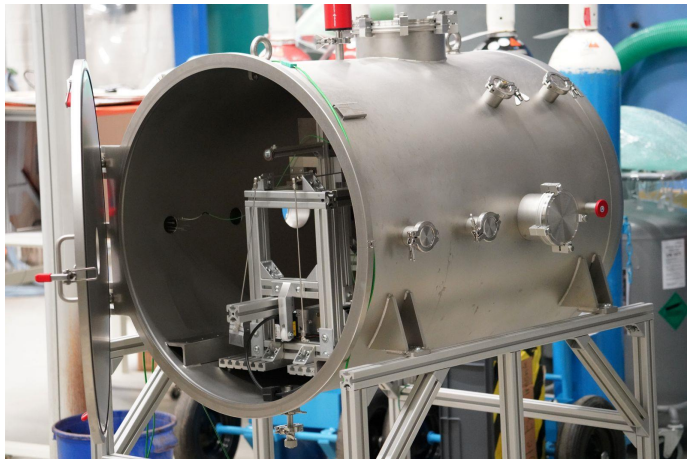


Propellant:	O2 with H2 or CH4
Mass flow:	30 g/s
Pressure:	5 - 40 bar
Thrust range:	~ 40 N

allows temperature-ramping of propellants

EVA

Vacuum facility



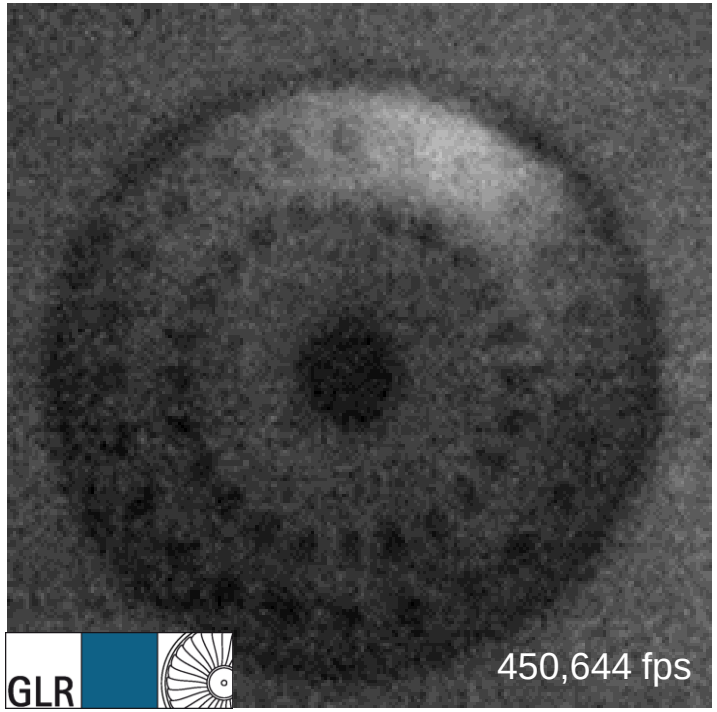
Chamber volume:	0.6 m^3
Vacuum level:	< 10 mbar

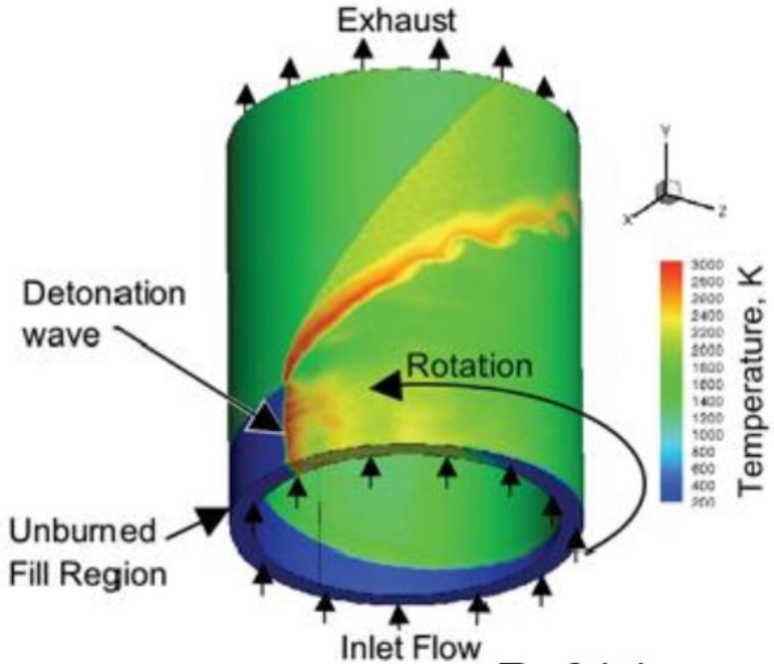
GLR SPACE PROPULSION RESEARCH
SMALL-SCALE RDE - MOTIVATION

TECHNISCHE UNIVERSITÄT DARMSTADT

Concept:

