Model based drift compensation after sample load

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Introduction

- Thermo Fisher Scientific Eindhoven develops and produces Transmission Electron Microscopes (TEM).

- Industries
  - Life science
  - Material science
  - Semi conductor

- Throughput at quality

Problem statement

Goal:

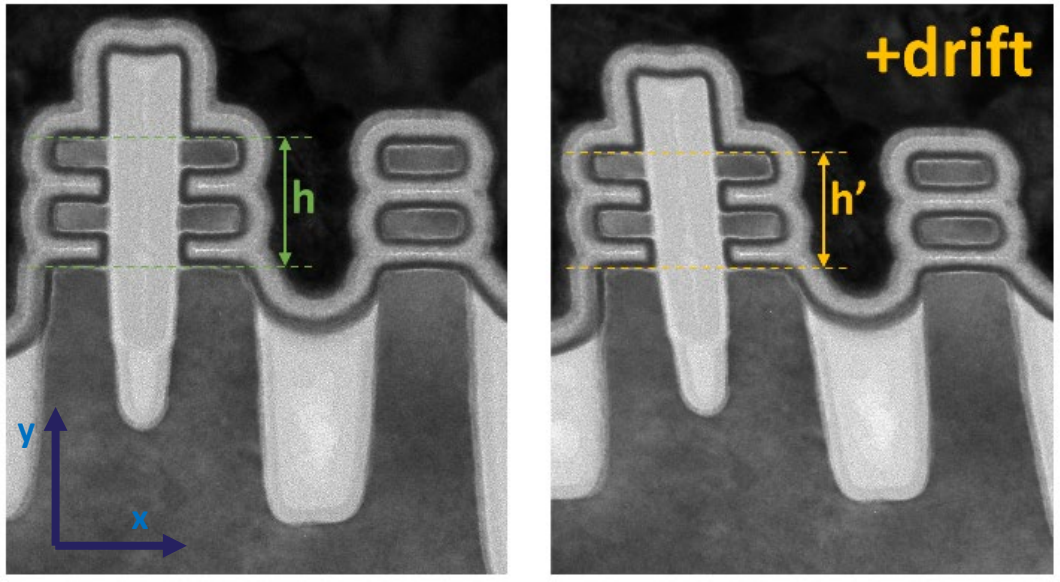
- Throughput at quality for the semi conductor industry

Issue:

- Sample drift w.r.t optical axis after sample holder insert

Impact:

- Motion blur
- Distortion



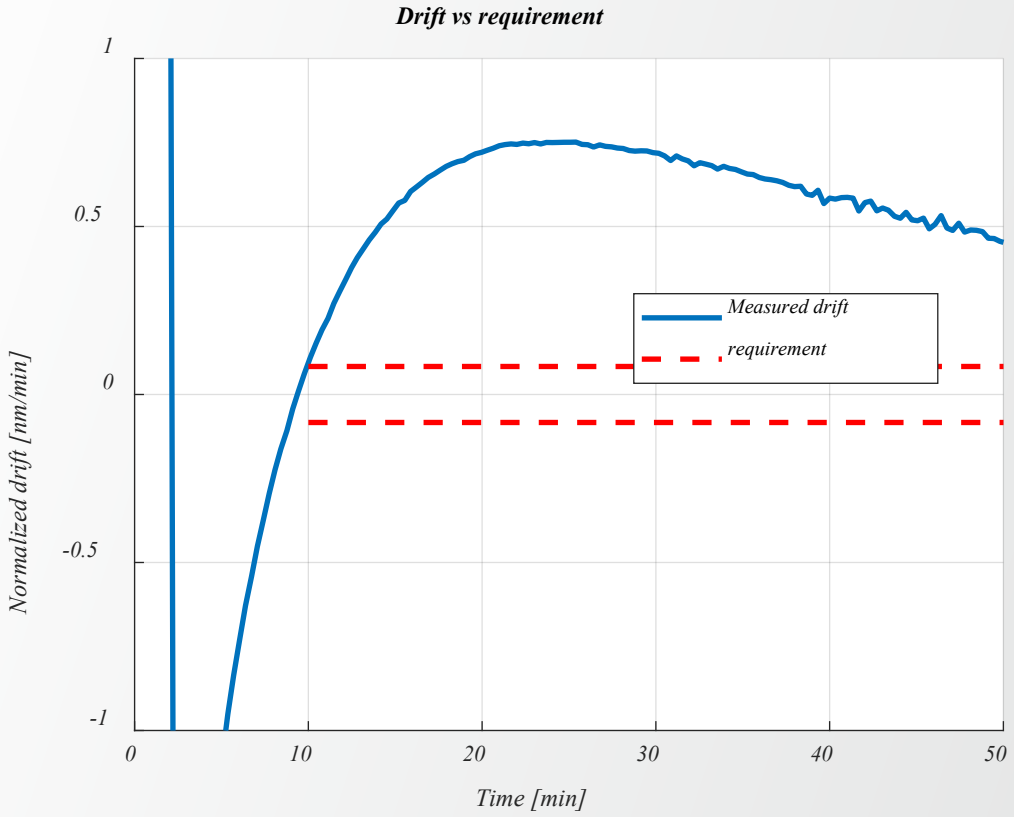
Problem statement

Goal:

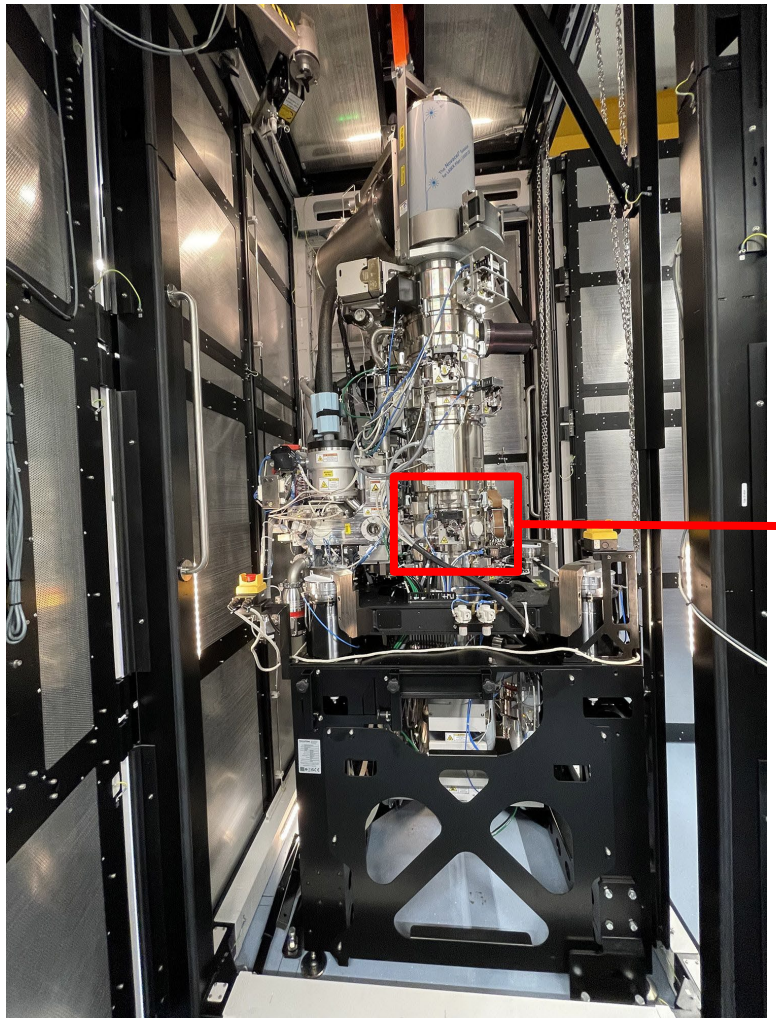
- Reduce sample drift w.r.t optical axis after sample holder insert

