Overview on the DLR M3 Test Infrastructure

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DLR M3 Test Infrastructure (1)

- in service for research and technology development for cryogenic rocket propulsion for more than 30 years

- investigation of fundamental processes in rocket combustion chambers and supply systems
  - propellant conditioning
  - transient, two phase flows
  - injection
  - ignition (sequencing)
  - combustion dynamics

The operating conditions correspond to
  - **orbital engines**
  - in individual aspects to **launcher engines**

DLR M3 Test Infrastructure (2)

- **3 test positions**
  - M3.1: injection, ignition & combustion dynamics
  - M3.3: injection, cryogenic flash boiling & atomization
  - M3.5: cryogenic flows, cryogenic fluid hammer, characterization of fluid mechanical components

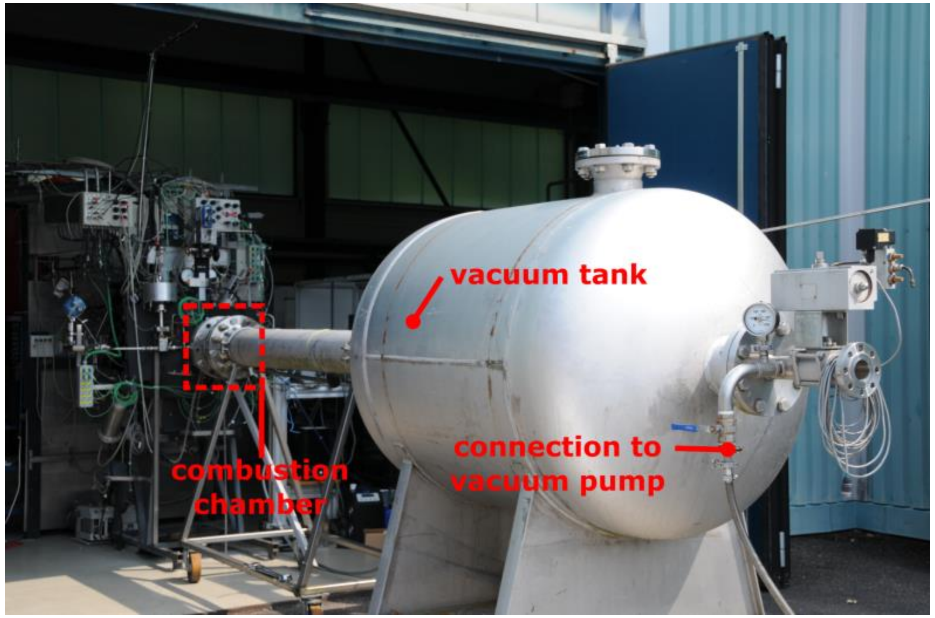
- **technology tests**
  - component tests for turbopumps
  - injector element characterization
  - ignition transients with varying background pressures
  - nozzle plume/ hot gas interaction with structural components (landing gear, heat shields, …)

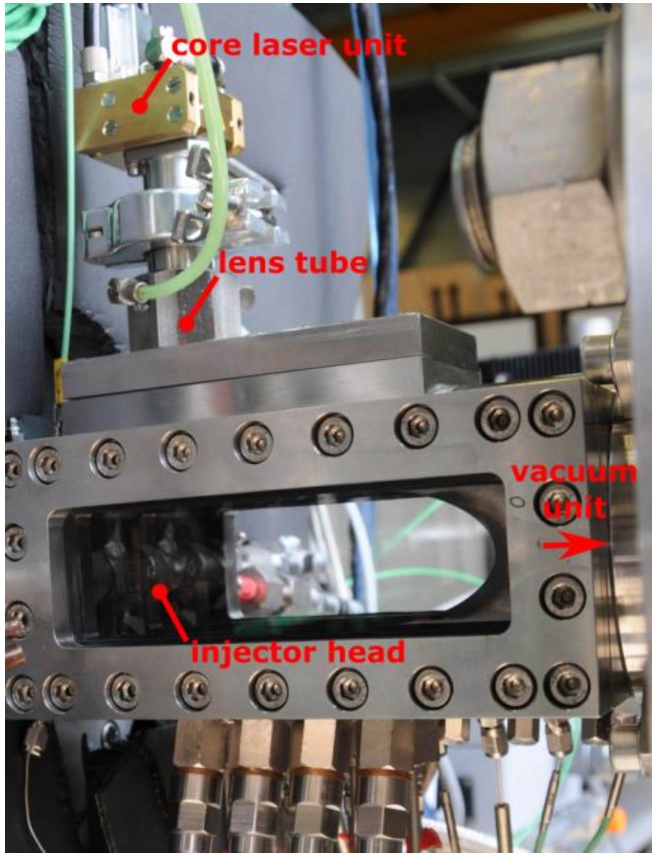
- **fluids**
  - liquid oxygen and liquid nitrogen
  - gaseous H2 or hydrocarbon fuels
  - feed-line pressures of up to 40 bar

M3.1: Ignition and Start Transients Research

- **Task area (research focus)**
  - Injection
  - Ignition sequencing
  - Laser ignition
  - Flame anchoring
  - Flammability studies
  - Material compatibility