- Continuous rotating wave in annular or hollow combustion chamber





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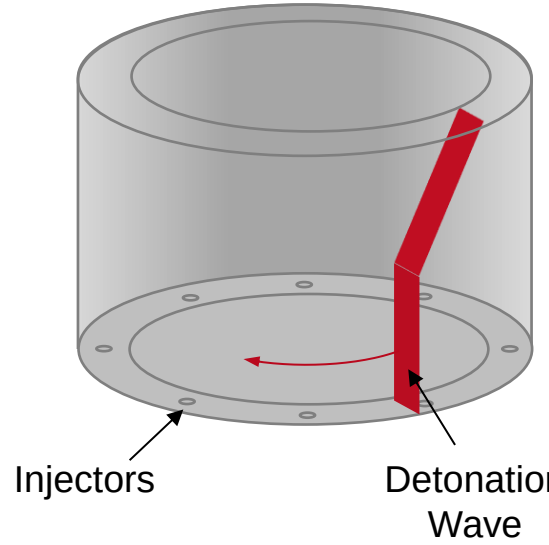
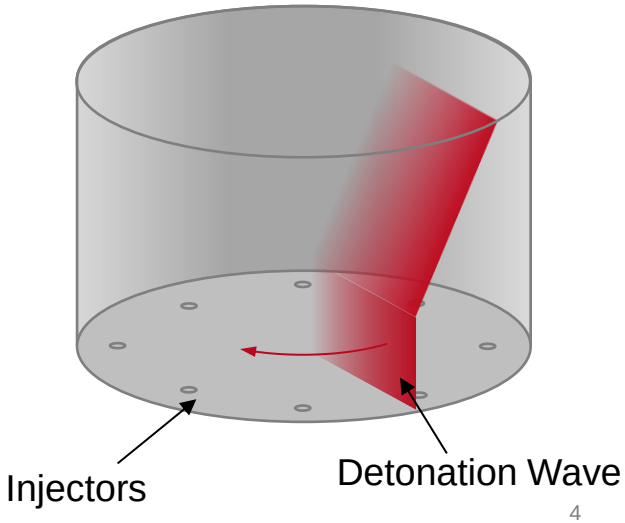




GLR SPACE PROPULSION RESEARCH
SMALL-SCALE RDE - MOTIVATION

TECHNISCHE UNIVERSITÄT DARMSTADT

Concept:

- Continuous rotating wave in annular or hollow combustion chamber

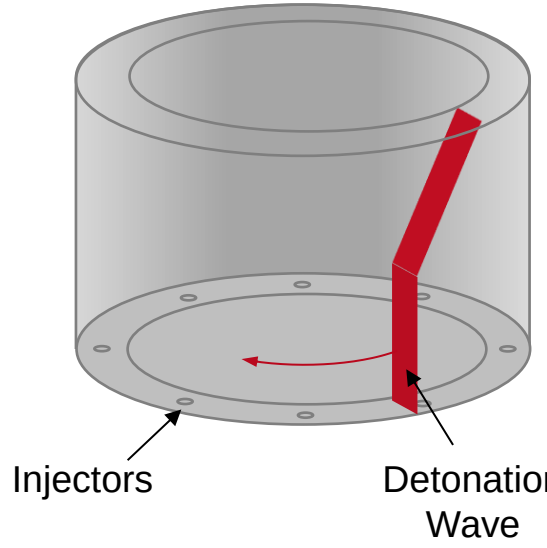
Motivation:

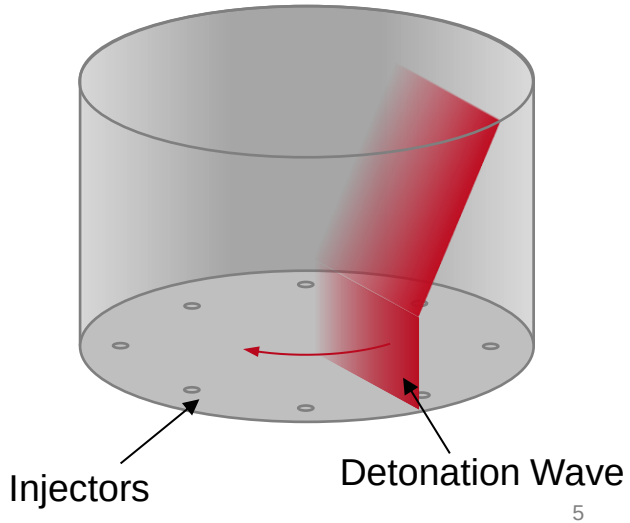
- Since ~1970s: No efficiency gain for space propulsion by deflagration (ISP < 450 s)
- High efficiency gains by pressure gain via detonation
- Benefit of compact size and potential high specific impulse and efficiency
- Efficient use of green propellants (hydrogen/oxygen or methane/oxygen)
- **Current research focus:** RDEs with high mass flow (triple digit g/s or even higher)

  → **Question:** Limits of small-scale RDEs?

Planned activities for space propulsion:

- Focus on experimental activity for small-scale RDEs for in-orbit applications





CURRENT RDE RESEARCH ACTIVITIES
OVERVIEW

2022: Hollow chamber RDC

- First H2/O2 RDC experiment in Germany
- Basic investigation to understand detonation phenomena in a small-scale RDC

2025: Disk-type RDC

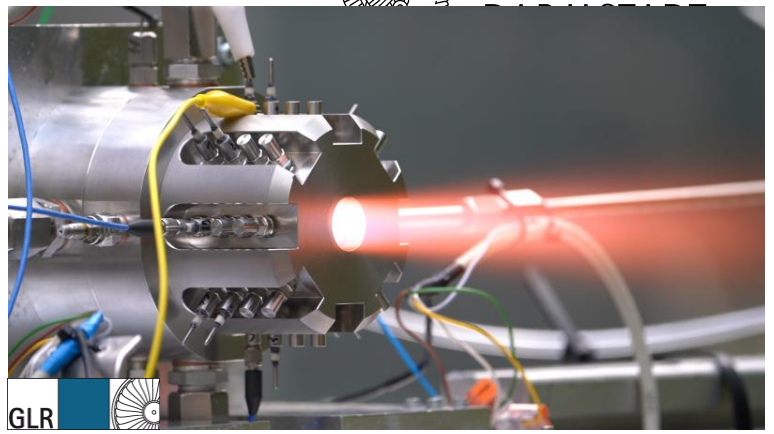
- First disk-type RDC at all in Germany
- Shorter engine size compared to cylindric RDCs

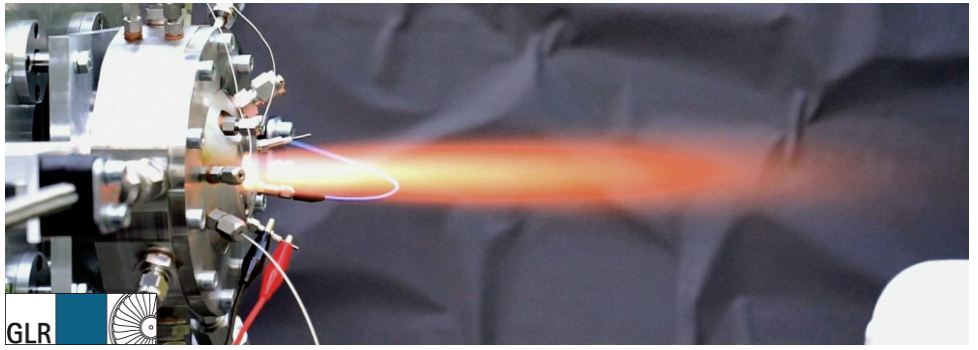
2025: Ionization probes as diagnostic for small-scale RDCs

- Diagnostic of small-scale RDE system is a challenge
- Potential miniaturized diagnostics