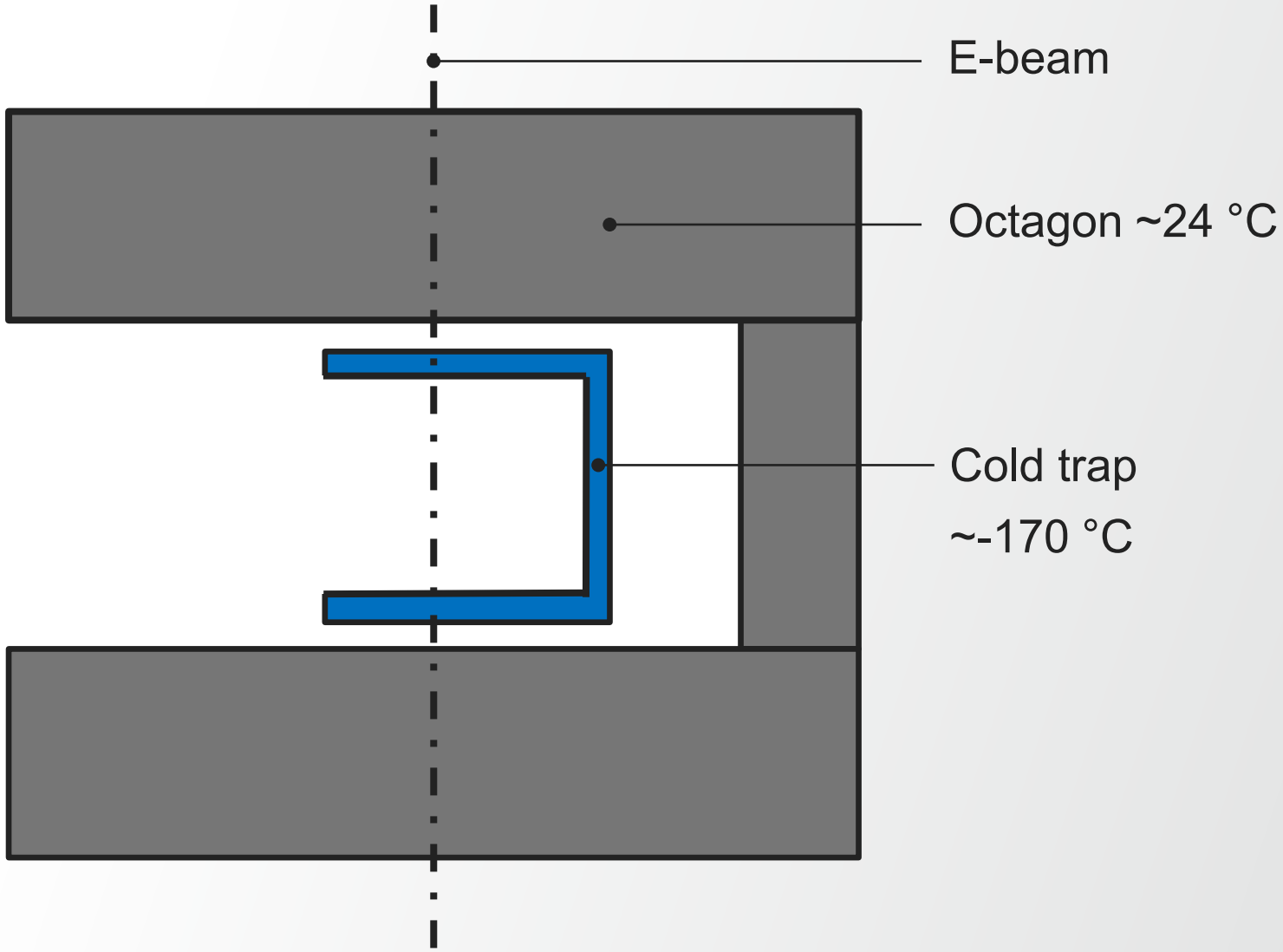
Issue:

- What causes the sample to move w.r.t optical axis after sample holder insert?



System description





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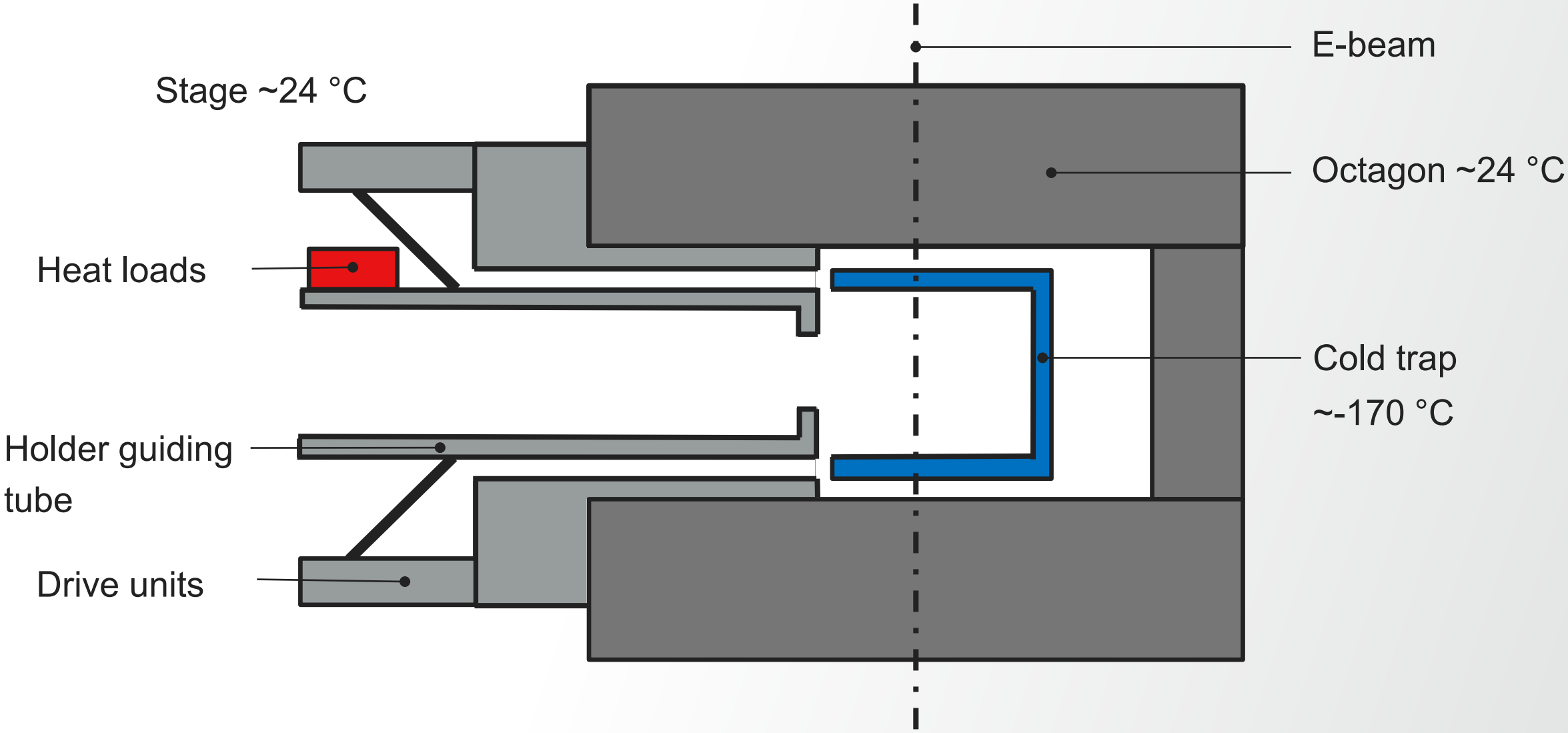