- **Global features and operation conditions**
  - LOX/H2 and LOX/Methane (sub-critical)
  - optically accessible combustors
  - chamber diameter up to 60 mm
  - temperatures:
    - H2: 200 K to ambient
    - CH4: ambient
  - ground ignition conditions
  - „in space" conditions
  - „retro-propulsion" conditions





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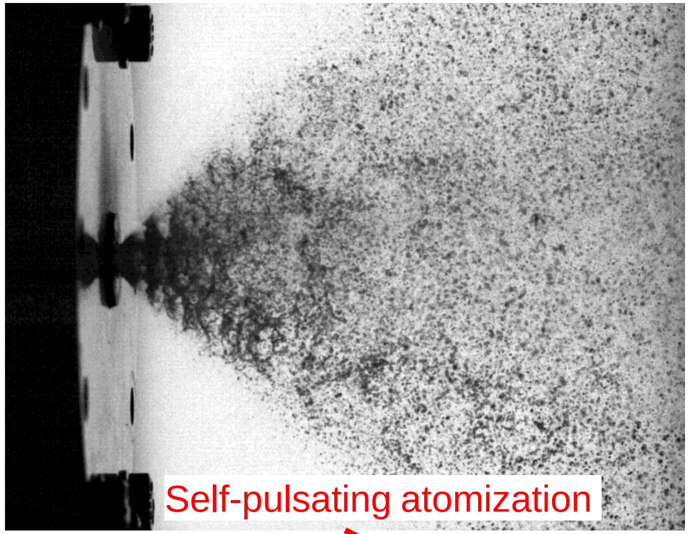

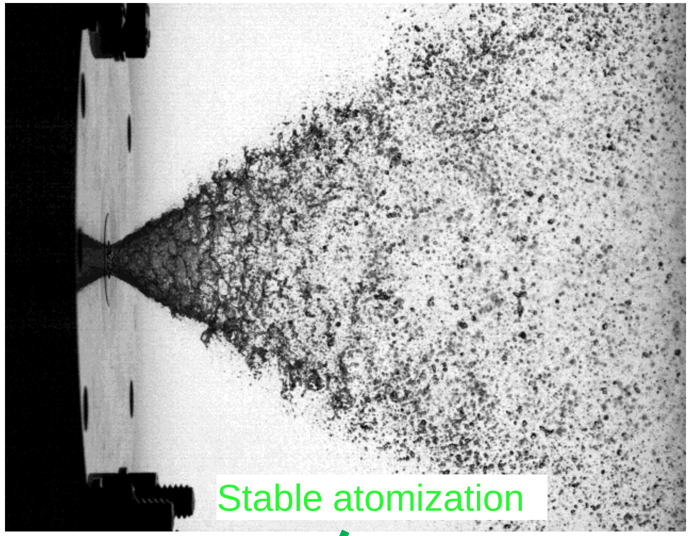

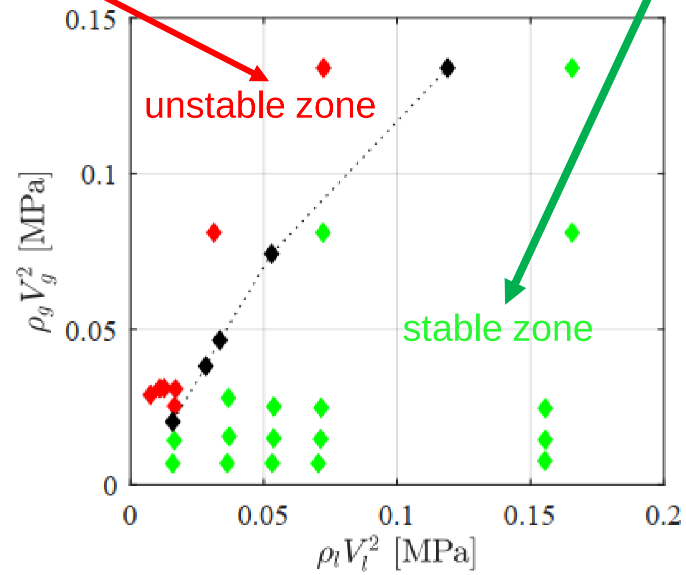

Source: Bee (2021), *Design and experimental comparison of swirl coaxial and shear coaxial injector elements for main combustion chambers of LOX/LNG engines*

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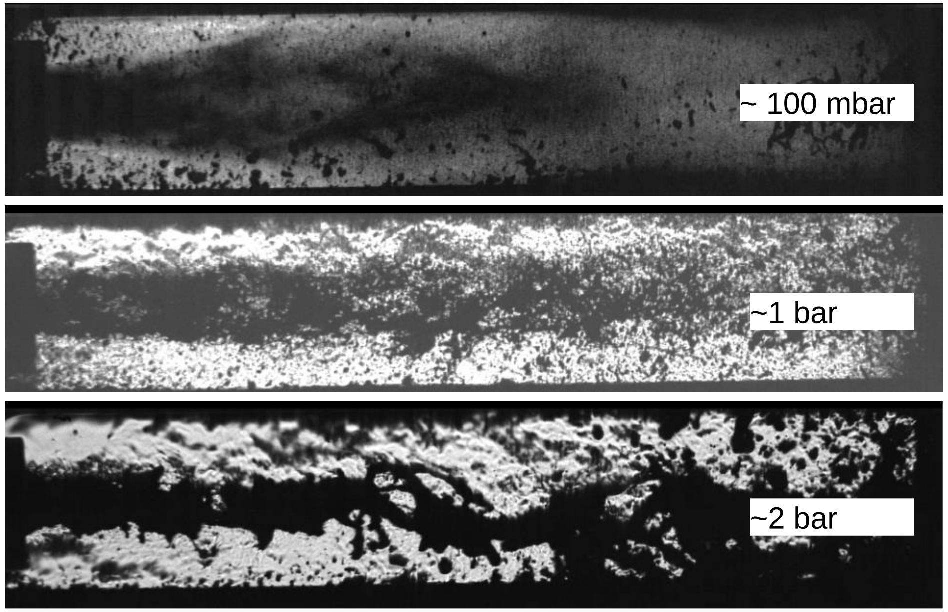