Next: Vacuum chamber

- Detonation dynamics and operation characteristics under in-space condition





HOLLOW CHAMBER RDC

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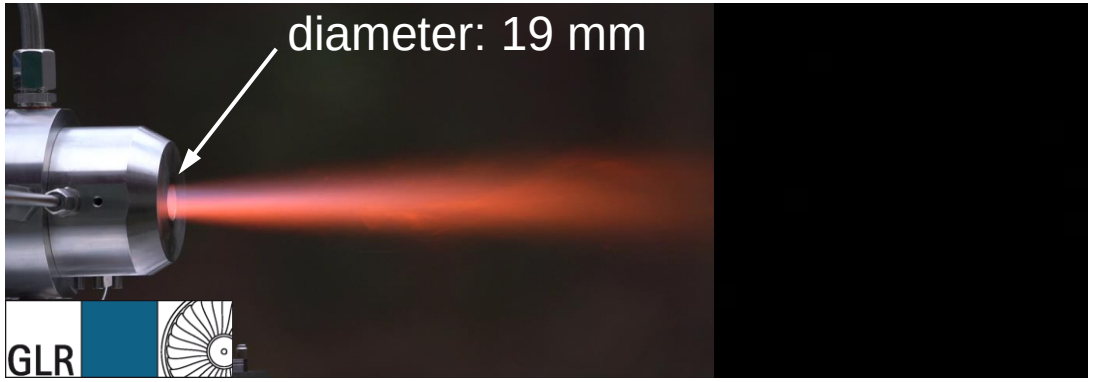
Key Parameters

- 19 mm inner diameter and 55 mm combustion chamber length
- 5 - 20 g/s of H_2 + O_2
- Modularized hollow core design
  - Reduced cooling effort for centerbody
  - Annular chamber configuration available

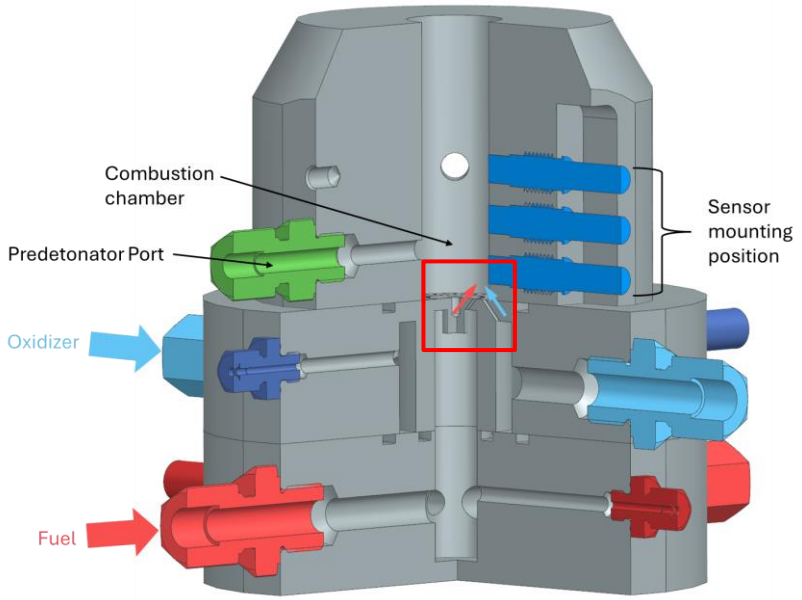


Status:

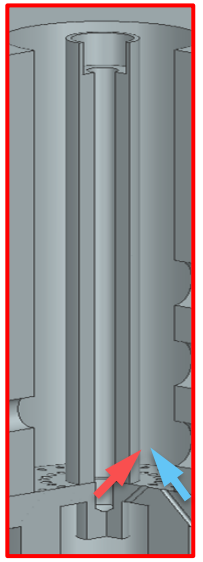
- Successful test and identification of detonation wave
- Analysis of operating characteristics

Roadmap:

- **Thrust measurements**
- Performance and overall system efficiency analysis
- Calorimetric analysis for heat load measurement
- Mission scenario analysis



