DE LA RECHERCHE À L'INDUSTRIE

LAST DEVELOPMENTS ON LMJ CRYOGENIC TARGETS FABRICATION

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Outline of the talk

- Cryogenic program at CEA target department
- Cryogenic equipment
- Current development and perspectives
- Conclusion

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Cryogenic program at CEA

- The cryogenic target program stopped in 2013 : priority given to HEDP experiments

- State of the art in 2013:
  - Cryogenic targets and layering procedures were tested on the Study Filling System (SFS)
  - Layered D_2 was obtained using infrared irradiation
  - The layer was characterized using backlit shadowgraphy
  - Theoretical, numerical and experimental studies were performed in parallel (temperature uniformity and stability, layer redistribution,…)

- From 2013 to 2018, CEA developed two cryostats for cryogenic target fabrication (MVT-S & CRYOTECI)

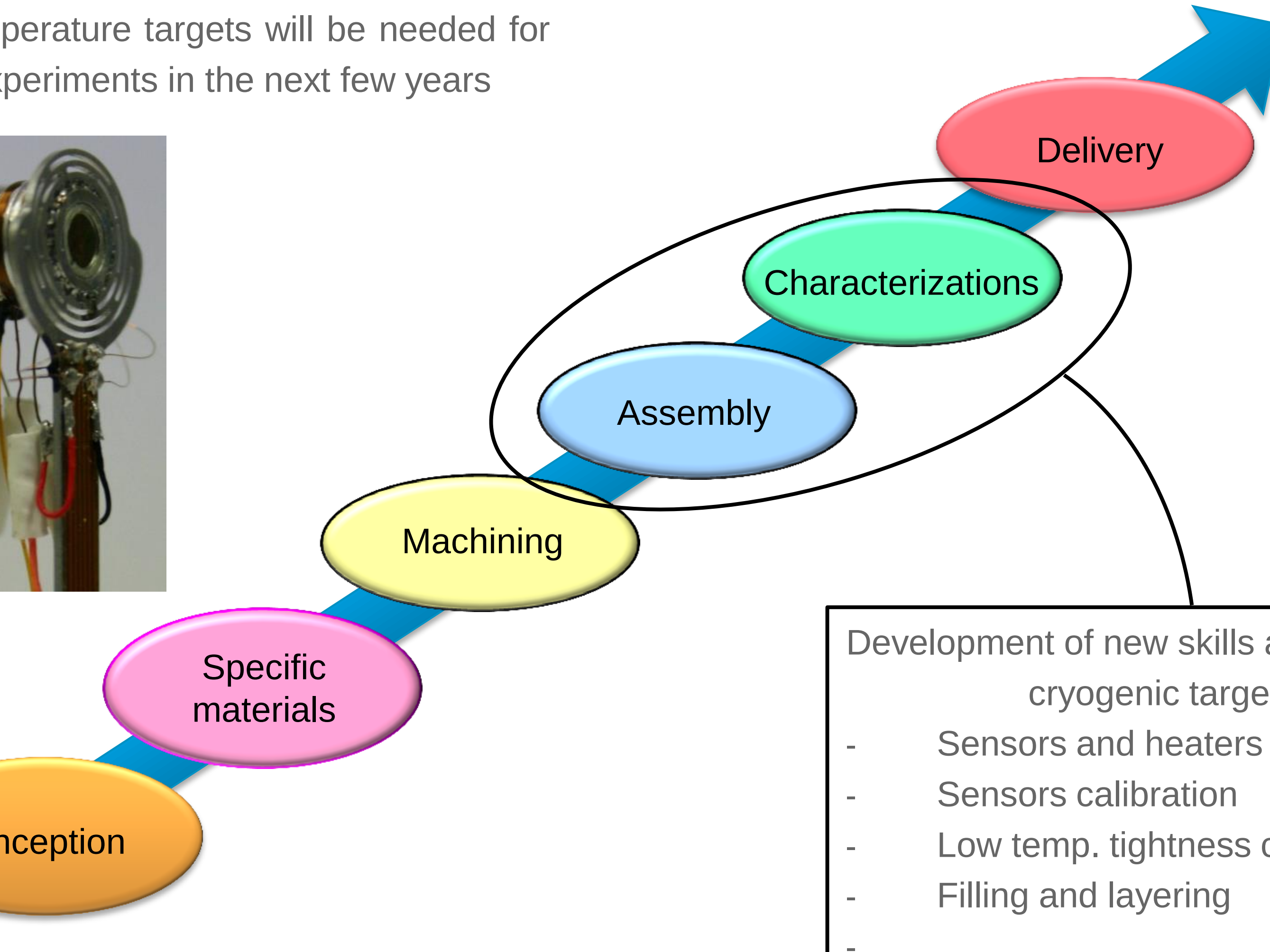
- In 2018, the cryogenic program was relaunched