Soller et al. (2020)
SPC2020-00687

Vis

Schlieren

*OH**

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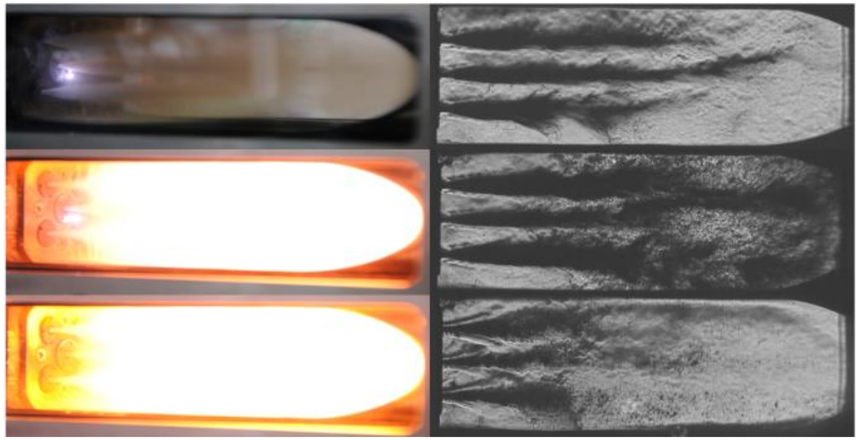
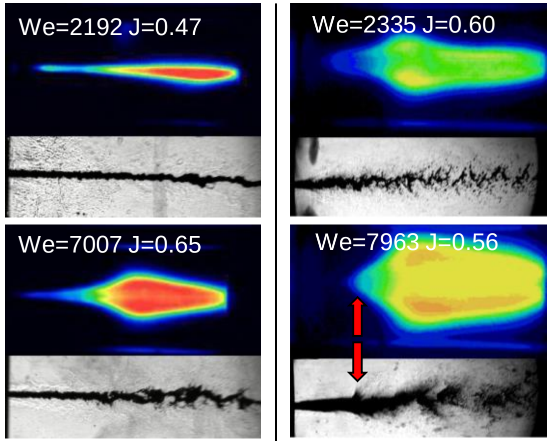


Börner et al. (2017)