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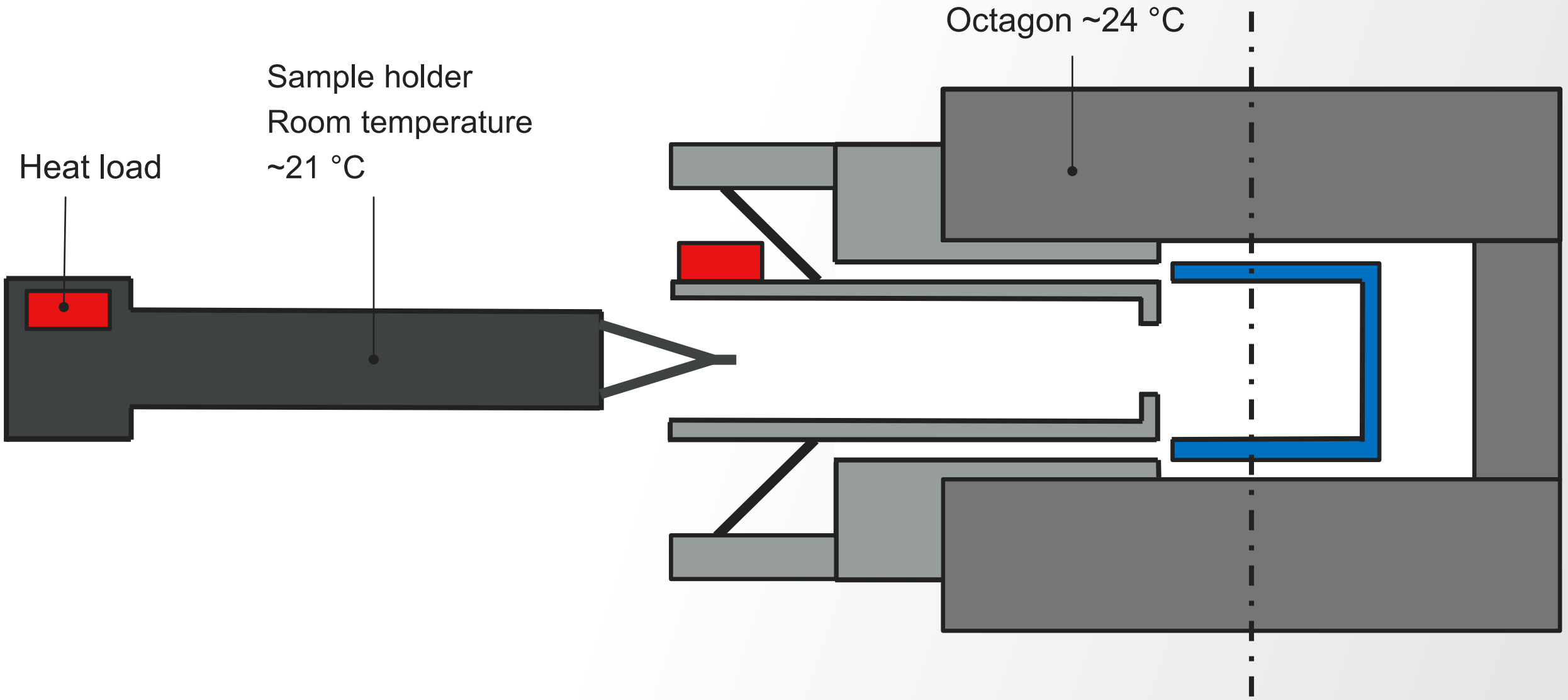
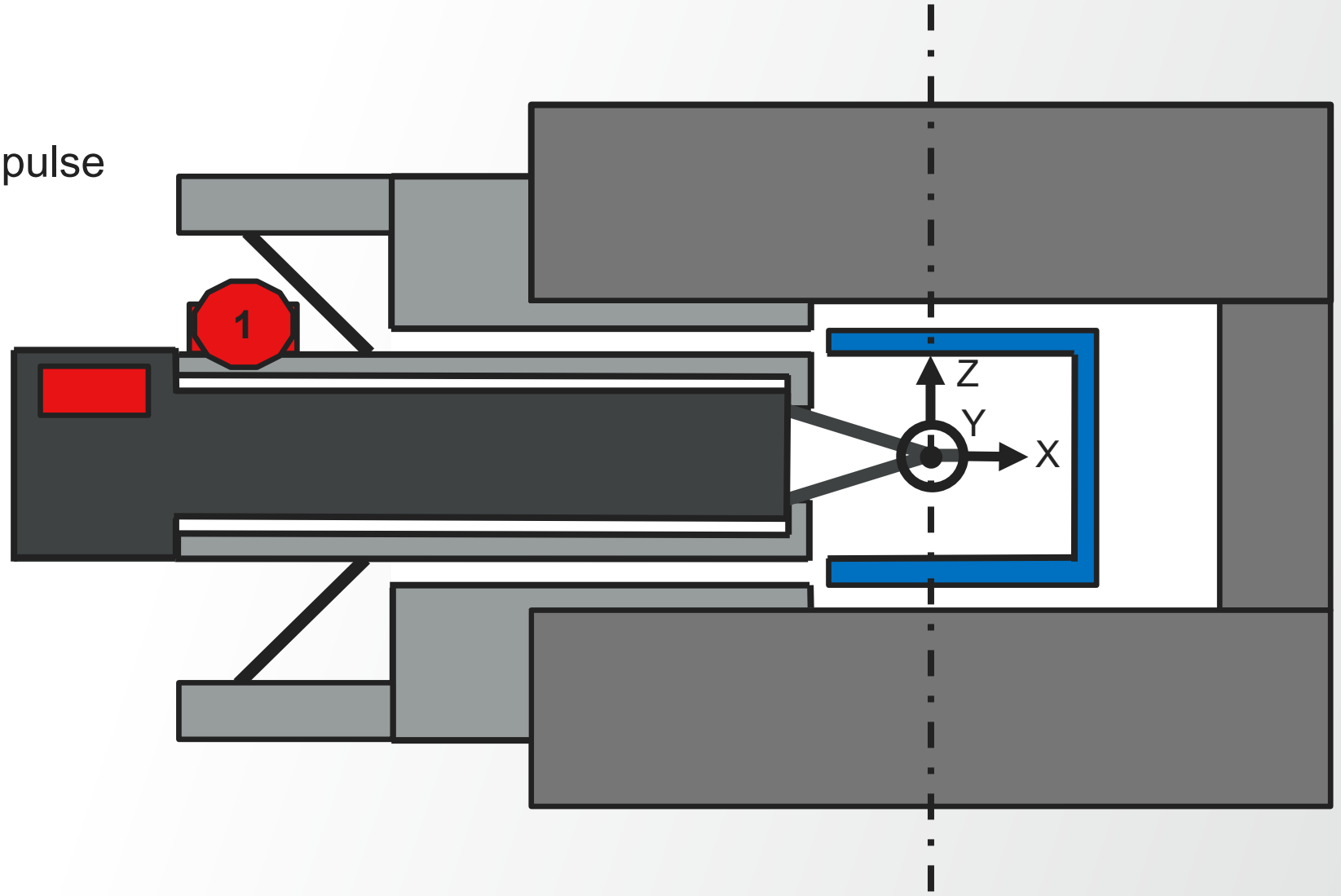