- Since then
  - the two cryostats were tested in the target department
  - a Keyhole target prototype has been manufactured

Target fabrication cycle at CEA

cf. L Jeannot's presentation

- Low temperature targets will be needed for LMJ's experiments in the next few years



Development of new skills and means for cryogenic targets:

- Sensors and heaters assembly
- Sensors calibration
- Low temp. tightness control
- Filling and layering
- …

Cryogenic targets on the LMJ

- Two main cryogenic target families are considered for LMJ experiments

	Keyhole	Ignition target
Filling	Liquid D_2	Layered DT
Temperature range	19 K – 23 K	17 K – 19 K
Temp. stability requirement	None	< ± 1 mK
Number of temp. sensors	2	4
Number of heaters	0	4
Validation of the filling	Absence of gaseous D_2 in the shell	Stringent constraints of layer thickness, roughness, size and number of defects, etc.

→ The ignition target is very challenging and imposes high quality constraints

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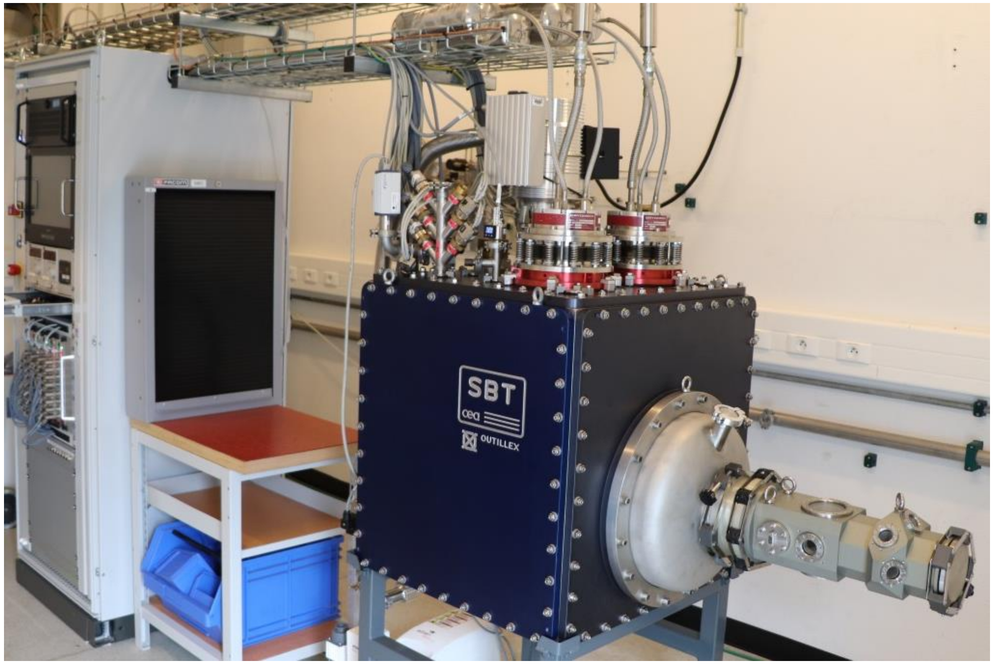
CRYOTECI and MVT-S



MVT-S

- Validation of the cryogenic target design and assembly
- Validation of the targets filling and layering
- Characterization of the obtained layer

