**CryoPHAEQTS – Cryogenic Phase Equilibria Test Stand**

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**Motivation**
- Cryogenic mixed refrigerant cascades (CMRCs) as efficient cooling method for applications below 63 K
- CMRC design requires fluid states (thermodynamic equation of state, surface tension) and transport properties to mass, momentum and energy equations

<table>
<thead>
<tr>
<th>Transport type</th>
<th>Transport coefficient</th>
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<tbody>
<tr>
<td>Mass</td>
<td>Diffusivity $\delta$</td>
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<tr>
<td>Momentum</td>
<td>Viscosity $\eta$</td>
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<tr>
<td>Energy</td>
<td>Thermal conductivity $\lambda$</td>
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**Phase equilibrium**
- Dynamic analytical method with vapor circulation
  - Cell temperature control by pulse tube cryocooler
  - Sampling VLE phases by electromagnetically actuated valves allowing volumes in the μL range
  - Analysis in gas chromatograph with molecular sieve type columns
  - SLE measurement by calorimetric method and visual analysis

**Optical experiments**
- Detection of scattered light intensity decay by Photon Correlation Spectroscopy (PCS)
  - Dynamic Light Scattering (DLS)
    - Laser light passes through bulk phase
    - Relaxation correlates with thermal conductivity, diffusion coefficient and sound attenuation
  - Surface Light Scattering (SLS)
    - Laser light crosses the phase boundary in VLE
    - Damping factor of thermally induced surface waves correlates with kinematic viscosity and surface tension

**Process design**

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<tr>
<th>Process parameters</th>
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<tr>
<td>Temperature range</td>
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<tr>
<td>Pressure range</td>
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<tr>
<td>Cell volume</td>
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<td>Fluids</td>
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**Mechanical design**
- Equilibrium cell consists of 1.4571 austenitic stainless steel and quartz glass, allowing optical experiments up to 15 MPa
- Helicoflex DELTA seals with disc springs
- Test stand safety ensured with pressure relief valves and rupture discs

**Fig. 1:** Setup for parallel determination of fluid state and transport properties.

**Fig. 2:** Process flow diagram without optical system.

**Fig. 3:** Mechanical design visualization of the test stand crystal interior.