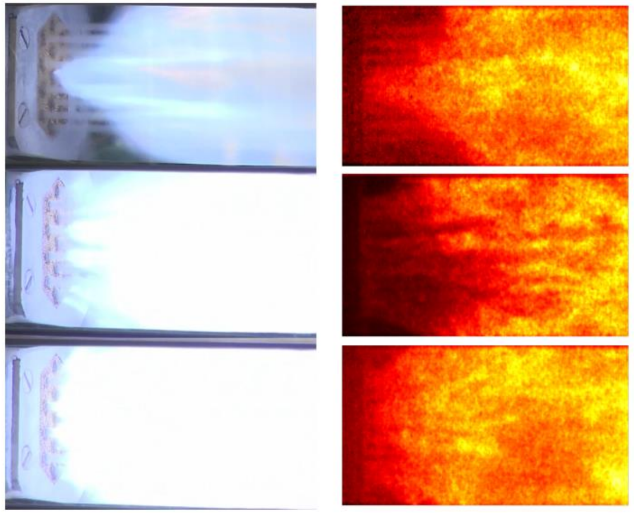


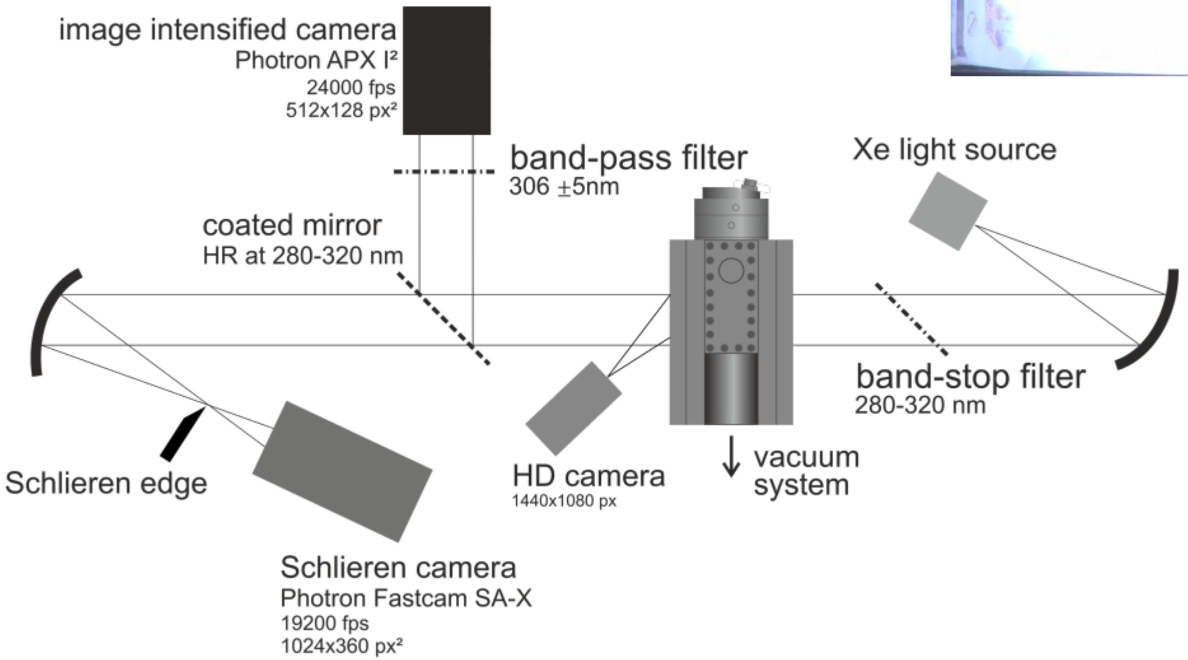
LOX/H_2 | LOX/CH_4

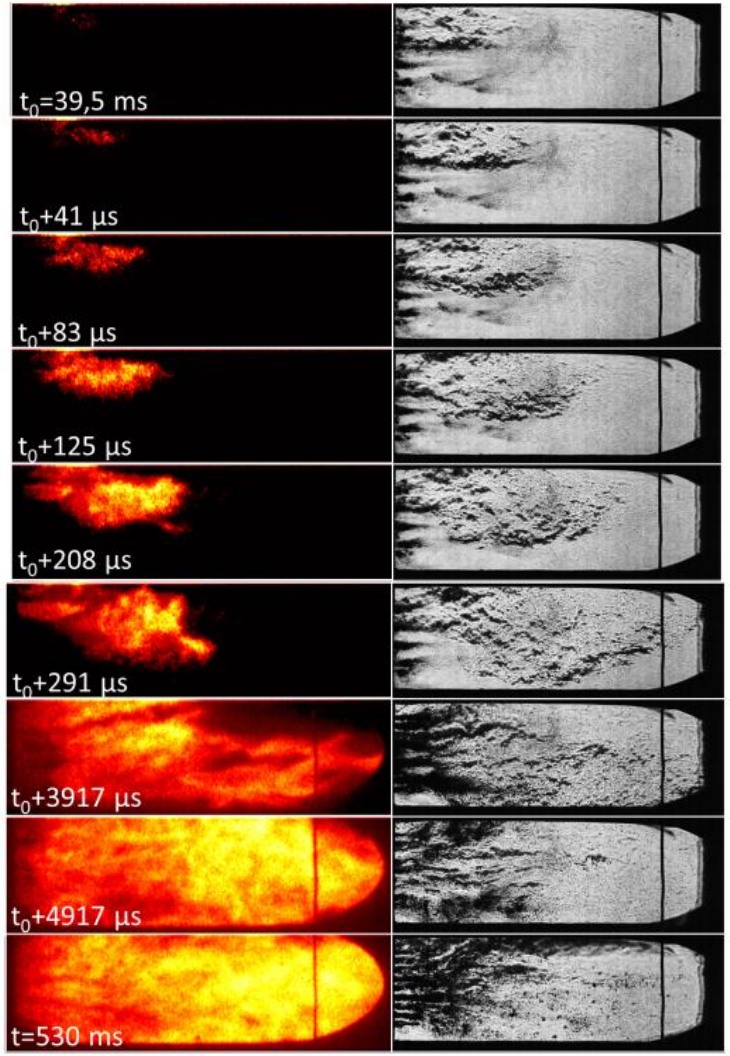
Yang, Cuoco & Oschwald (2007)

M3.1: Ignition and Start Transients

- **Applied software and diagnostic tools**
  - Simultaneous and same field of view for
    - High speed schlieren
    - High speed OH*/CH*
  - LIBS







