

A close-up, high-angle photograph of a turbo compressor or expander turbine. The image shows the complex, curved blades of the turbine, which are highly polished and reflect light, creating a sense of depth and precision. The overall color palette is a cool, monochromatic blue.

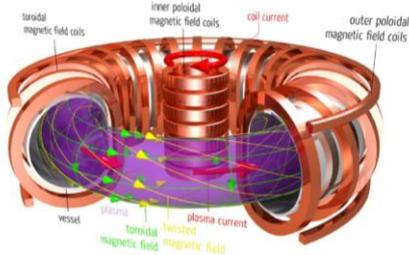
*Patrik Fröhlich, 30.10.2025*

# Motivation

- **Prevent boil-off (zero boil-off) for space and ground applications**
- **Cryogenic cooling for physical experiments and medical**
- **Decentralized, small scale hydrogen liquefaction**
  - Close to end-use application (fueling-stations for low to heavy duty trucks, energy storage for grid stabilization, military and civil drones) allows for short term storage → no ortho-para conversion required (up to 40 % lower energy consumption)
- **Cooling for quantum computing**
- **Super conducting cables, motors/generators and magnets**

 **Compressors and expanders with gas bearings are key products in these applications**

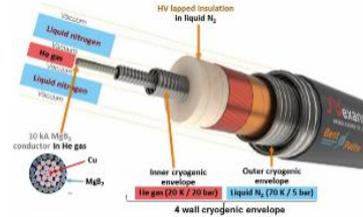
# Cryogenics: Application areas



Superconducting magnets



High voltage cryocooled electric machines/generators



High voltage cryocooled cables



Quantum computing



Zero-boil off



Small scale hydrogen liquification



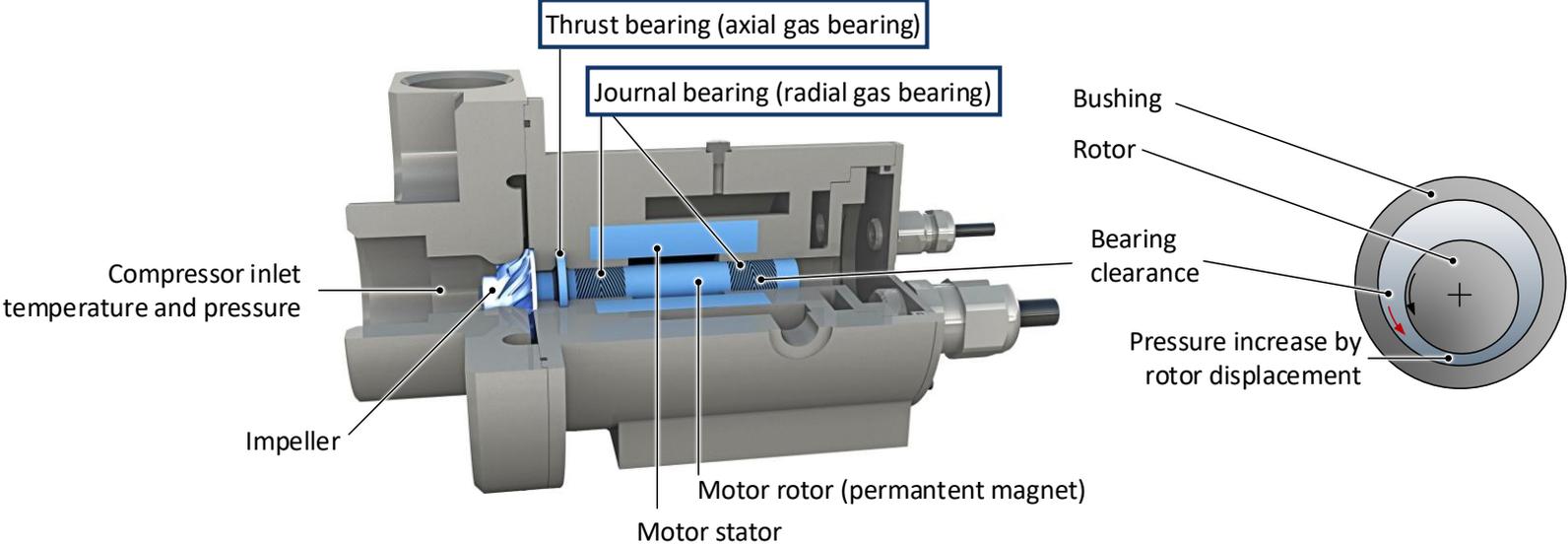
Cooling of rocket shields (2nd stage)