optional centerbody



DISK-TYPE RDC

TECHNISCHE UNIVERSITÄT DARMSTADT

Key Parameters

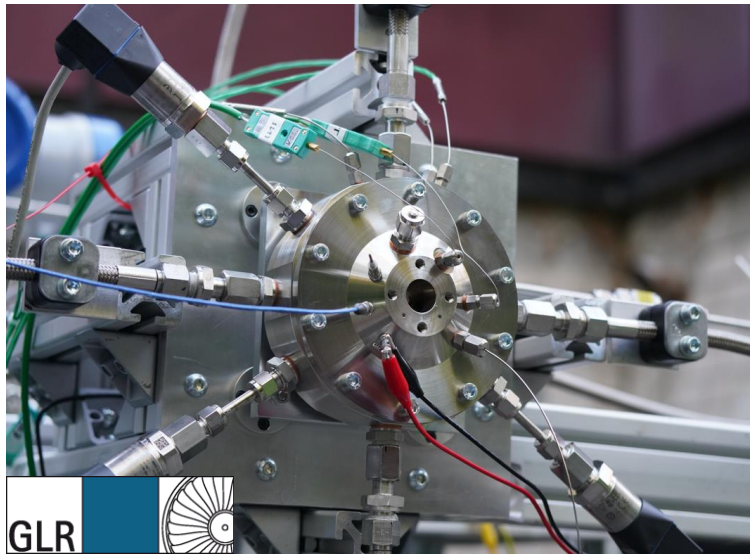
- Disk-type design for increased pressure gain & reduced axial length
- Modularized design
  → Option for aerospike & de Laval nozzles
  → Option for different combustion chamber geometries
- 5 - 30 g/s of H_2 + O_2 or CH_4 + O_2

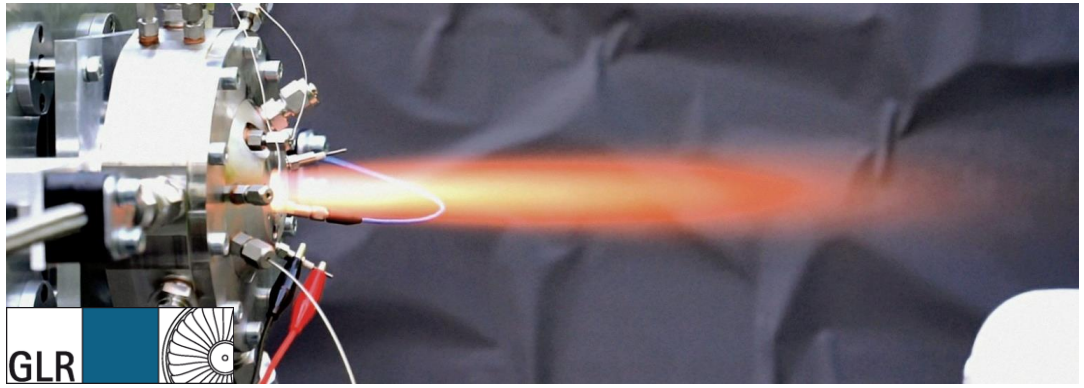
Status:

- First test data available since 02.10.2025

Roadmap:

- **Characterization of detonation waves**
- **Understanding of wave dynamics**
- Demonstration of various configurations
- Thrust measurement
- Performance and overall system efficiency analysis





IONIZATION PROBE

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Measurement principle

- Two electrically isolated electrodes
- Direct measurement of electric conductivity for wave detection

Potential

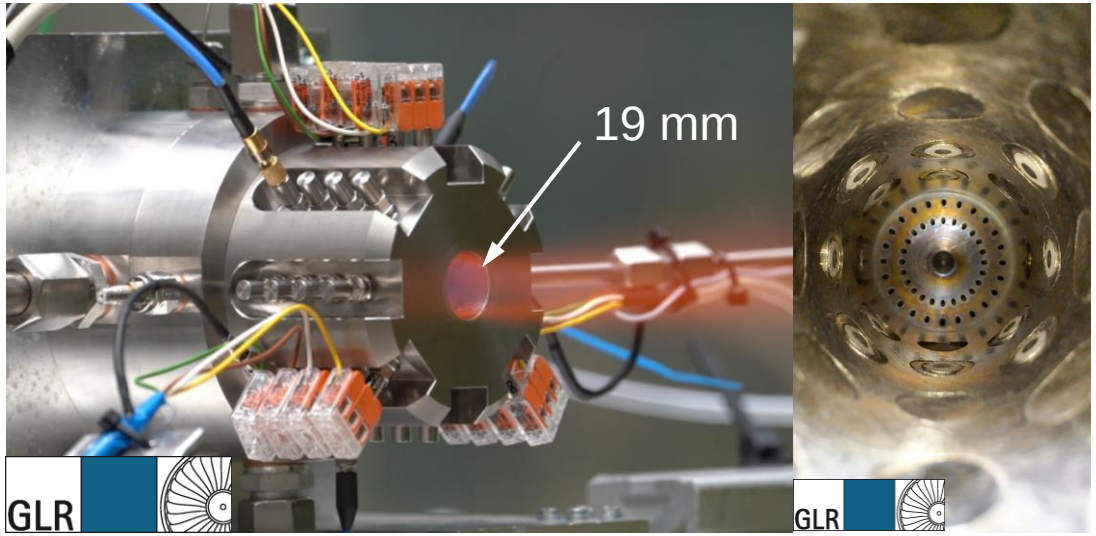
- Low-cost solution and miniaturized hardware size
- Longer life-time compared to conventional diagnostics (no thermal shock)