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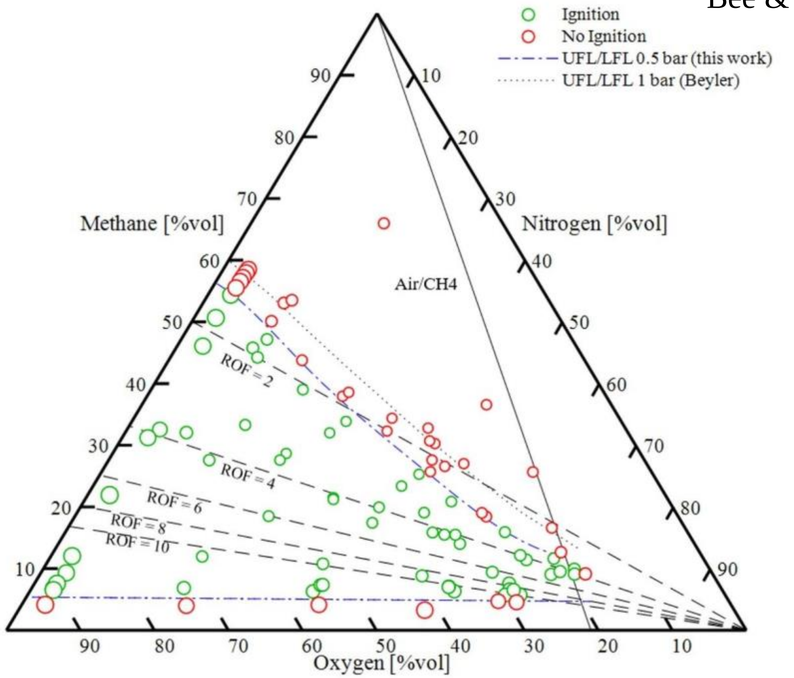
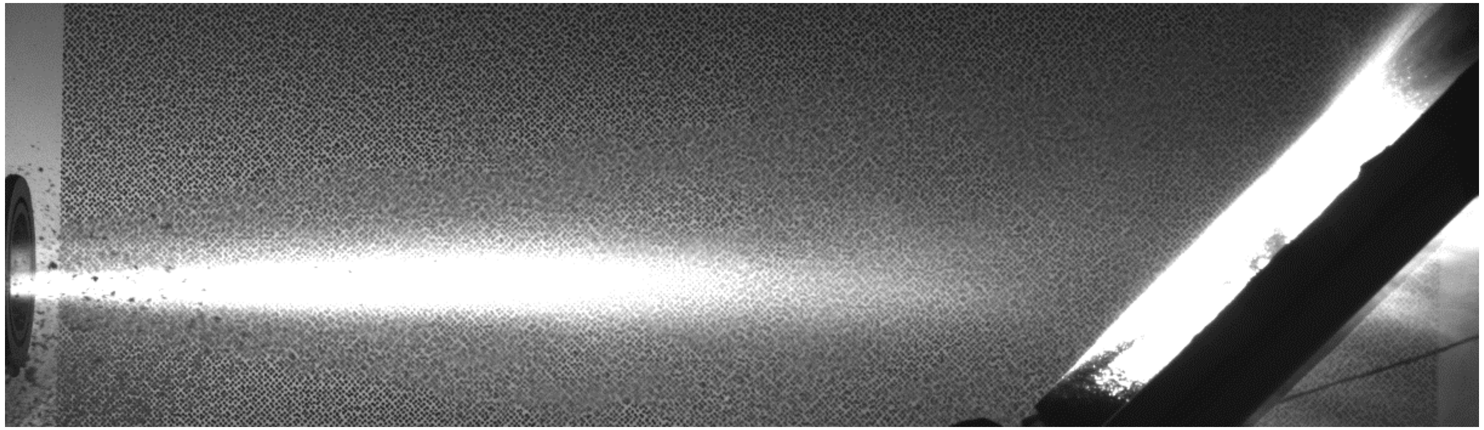
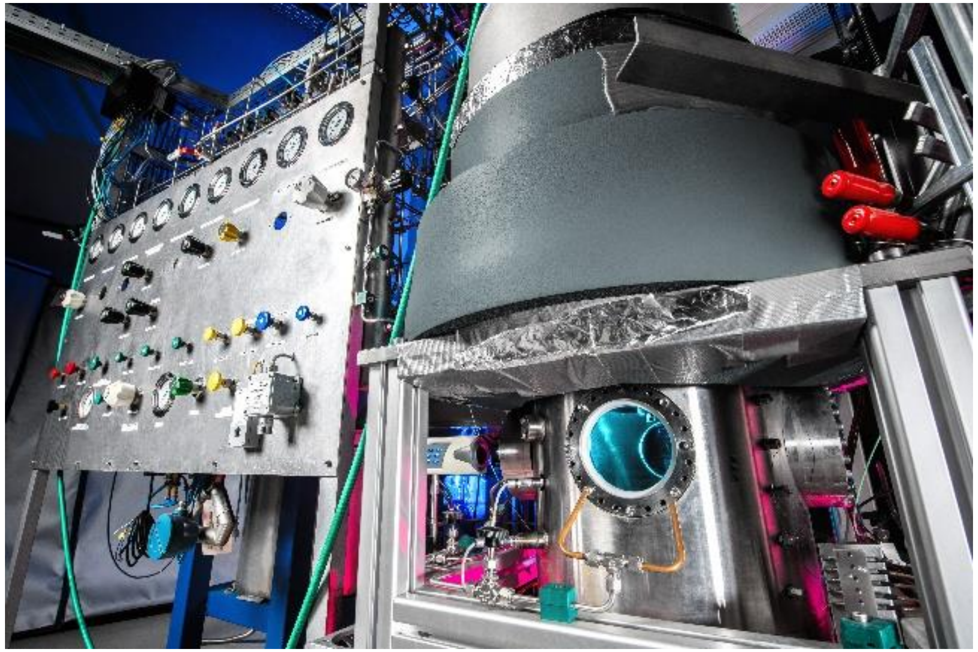
Bee & Börner (2021)