Cooling of instrument optics/detectors

# Gas bearing turbo compressors

# Gas bearing turbo compressor - Technology



# Bearing technology – why gas bearings?

- **Ball bearing**

- + High stiffness / load capacity
- + Commercial available
- + Easy handling
- lubricant
- lifetime



- **Gas bearing**

- + Lifetime
- + No lubricant
- + High load capacity
- + Start / stop-cycles
- Complex rotor dynamic
- Tight manufacturing tolerances



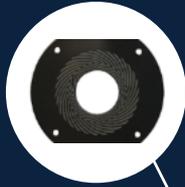
- **Limitations of others bearings**

- Plain bearings – wear
- Oil bearings – oil degradation and leakage
- Magnetic bearings – low load capacity and high complexity

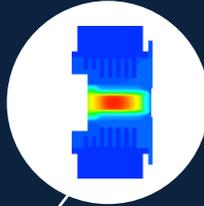
# Multi-disciplinary design



Gas bearing



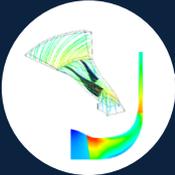
Thermal design



Control software

```
register 002 temp_val;  
register 003 temp_val2;  
temp_val = (000)state_ptr->temp *  
... = valueIn("dial(100kBIT)")  
temp_val = at4to_ptr->val * 1.1;  
IF (0 < 4)temp_val = temp_val * 0;  
DISCNT = 0.00000;  
temp_val = sat100(temp_val); st.
```

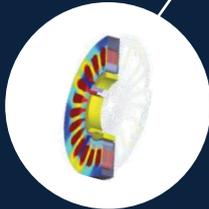
Aero-dynamics



Rotor dynamics



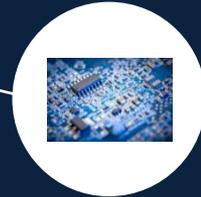
Electric motor



Mechanical design



Power electronics



Patent protected and FTO proven

# Gas bearing technology – USPs



Standardized  
solution



Oil-free



Cryogenic  
operation



Compressor-  
inverter system



Leak-tight



Efficient



Service life



Micro vibration-  
free

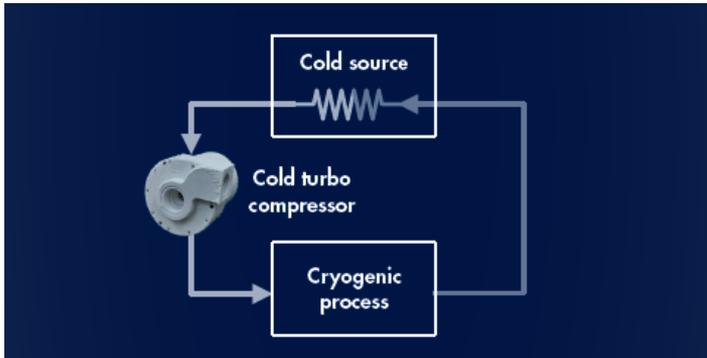
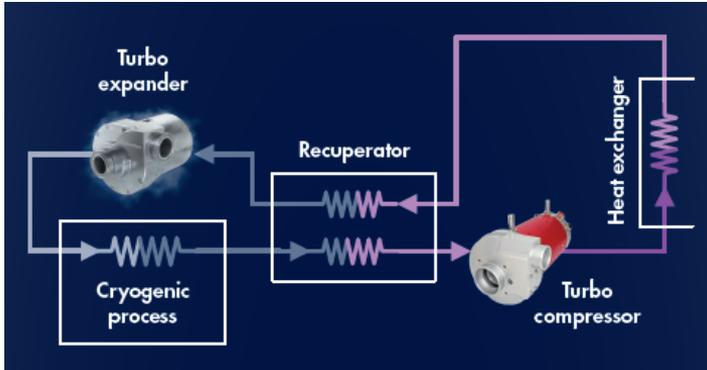


Compact and  
lightweight

# **Solutions for cryogenics**

**Turbo compressors (warm and cold) and turbo expanders**

## ▪ Turbo compressor and expander for Reverse Turbo Brayton (RTB) Cryocooler



### ▪ Example configuration

#### ▪ Turbo expander

- $T_{start-up} = 15 \dots 300 \text{ K}$
- $T_{in} = 15 \dots 90 \text{ K}$
- $p_{in} = 500 \dots 200 \text{ kPa}$
- $P = 500 \text{ W}$