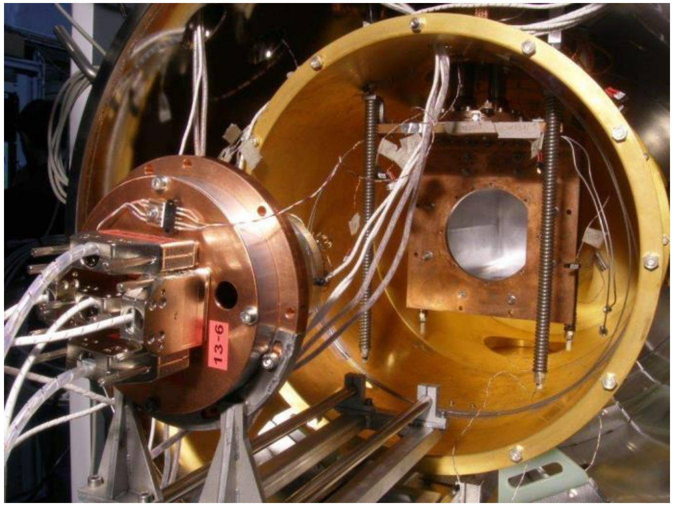
CRYOTECI

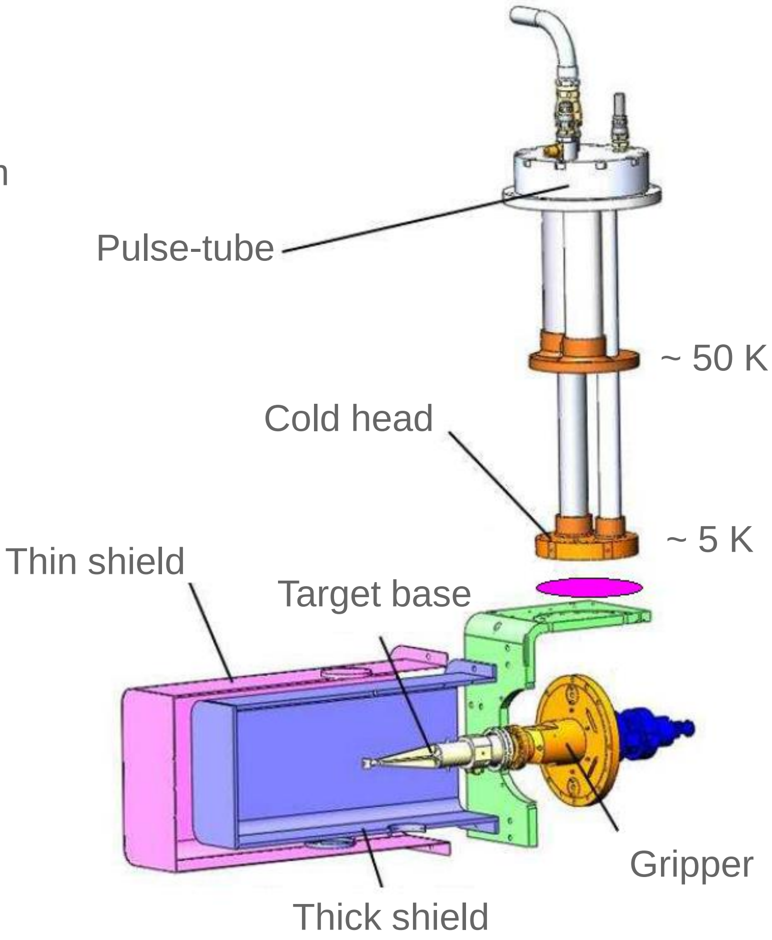
- Calibration of the target's temperature sensors
- Tightness control of the target at 15 K

CRYOTECI: Description

CRYOTECI is composed of:

- A vacuum vessel and two vacuum pumps
- A pulse-tube cryocooler
- A cryogenic gripper
- Three shields guaranteeing nearly perfect target isotherm
- A centralized command system for:
  - Process management
  - Information gathering
  - Temperature regulation
- A target sensor calibration system