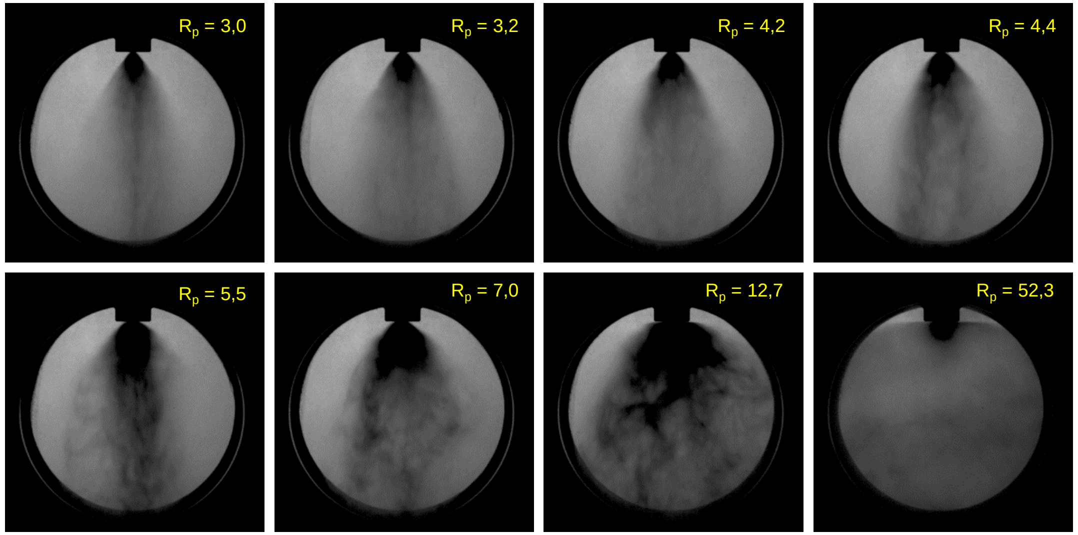




M3.3

- injection, cryogenic flash boiling & atomization
- cryogenic nitrogen and oxygen
- temperatures down to 76 K
- vacuum levels around 30 mbar
- investigation of cryogenic flash boiling and atomization
- optical spray diagnostics





Rees (2020)