#### ▪ Turbo compressor

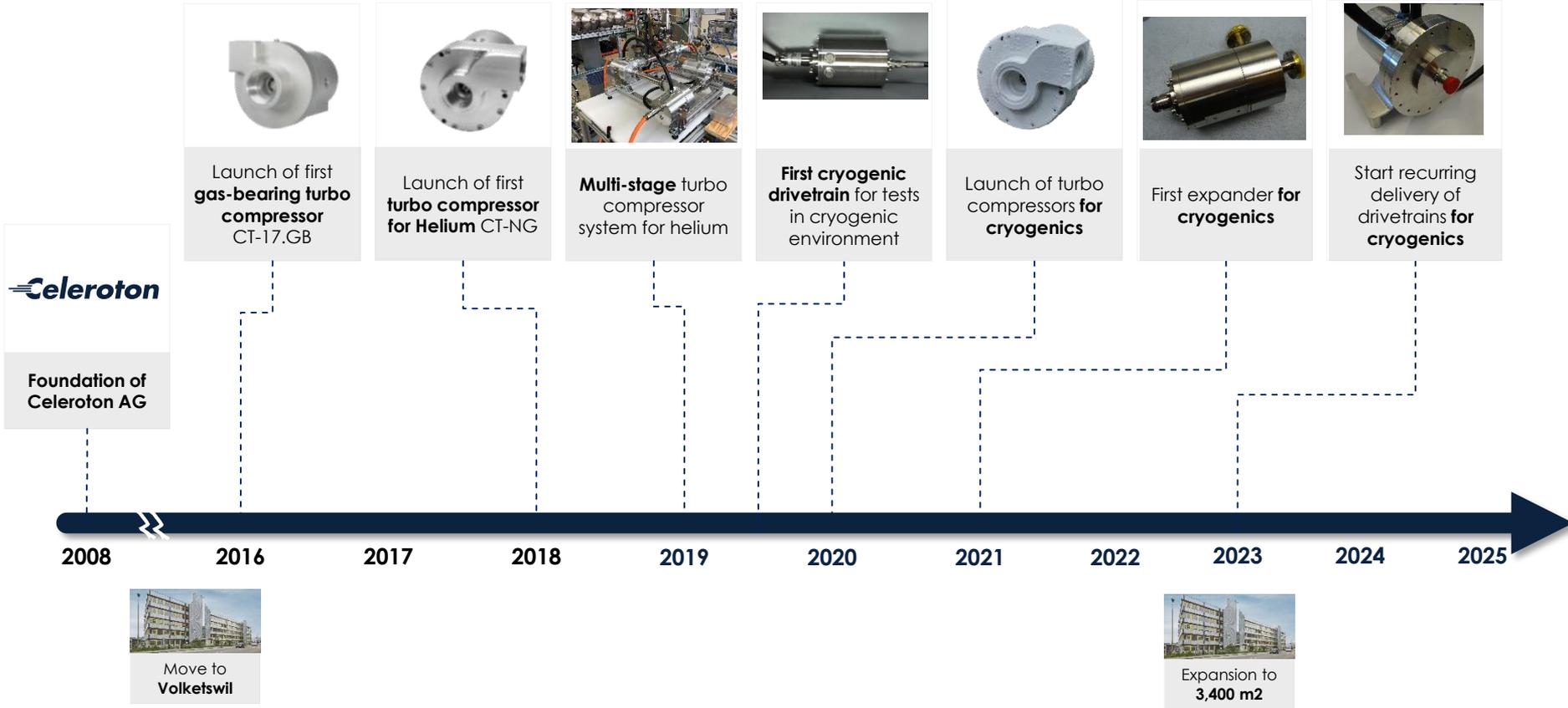
- $T_{in} = 250 \dots 300 \text{ K}$
- $p_{in} = 200 \dots 500 \text{ kPa}$
- $P = 50 \text{ kW}$   
(multi stage)

### ▪ Example configuration

#### ▪ Cold turbo compressor

- $T_{start-up} = 15 \dots 300 \text{ K}$
- $T_{in} = 15 \dots 90 \text{ K}$
- $p_{in} = 500 \dots 200 \text{ kPa}$
- $P = 130 \text{ W}, 60 \text{ W}$  additional heat at  $20 \text{ K}, 400 \text{ kPa}$