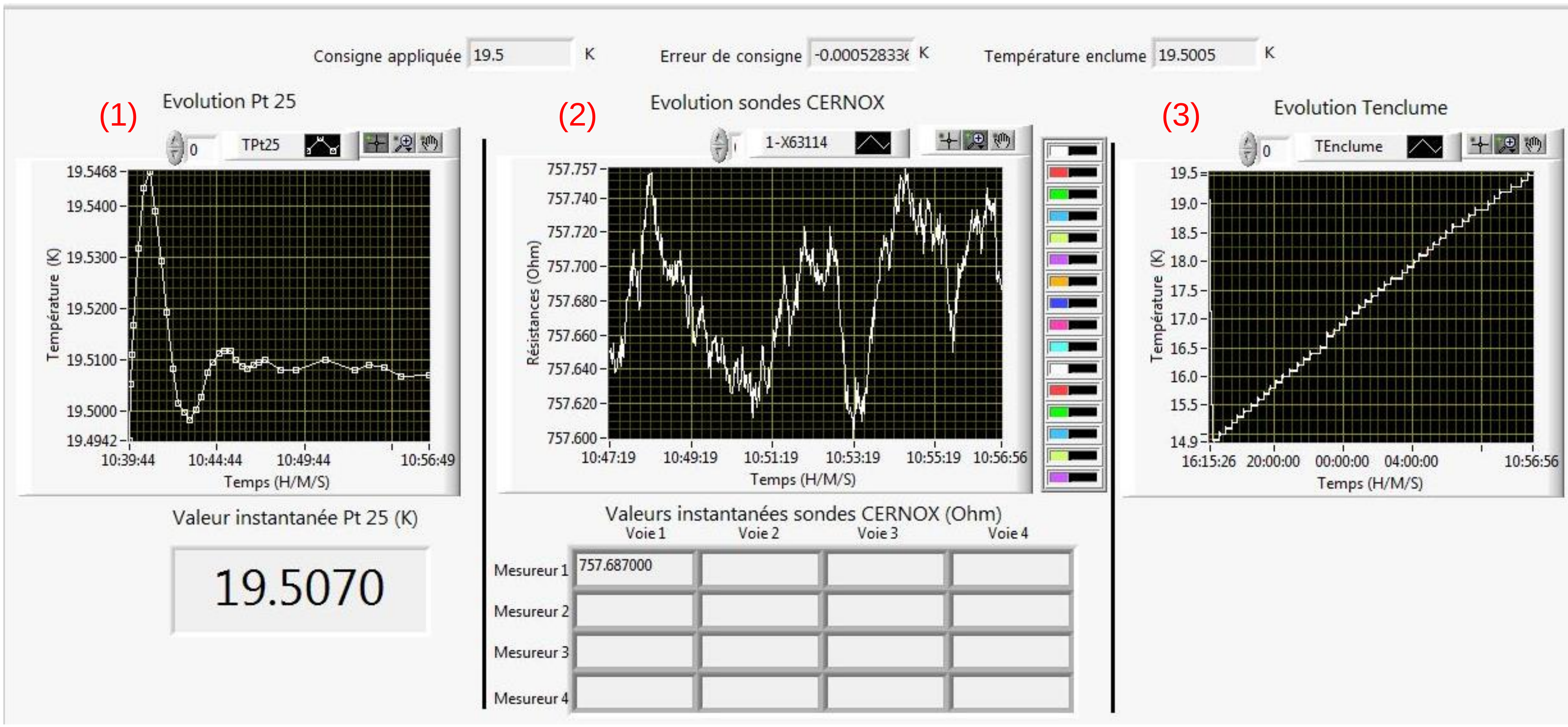
CRYOTECI: Sensor calibration procedure

Temperature is measured with a high accuracy platinum sensor (1)

Sensors resistances are measured (2)

Repeat on a range of temperatures (3)

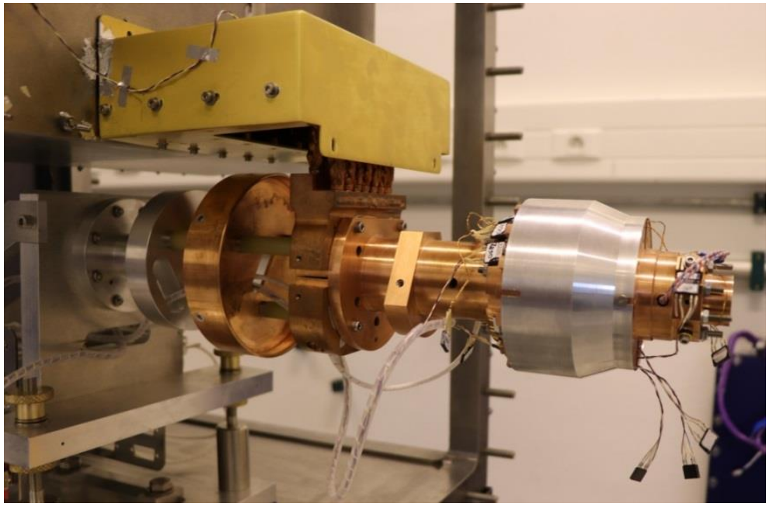
→ T = f(Ω) is then fitted using polynomials