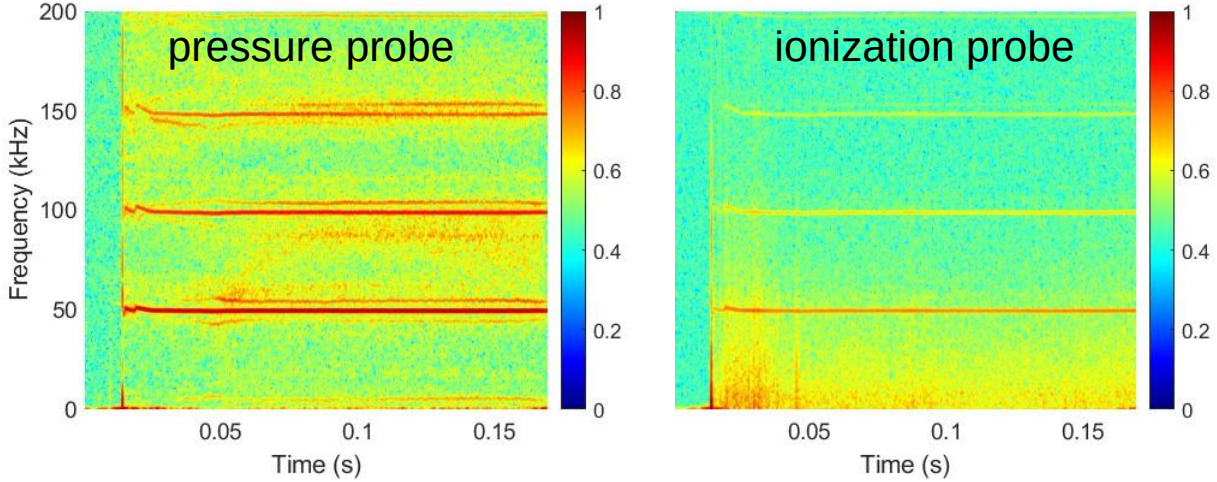
Status

- Qualitative and quantitative approach
- Measurement agreements verified against pressure sensors

Roadmap:

- Miniaturization and optimization for small-scale RDEs





NEXT STEPS
VACUUM CHAMBER FOR IN-SPACE PROPULSION

TECHNISCHE UNIVERSITÄT DARMSTADT

General

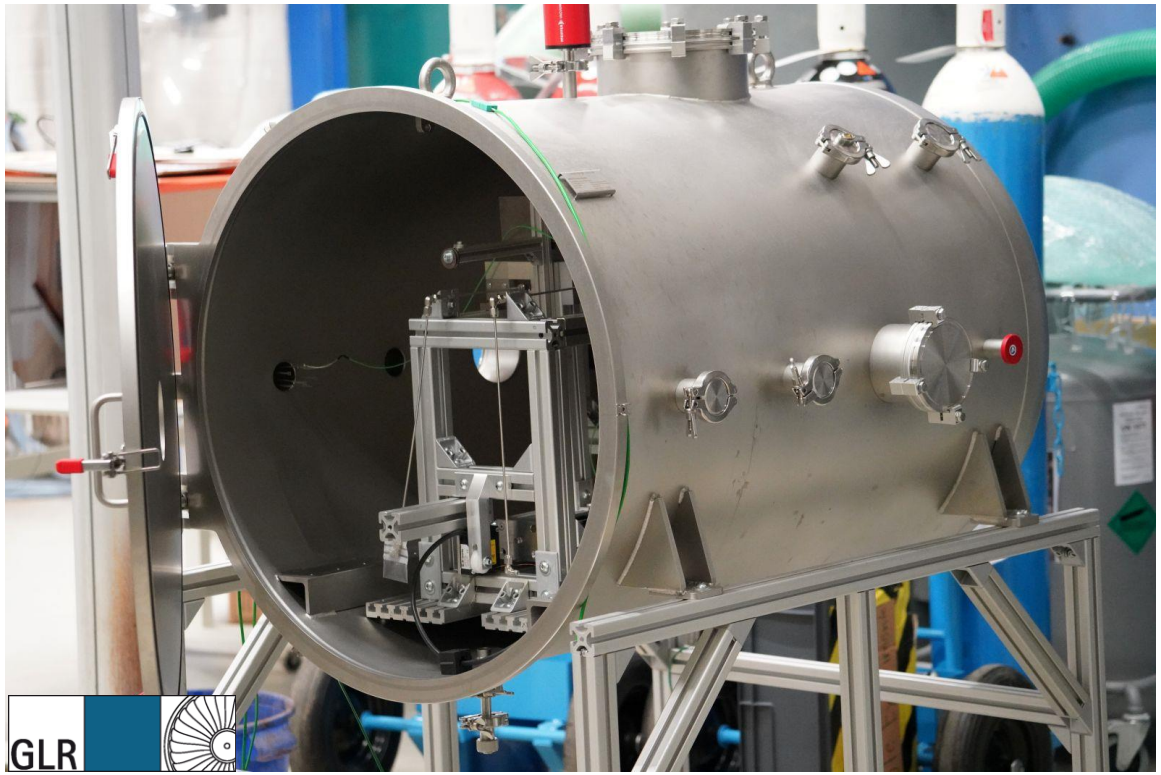
- Vacuum level < 10 mbar
- Combination with other testbenches possible