# Milestones



Foundation of Celeroton AG



Launch of first gas-bearing turbo compressor CT-17.GB



Launch of first turbo compressor for Helium CT-NG



Multi-stage turbo compressor system for helium



First cryogenic drivetrain for tests in cryogenic environment



Launch of turbo compressors for cryogenics



First expander for cryogenics



Start recurring delivery of drivetrains for cryogenics



Move to Volketswil

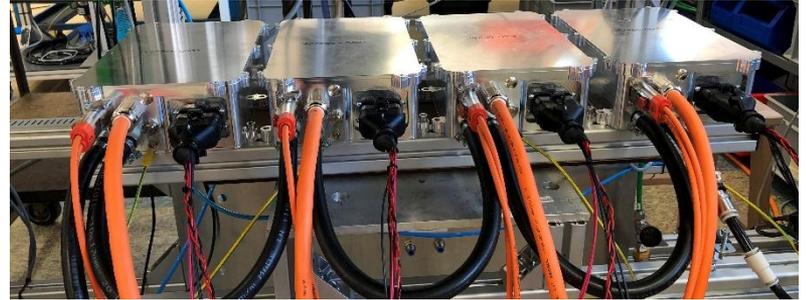


Expansion to 3,400 m2

# Example: Turbo compressor and expander system



- 4-stage turbo compressor system on closed-loop test bench
  - Operation in helium on test bench with 10 kW input power
  - Synchronized operation with 4 COTS converters (electronics) from Celeroton

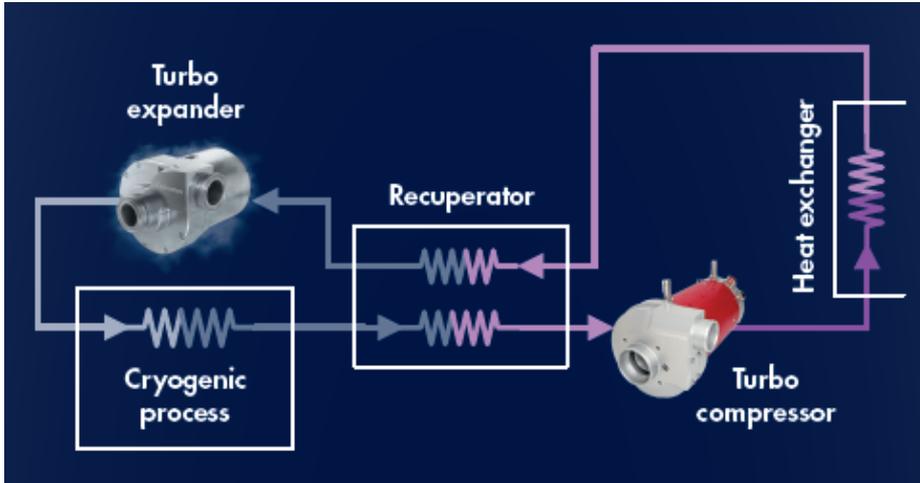


Single stage cryo expander with

- 150 W @ 20 K
- Synchronized operation with COTS converter including active and passive safety features to prevent run-away (max. breaking power of >7 kW)