MVT-S: Description

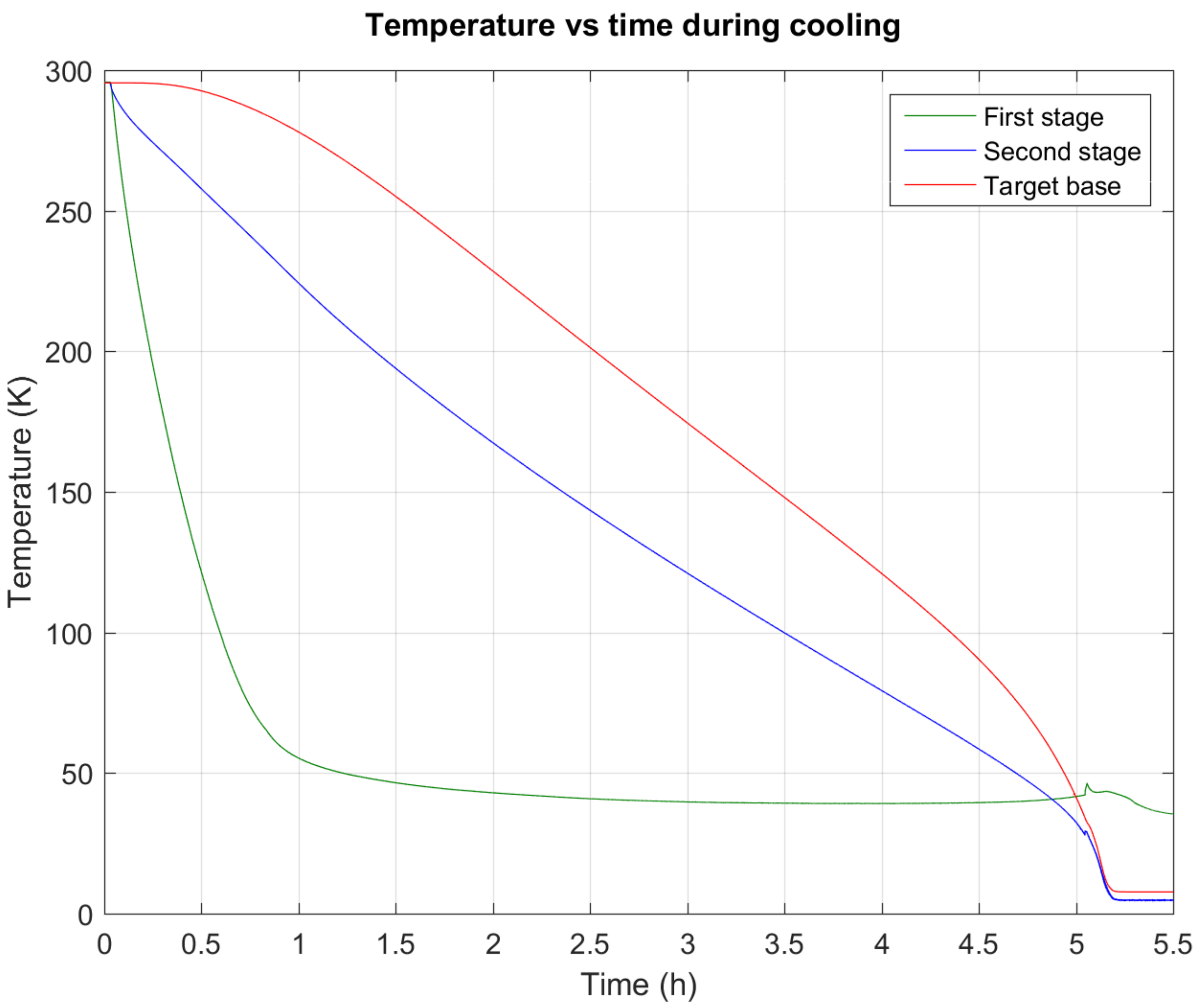
The MVT-S is composed of:

- A vacuum vessel and an observation chamber
- Two vacuum pumps
- Two pulse-tube cryocoolers
- A cryogenic gripper
- A thermal shield reducing radiation on cold pieces
- A centralized command system for:
  - Process management
  - Information gathering
  - Temperature regulation