System description

Holder insertion:

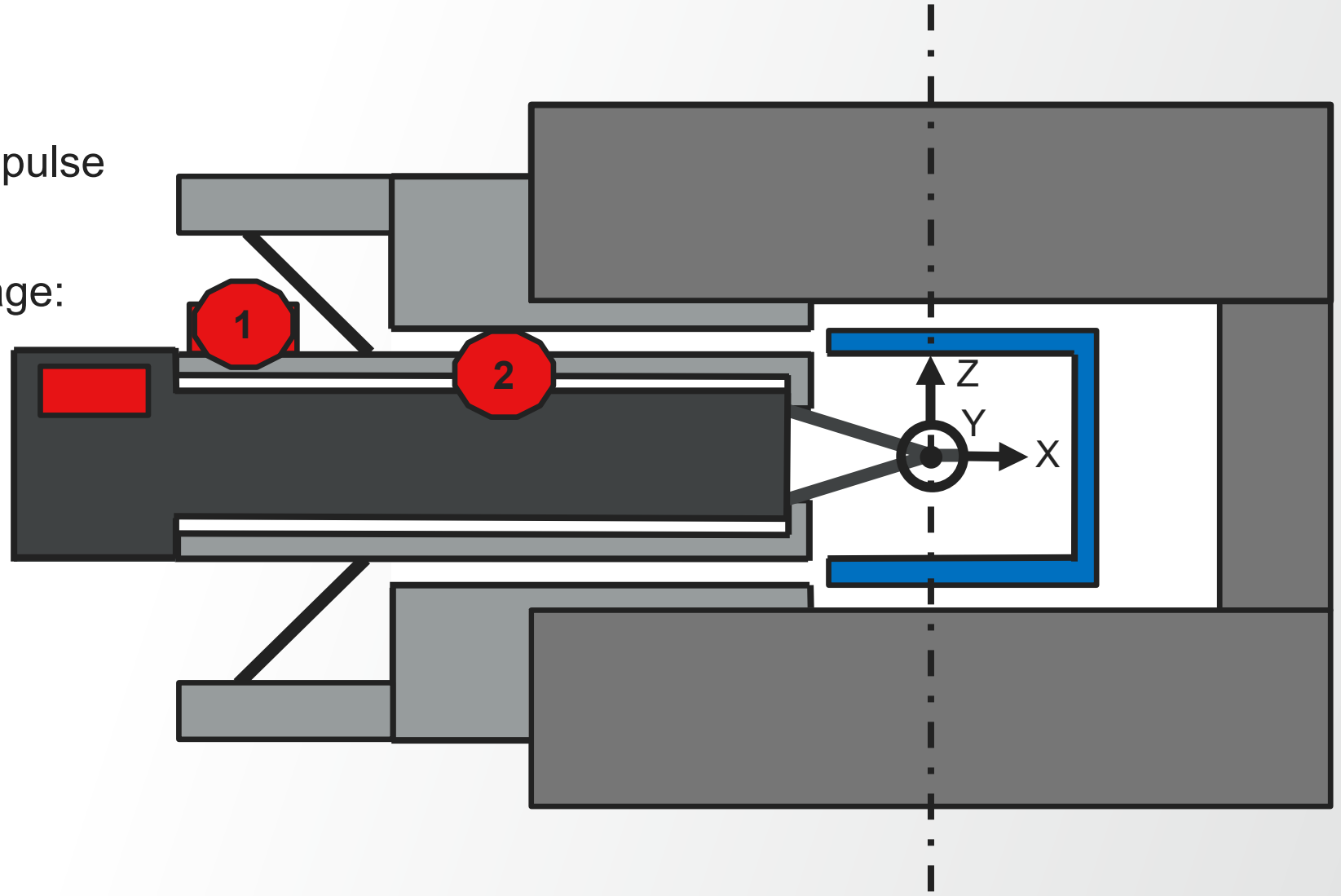
1. Stage heat load activates → impulse heat load



System description

Holder insertion:

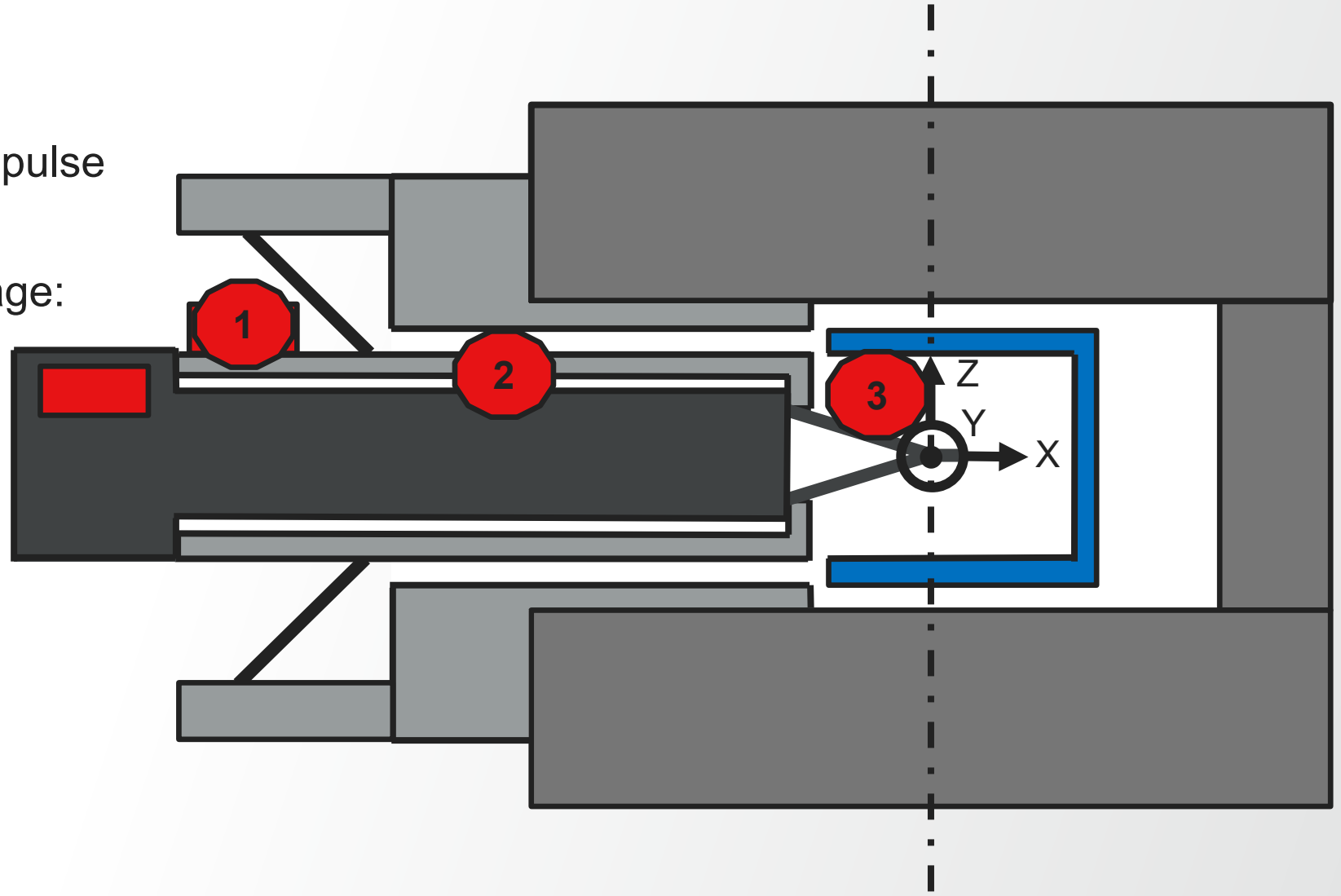
1. Stage heat load activates → impulse heat load
2. Thermal contact holder with stage:
   - Mechanical contacts
   - Conduction across airgaps and O-rings
   - Radiation