# Celeroton product offer



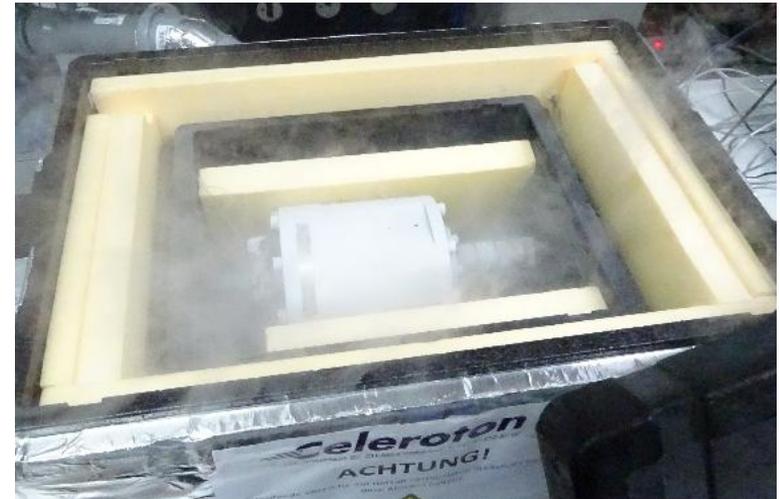
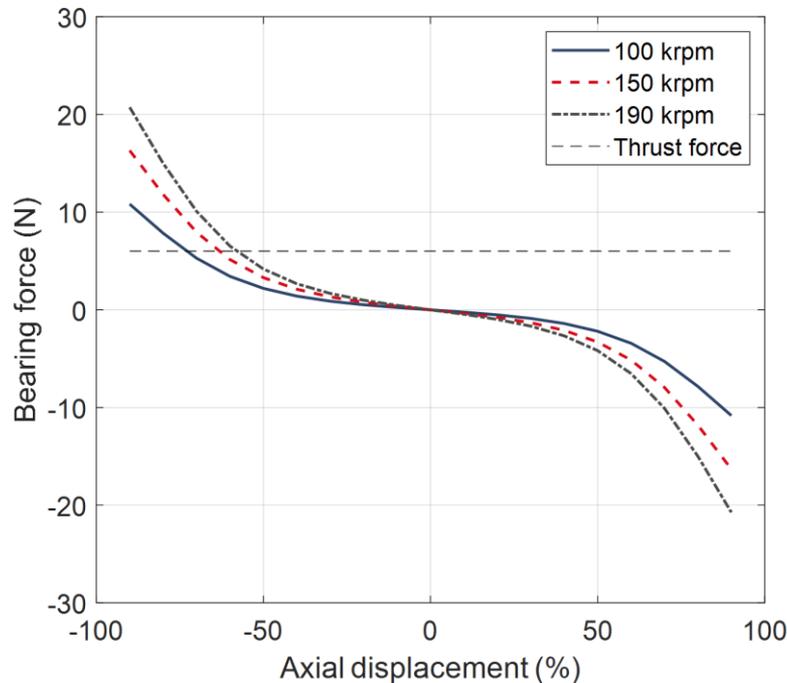
- Turbo compressor for warm and cold operation
- Turbo expander for cryogenic operation down to 20 K
- Electronics for operation of compressor and expander (generator mode) and energy recovery to the grid

# Results

**Commissioning at 20 K, thrust load, losses and micro-vibrations**

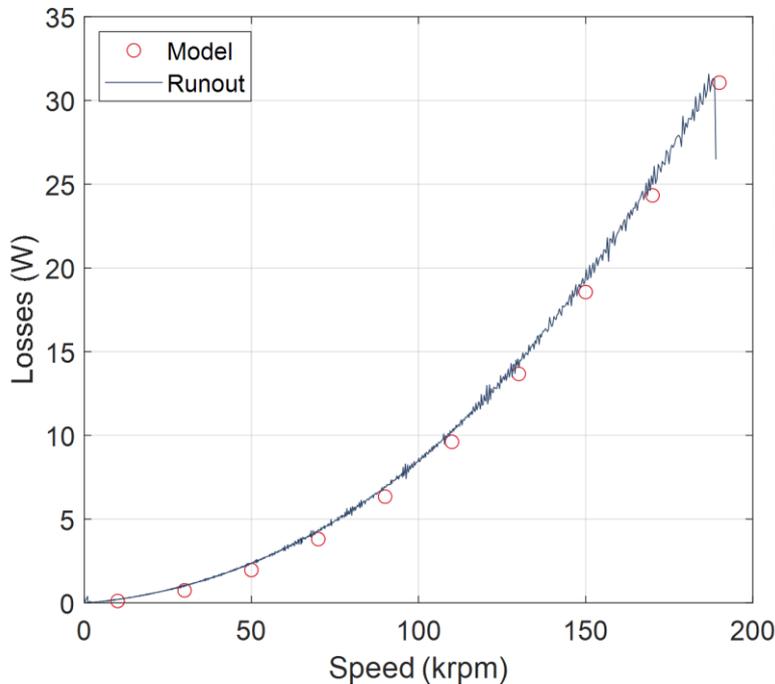
# Gas bearings and losses

**Thrust bearing** load capacity and axial force by impeller at rated operating point  
( $PR = 1.4 @ 9 \frac{g}{s}$ ;  $T_{in} = 20 K$ ,  $p_{in} = 3.4 bar$ )