Feature

- Dual-use concept:
  - Thruster installation inside vacuum camber
    → Thrust measurement up to 1 N
  - Thruster connection via flange
- Feed throughs for propellants and electronics
- Windows for visual access

Roadmap:

- Functionality expansion for higher thrust measurement (up to 40 N)



SUMMARY & OUTLOOK

TECHNISCHE UNIVERSITÄT DARMSTADT

Current research at TU Darmstadt aims at

- Investigation on various small-scale RDC configurations
- Understanding of wave dynamics, operational characteristics and detonation phenomena
- Development of miniaturized diagnostic for small-scale RDEs

Roadmap / Outlook:

- Performance and overall system efficiency analysis
- Influence of vacuum conditions on the operational characteristics of RDEs
- Mission scenario analysis based on the operational characteristics and thrust range

THANK YOU FOR YOUR ATTENTION

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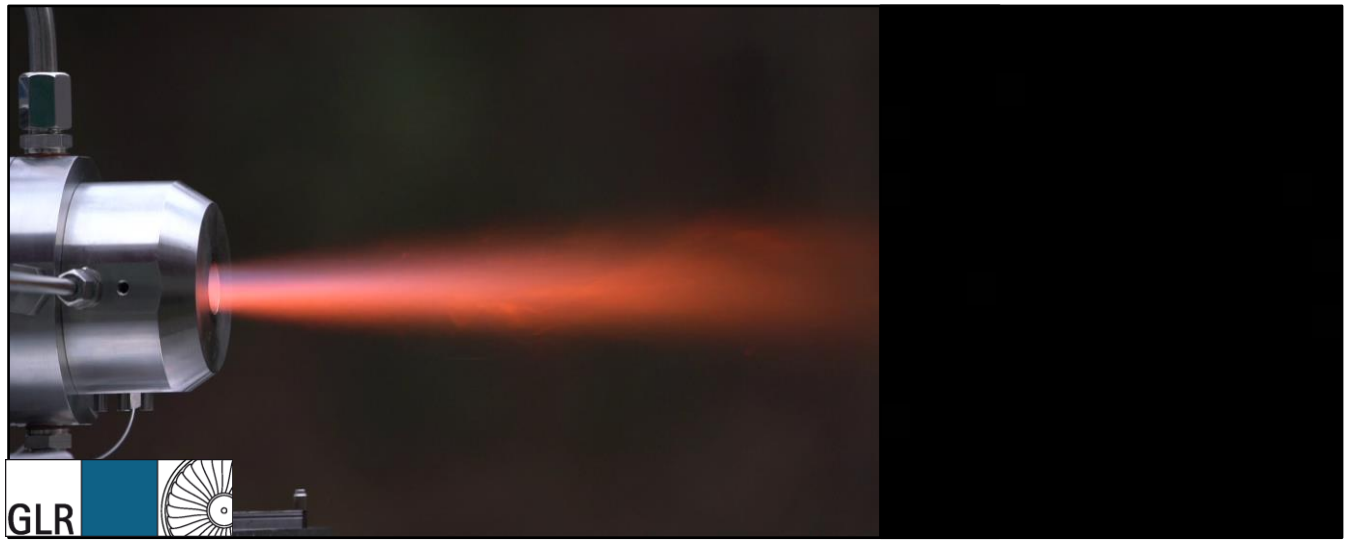