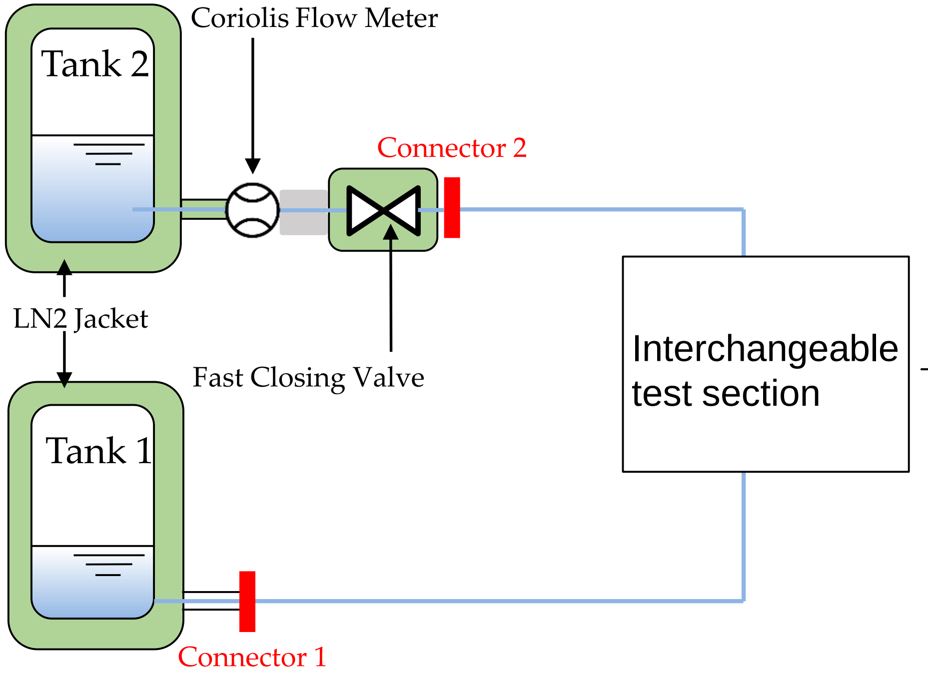
M3.5: Overview

Tanks:
- $V = 80$l
- $P = 50$ bar
- Pressure Control
- LN2 jacket isolation

Working fluids:
- LN2
- LOX

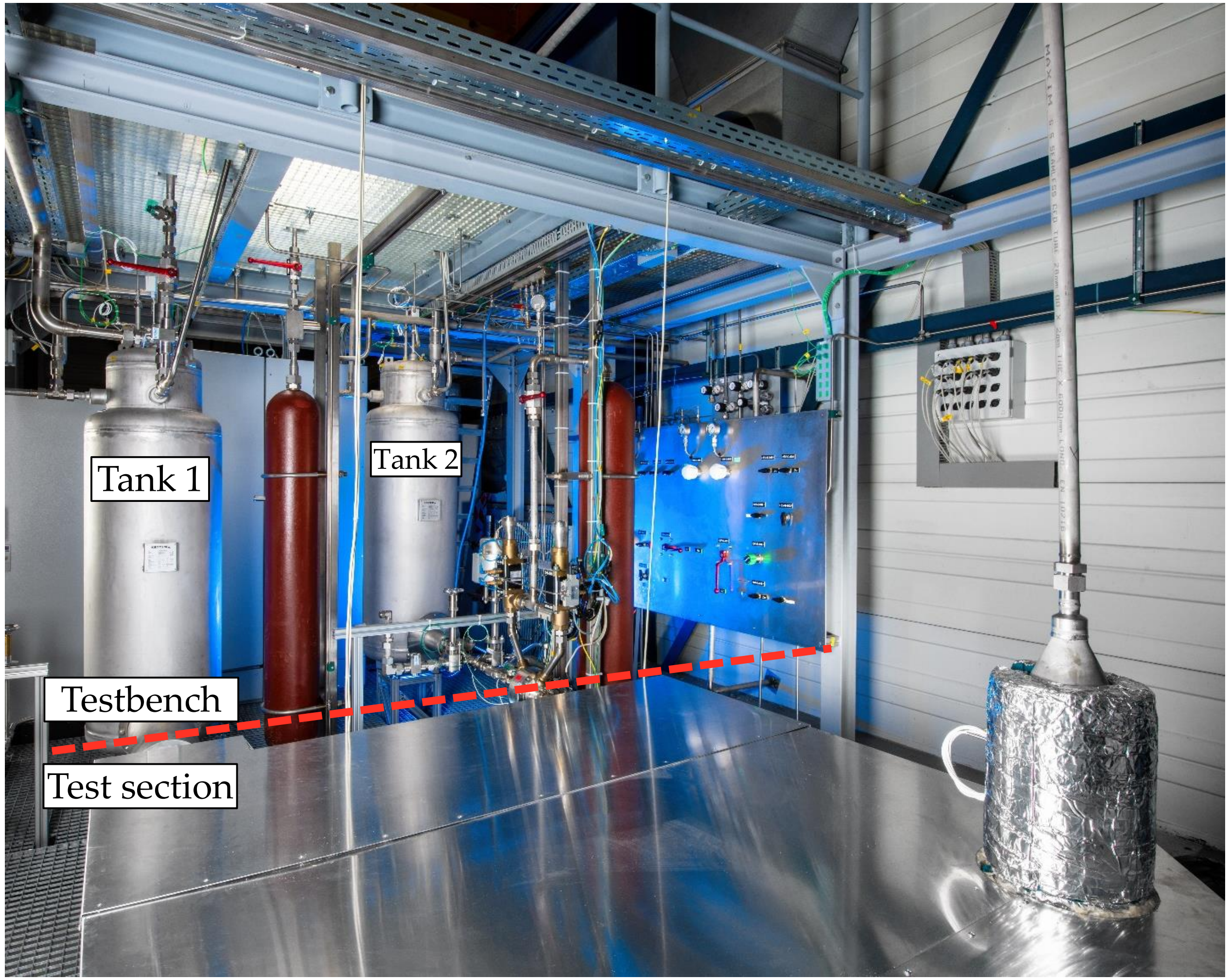
Mass flow:
- 2.8 kg/s

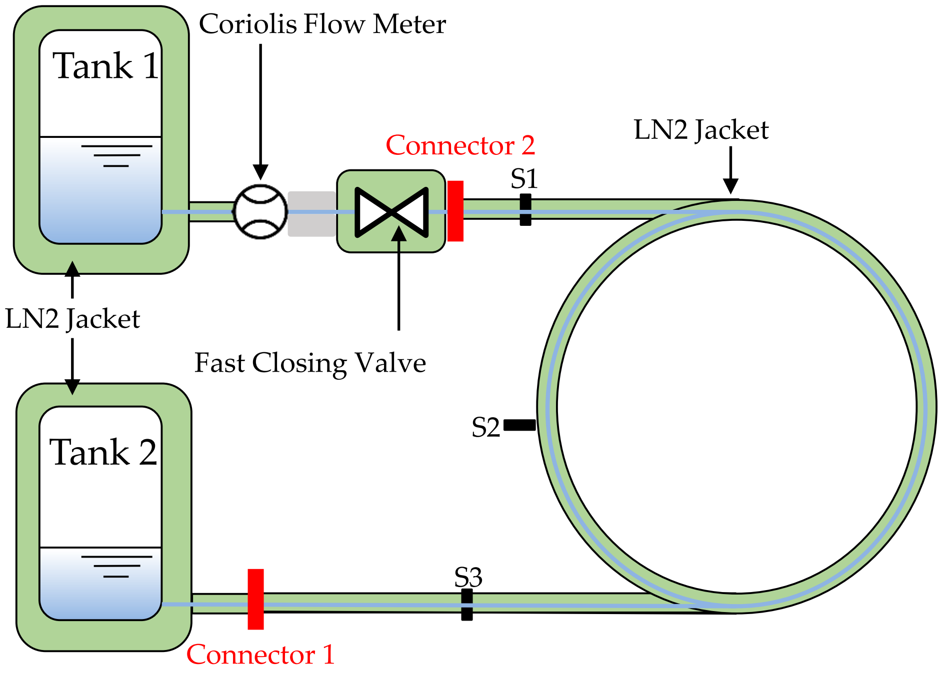
Valve:
- Axial Valve
- Closing Time: 18 ms
- LN2 bath



- Cryogenic Fluid Hammer
- Acoustic Cavitation
- Flow visualization
- Characterization of fluid mechanical components
- Benchmarks for numerical codes
- etc.