# Gas bearings and losses

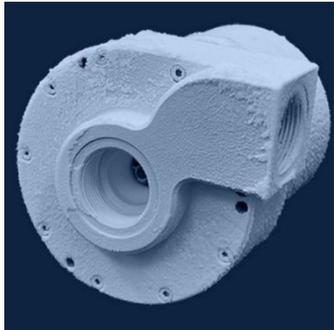
Bearing and motor **losses** at the rated operating point, design results and measurements  
( $PR = 1.4 @ 9 \frac{g}{s}$ ;  $T_{in} = 20 K$ ,  $p_{in} = 3.4 bar$ )



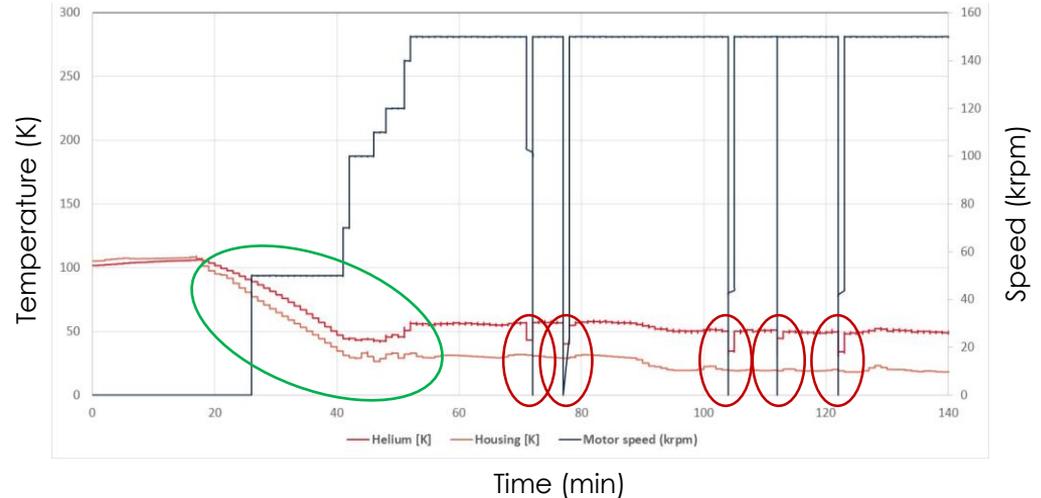
	Design result	Measurements	Unit
<b>Journal bearing losses</b>	2 x 4.8 @48 K	2 x 4.75 @ 48 K	W
<b>Thrust bearing losses</b>	8.6 @48 K	6.2 @ 48 K	W
<b>Gas friction losses</b>	10.8	9.5	W
<b>Motor losses</b>	6.9	5.8	W
<b>Total losses</b>	<b>35.9</b>	<b>31.1</b>	<b>W</b>



# Validation in cryogenic temperatures



- Run-down test from ambient to 20 K (here shown from 100 to 20 K)
- Stop/start at 20 K



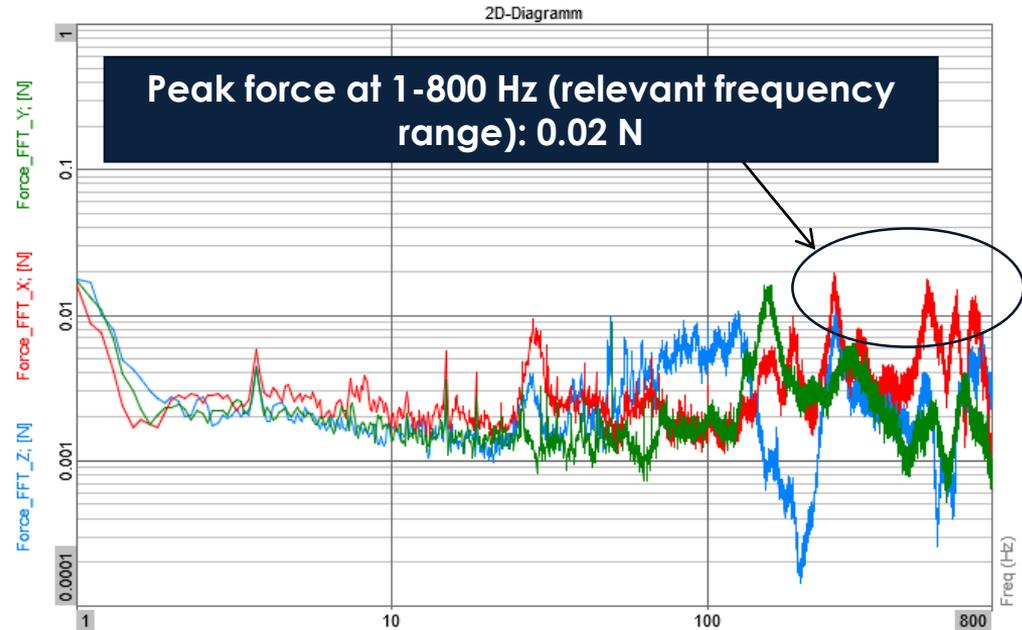
# Micro-vibration measurement of a gas bearing turbo compressor