System description

Holder insertion:

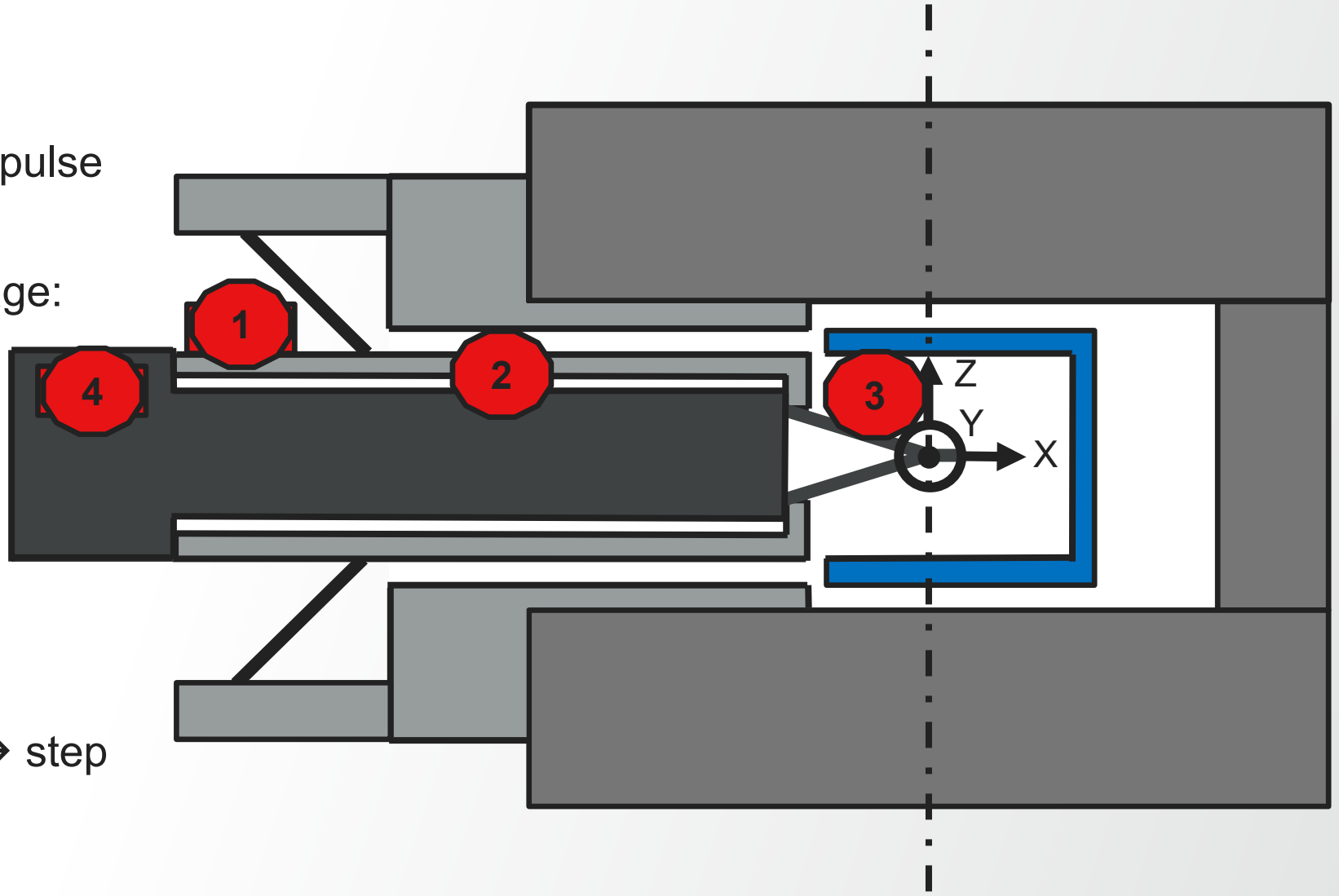
1. Stage heat load activates → impulse heat load
2. Thermal contact holder with stage:
   - Mechanical contacts
   - Conduction across airgaps and O-rings
   - Radiation
3. Radiation between holder and cold trap



System description

Holder insertion:

1. Stage heat load activates → impulse heat load
2. Thermal contact holder with stage:
   - Mechanical contacts
   - Conduction across airgaps and O-rings
   - Radiation
3. Radiation between holder and cold trap
4. Holder heat load switched on → step heat load