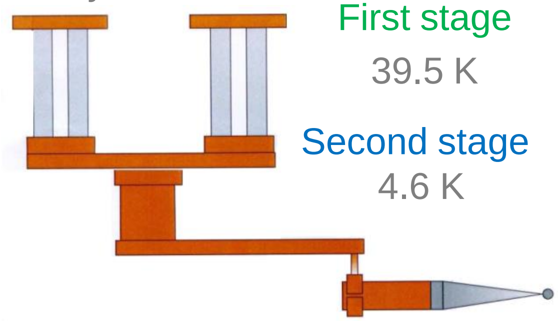


Copper made gripper

MVT-S: Performances



Final temperatures:



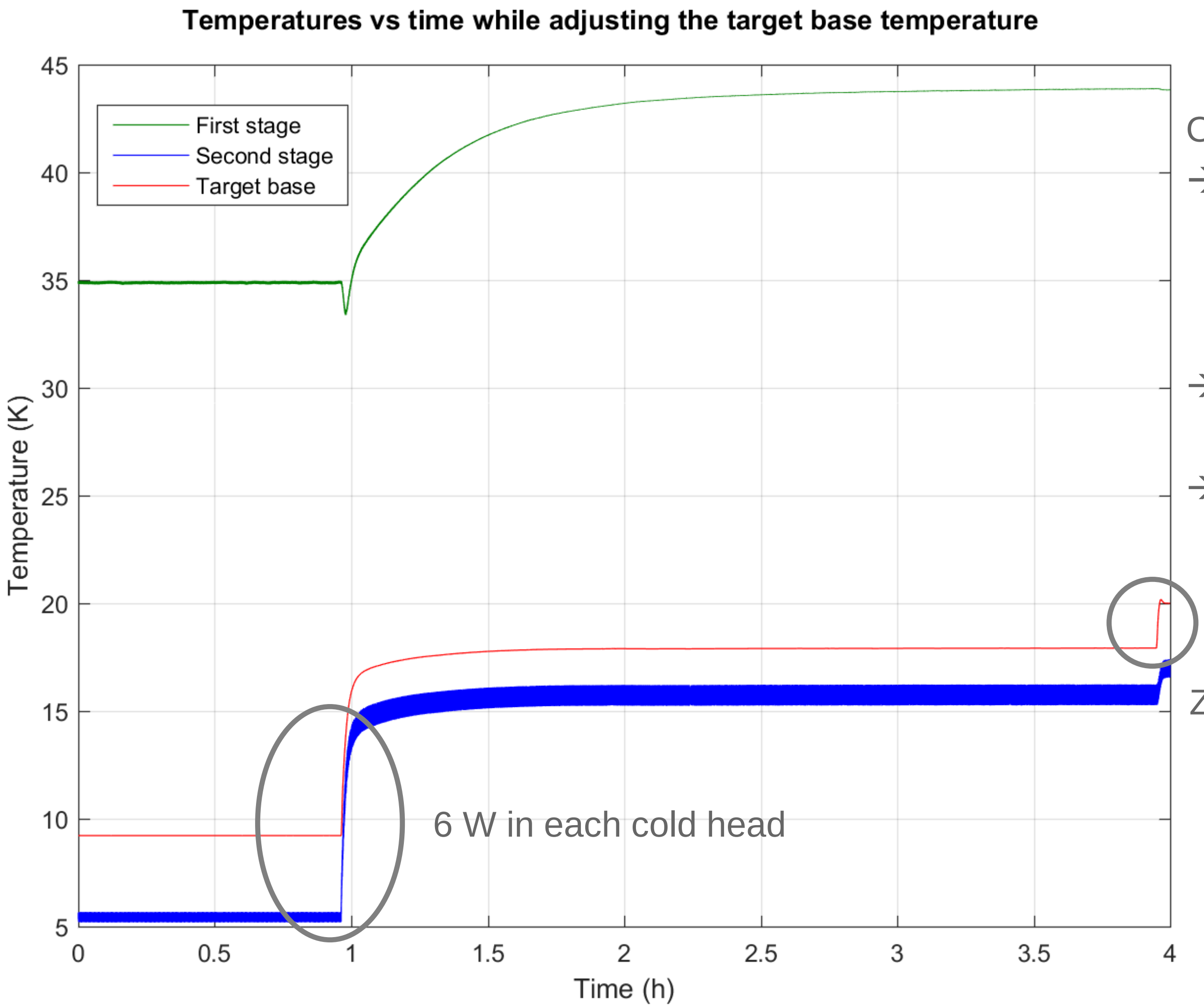
First stage
39.5 K

Second stage
4.6 K

Target base
7.7 K

→ Validated for ignition target

MVT-S: Temperature regulation (1/2)