## Measurement setup with gas bearing turbo compressor:

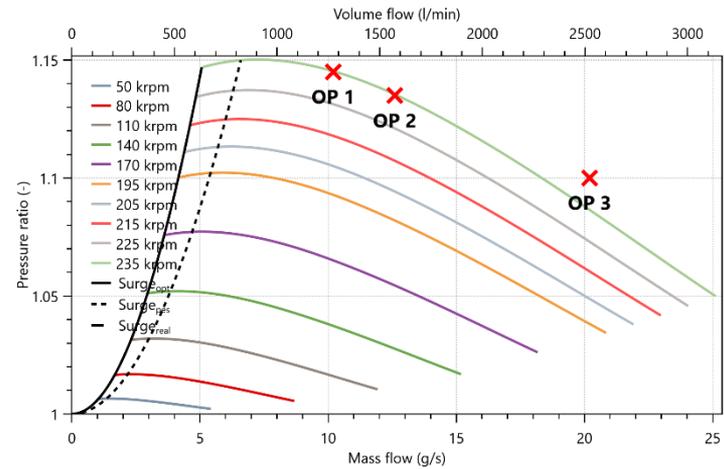
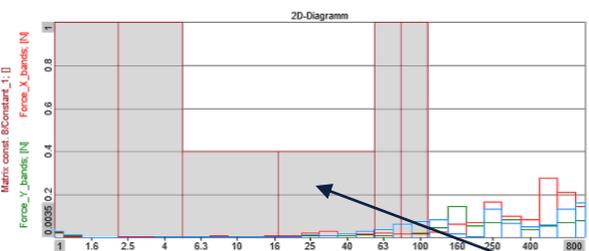
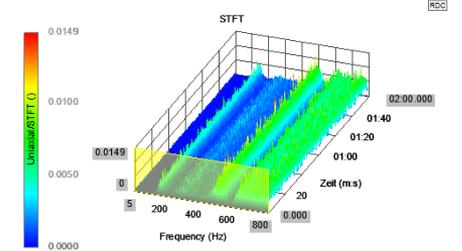
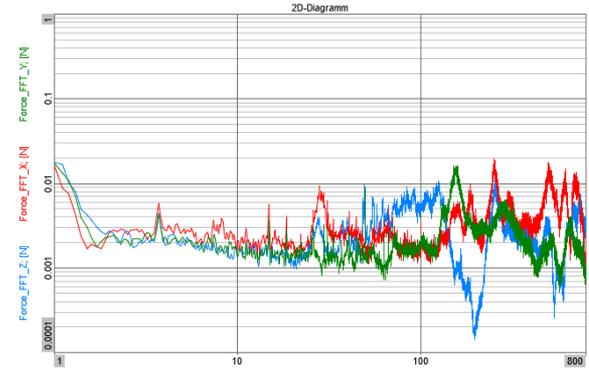
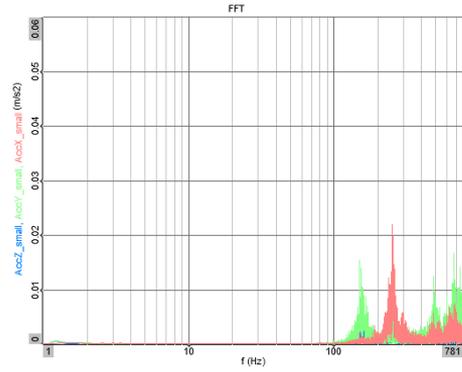
- Power: 2 kW
- Operation in helium
- Speed: 232 krpm (3'866 Hz)



Acknowledgement: measurements at ESO HQ



# Micro-vibration measurement of a gas bearing turbo compressor



Gray area: Threshold for ESO ELT instrument

**Peak force at relevant frequency range (1-800 Hz): 0.02 N**



**Thank you!**

**Visit us at booth no. 2**

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