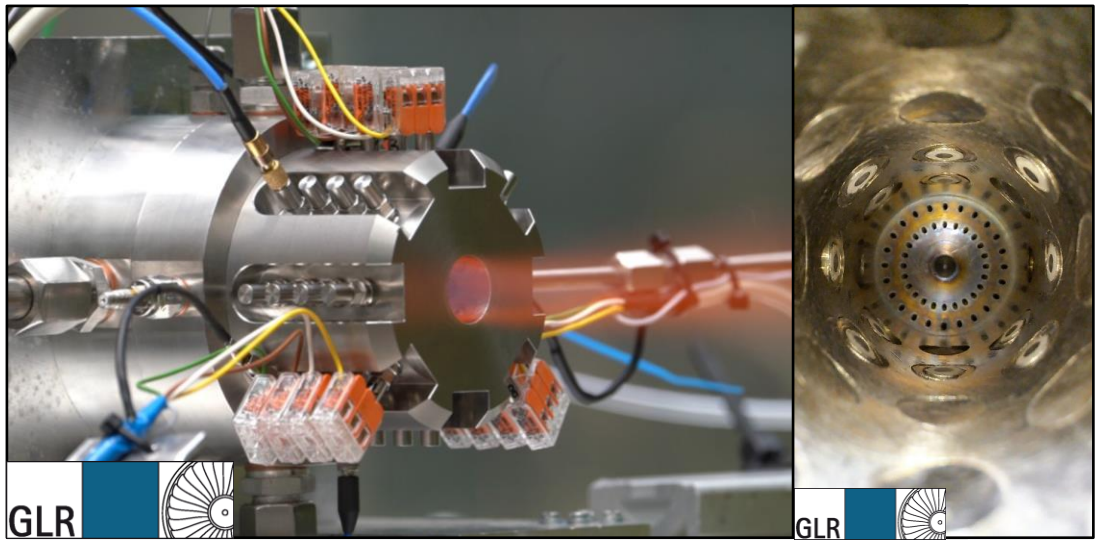

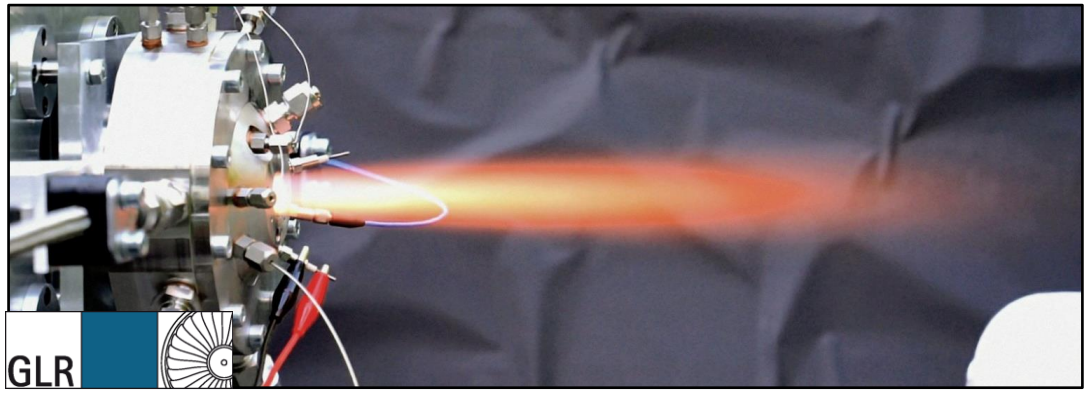

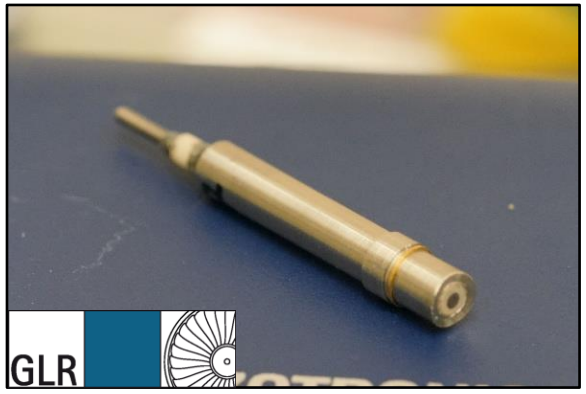

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