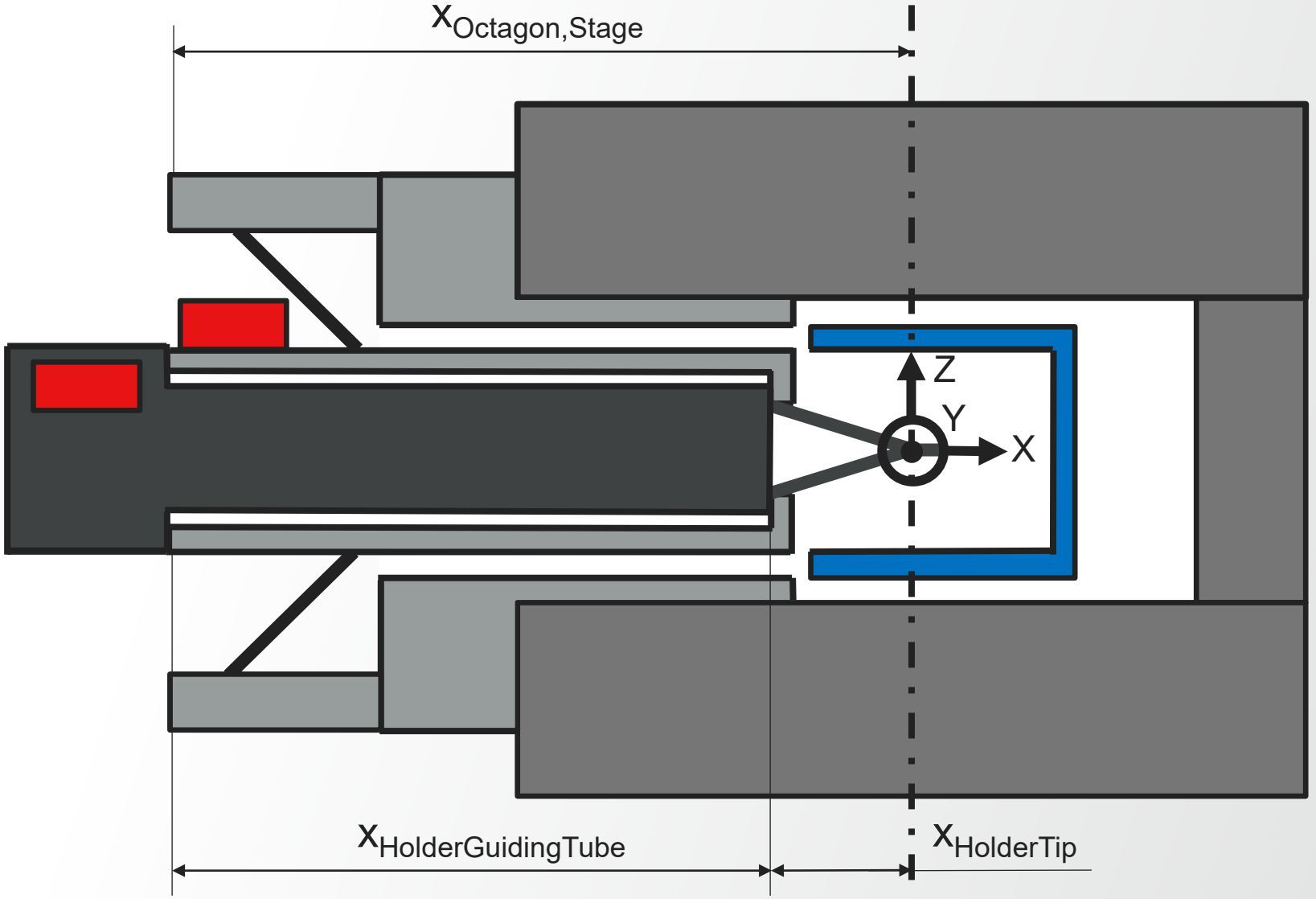


System description

Expansion path:

Dominant drift direction: X

- $x_{Octagon,\ Stage}$
  Stable (no temperature change)
- $x_{HolderGuidingTube}$
  Large expansion length
- $x_{HolderTip}$
  Small expansion length



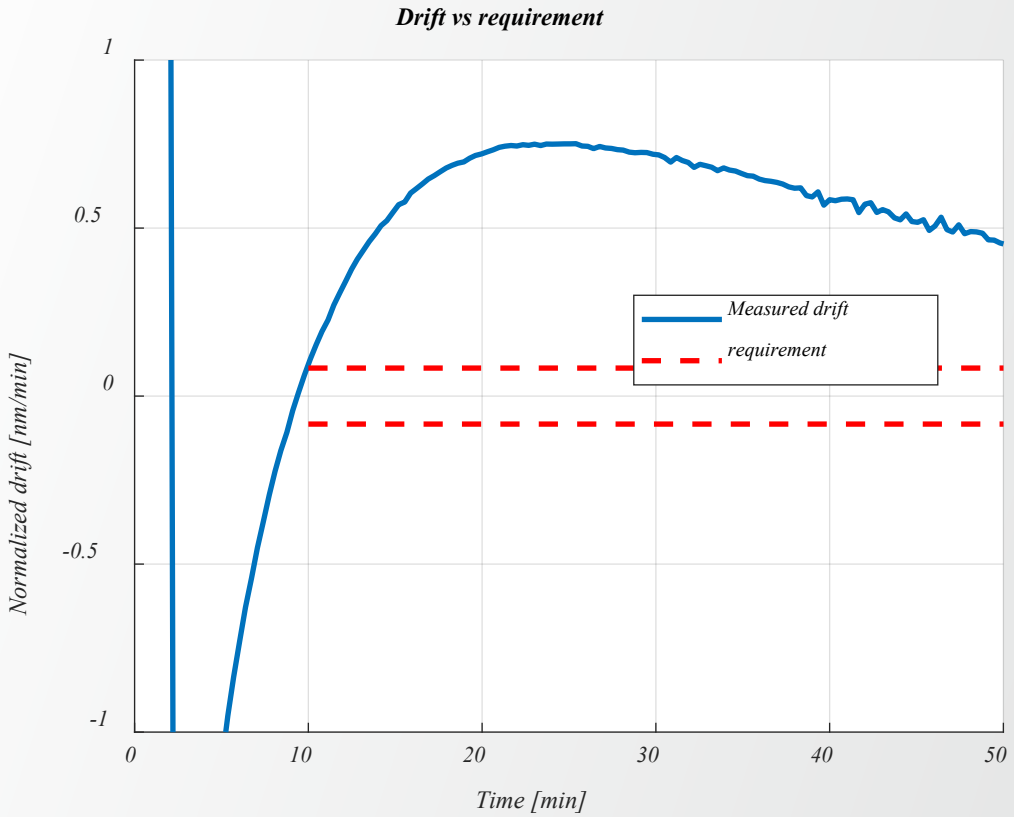
Root cause

Root cause:

- Thermal effects
  - Switching heat loads
  - Temperature differences after sample holder load
- Main expansion path
  - Holder guiding tube
  - Tip of the holder

Solution:

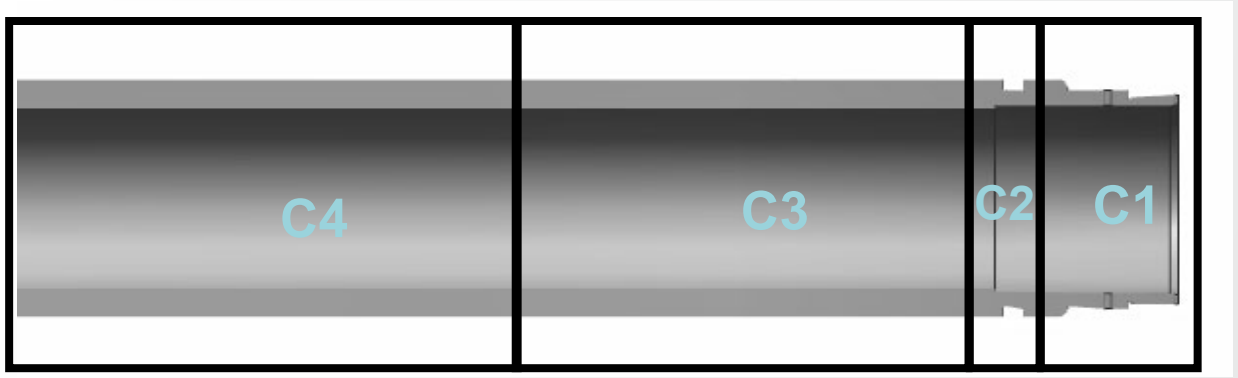
- Passive compensation
- Active compensation