M3.5: Fluid hammer test section (example)



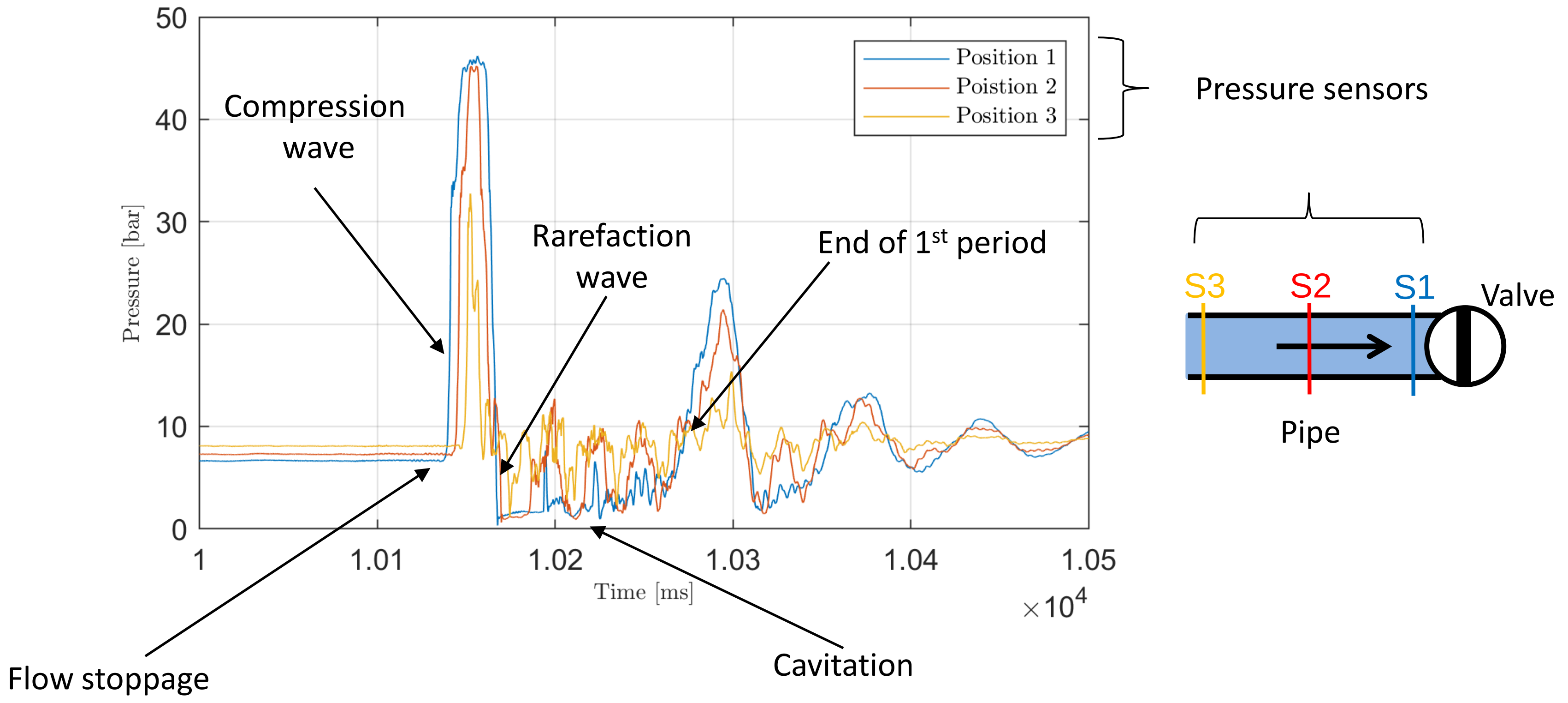


Pipe length:	9,294 m
Pipe inner Diameter:	19 mm
Sensor Position:	S1,S2,S3

M3.5: Fluid hammer test section (example)

Fluid Hammer

- Flow stoppage
- Pressure oscillations
- Cavitation



Why to test at M3?

- **fast iteration of technology** development to **increase the TRL**
  - ➢ early identification of „show-stopper“
  - ➢ first step from ideal laboratory environment to „real world“ environment
- many tests per test day with access to the test article
  - ➢ **hardware- and sequence-oriented test matrices**
- **test capacity available on short notice**
- **trained and experienced personnel**
- support by experienced **optical diagnostics** group
- breadboard **hardware available** to test individual components
  - ➢ save costs: no need to manufacture a complete set of test hardware

A test bench to test test bench technology

- In 2023 at M3.1: new control and measurment system to test technologies of test benches
  - full access to all sub-components and routines
  - topics to be adressed
    - ➢ intelligent control
    - ➢ photonic technologies
    - ➢ robotic technologies
    - ➢ (wireless) sensor networks
    - ➢ predictive maintenance

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Thank you for your attention!