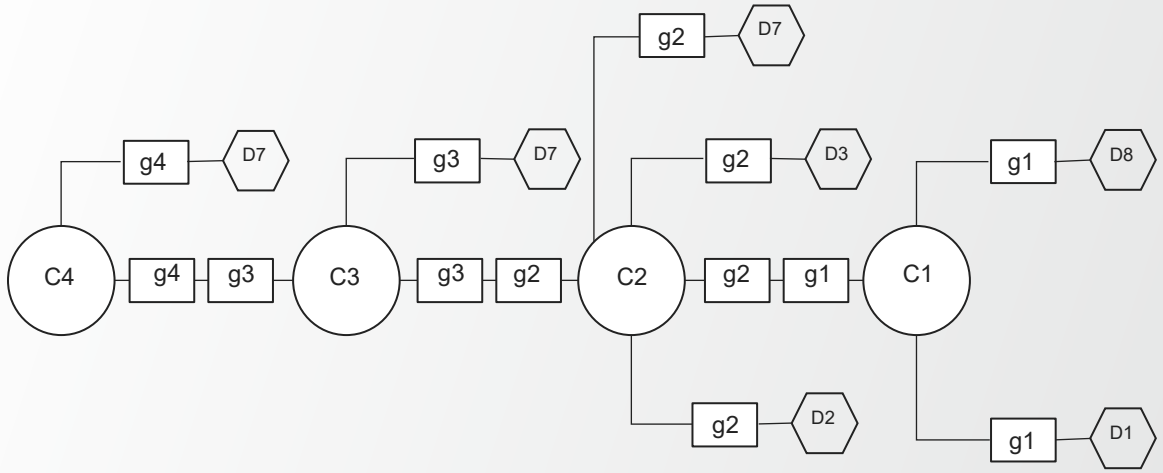


Modeling method

- Lumped element modeling
  - Thermal mass
  - Resistance
  - Environment
- 400+ lump model

- Identify different thermal effects
- Give suggestions on what to measure during tests
- Use the model for active drift compensation





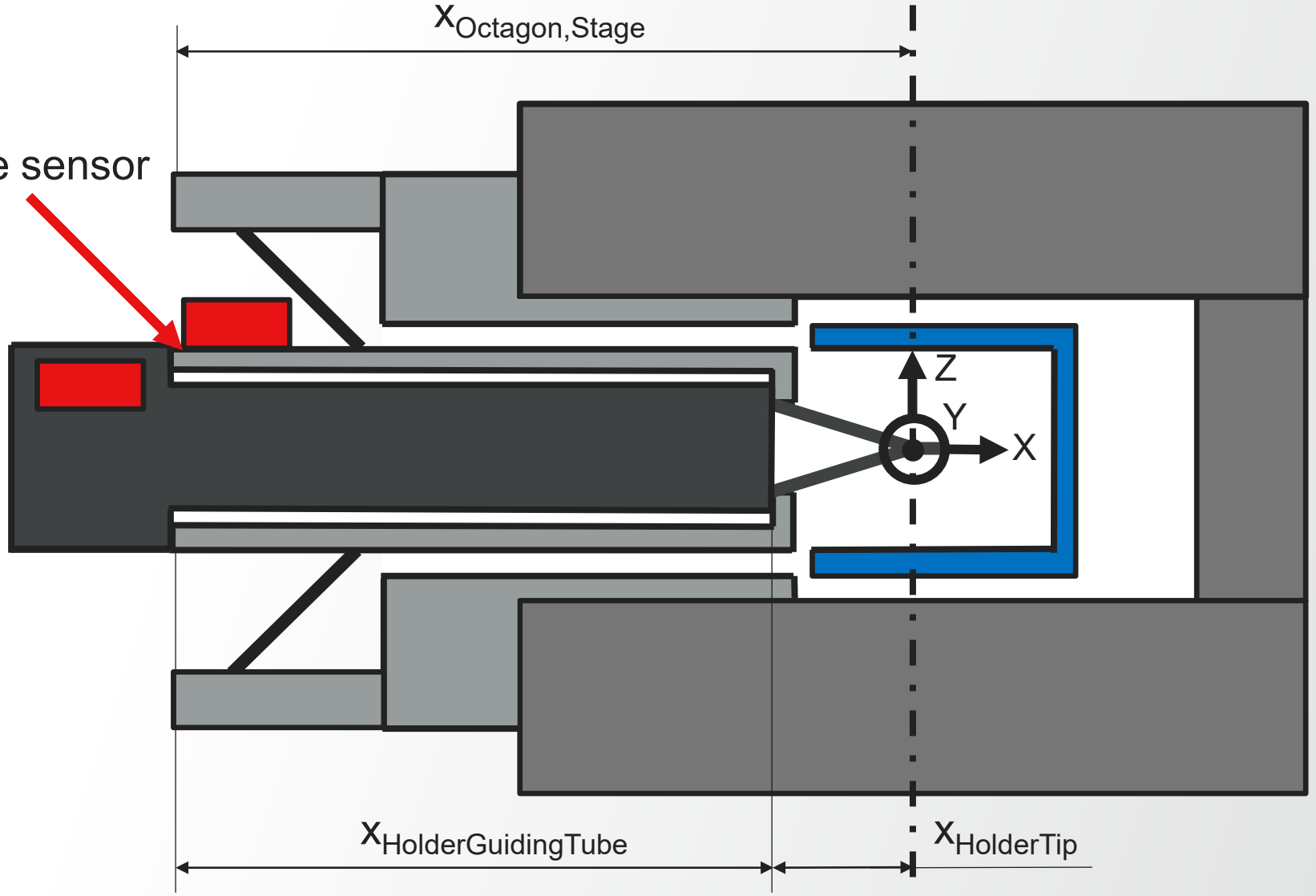
Lumped element model + Sensor inputs

Model inputs:

- Temperature of the sensor
- Holder insert moment
- Holder retract moment
- Switching of heat loads

Sample manipulating stage

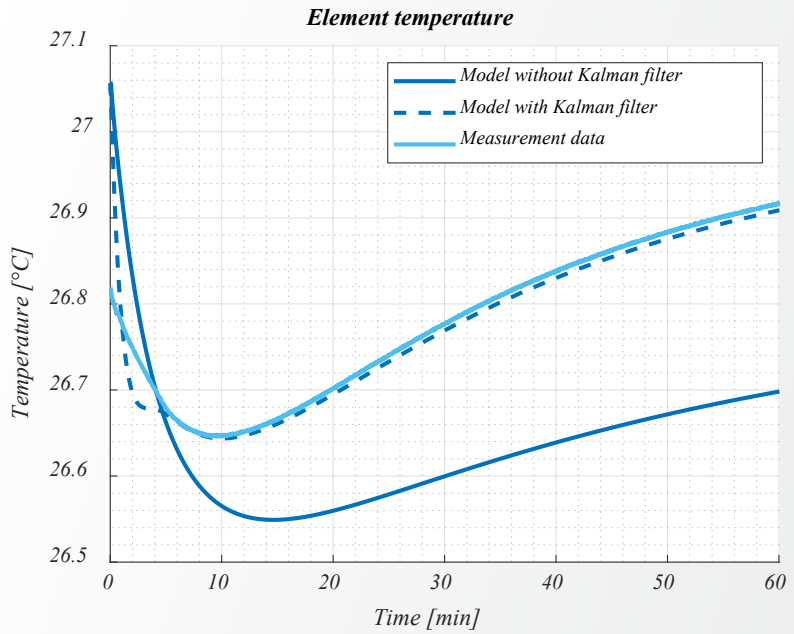
- Move in the opposite direction of the predicted drift



Results

Temperature results

- Kalman filter
- Lump temperature close to measured temperature



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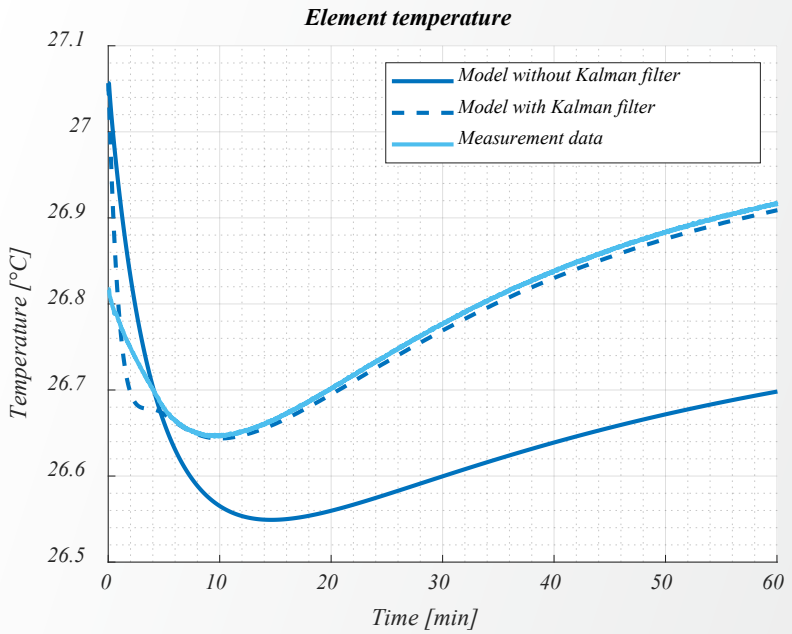
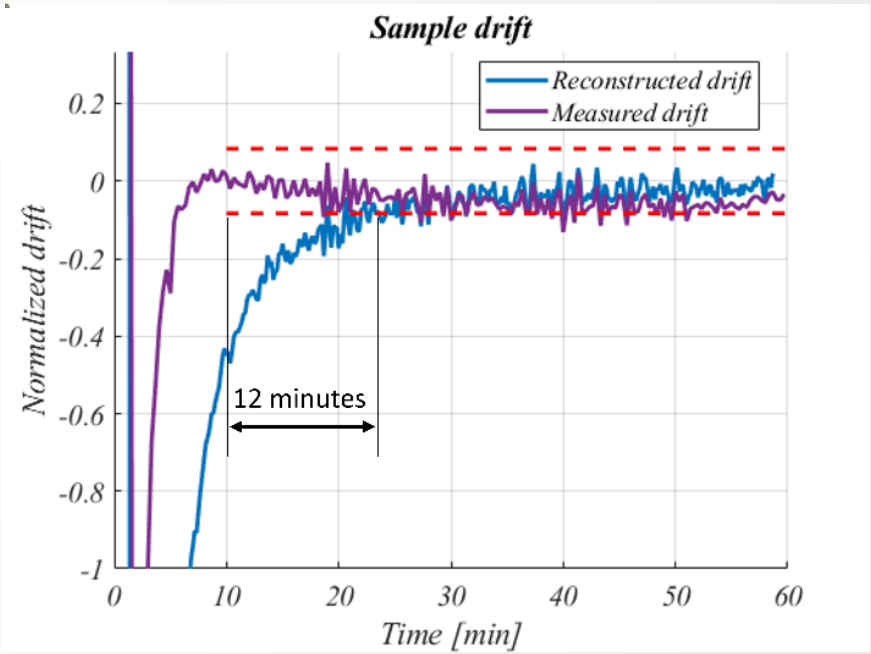


Drift results

- 12 minutes earlier within spec
- Improvement in the first 20 minutes
- Measurement noise sometimes out of spec

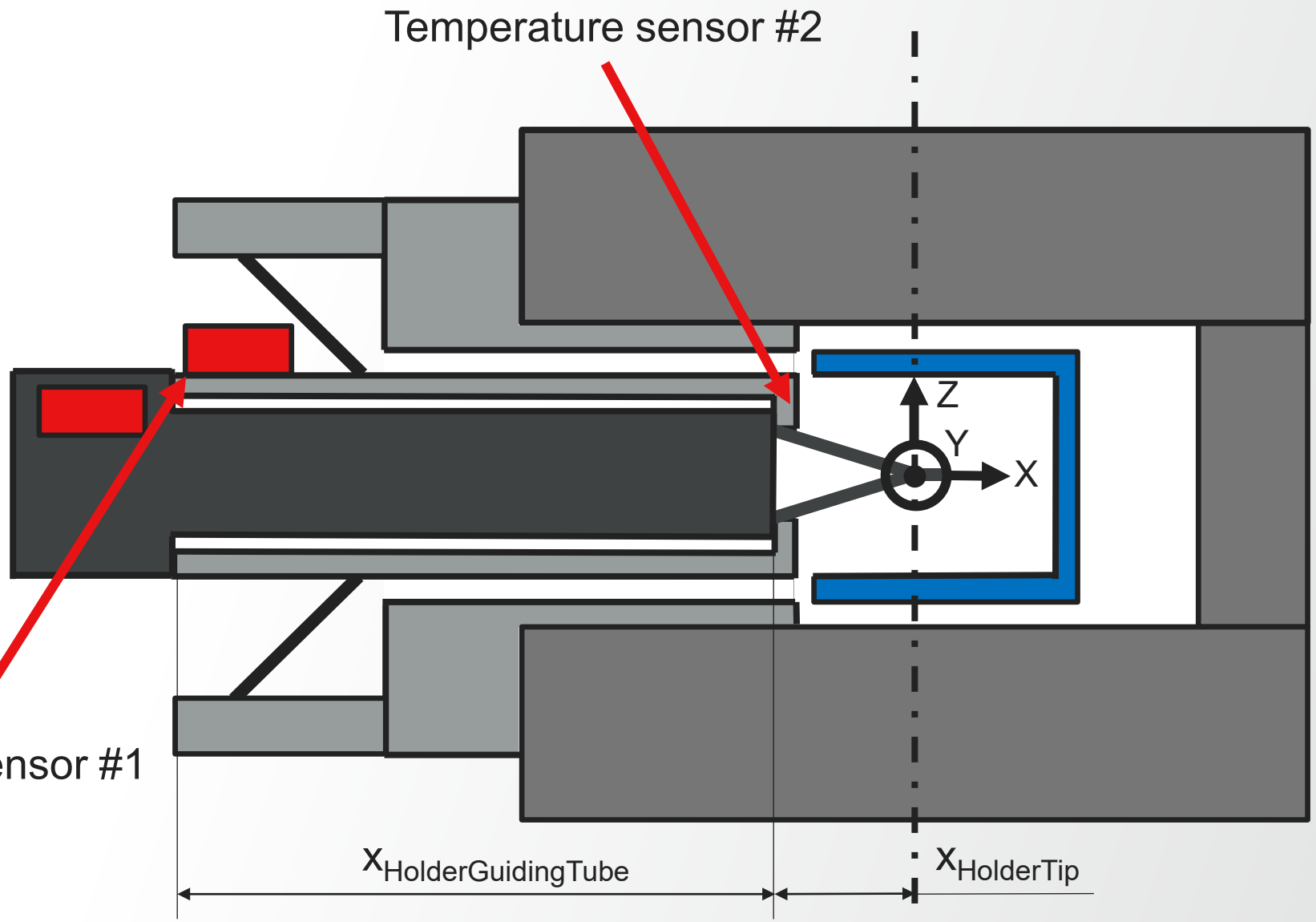


Improvements

- Model improvements did not help
- Variations between different holder/stage combinations too big

Suggestion

- Place an extra sensor in the holder guiding tube



Summary & conclusion

- Thermal effects → sample drift w.r.t. optical axis
- Thermal modeling
  - Understand effects
  - Active drift compensation
- Good results for the number of available sensors
- More sensors are required to productize model-based drift compensation

End

Thank you for listening!