Need

Obtain liquid D_2

→ ~20 K on the target base

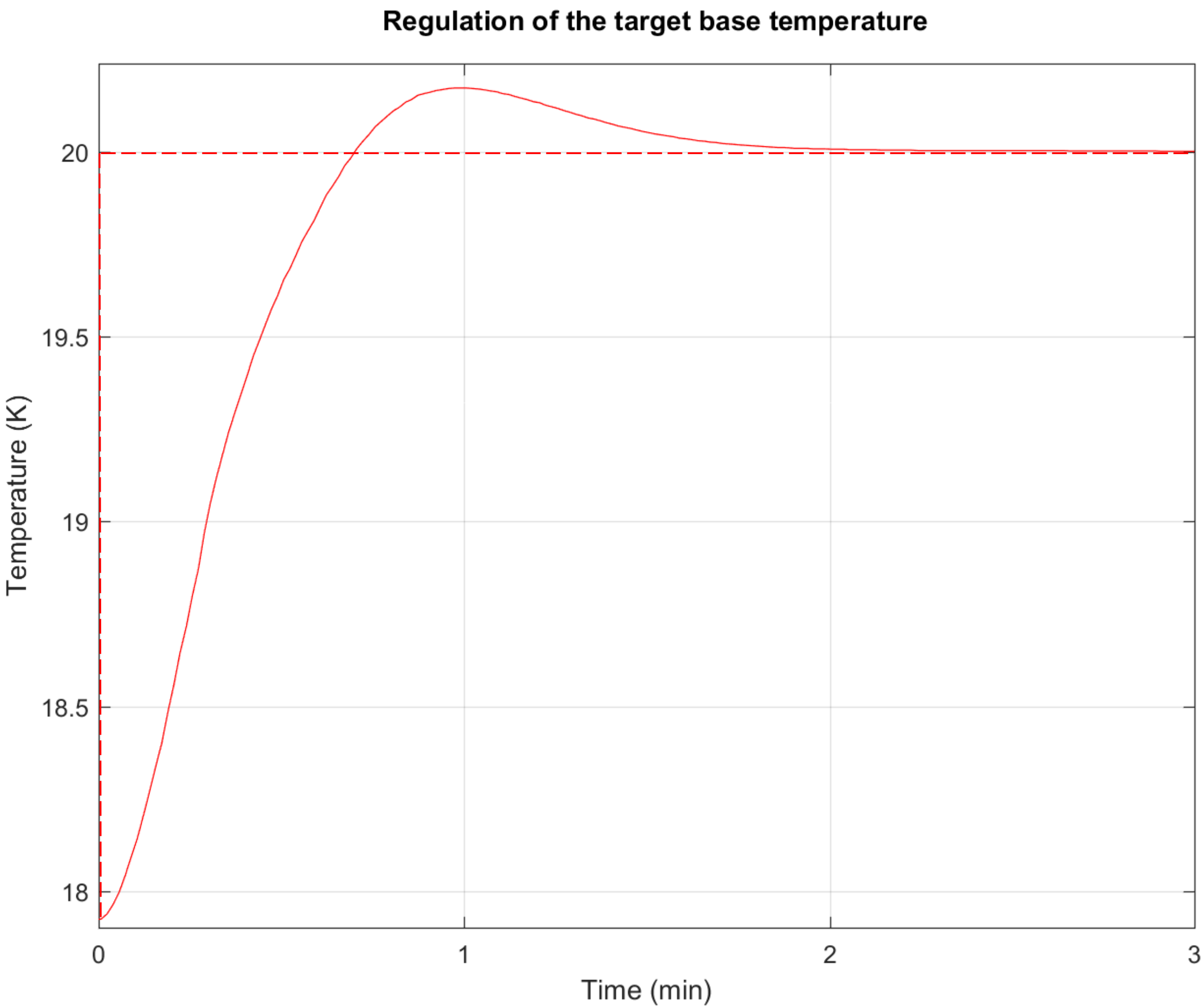
Method

→ Rough heating in the cold heads (slow dynamic)

→ Precise regulation using heaters on the target base (faster dynamic)

Zoom next slide

MVT-S: Temperature regulation (2/2)



Keyhole target:

Temp. regulation is achieved by mean of a PID controller

→ $tr_{95\%} = \sim$ 2 min

→ ~ 10% overshoot

Ignition target:

Regulation will be implemented directly on the supporting arms and on the hohlraum

→ Faster dynamic

→ Overshoot needs to be controlled for ignition target

MVT-S: Temperature stability

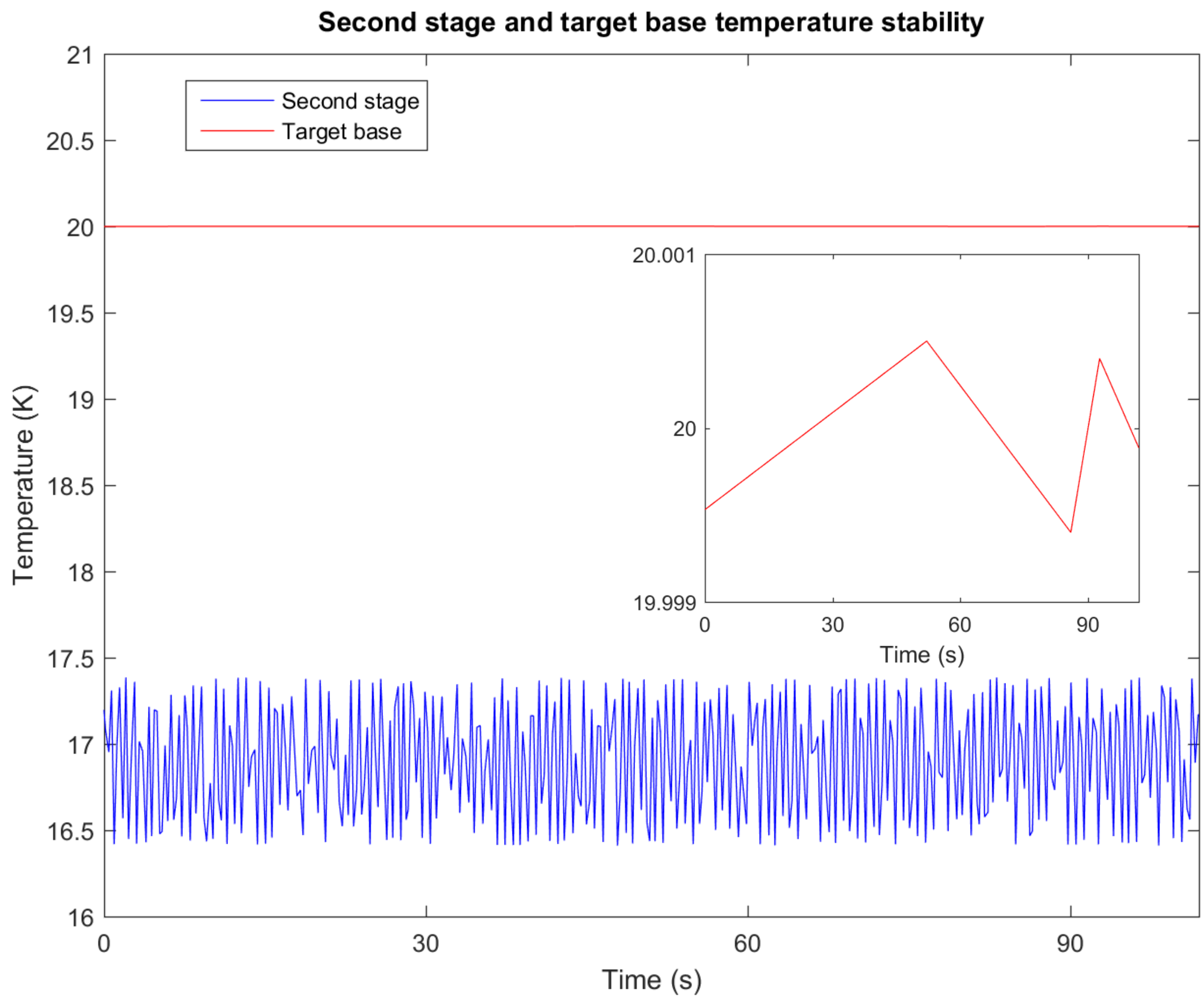
Target base temperature stability < ± 1 mK needed for DT layering

Temperature stability

Second stage: ~ ± 0.5 K

Target base: ~ ± 0.6 mK

→ Temp. stability validated for ignition target



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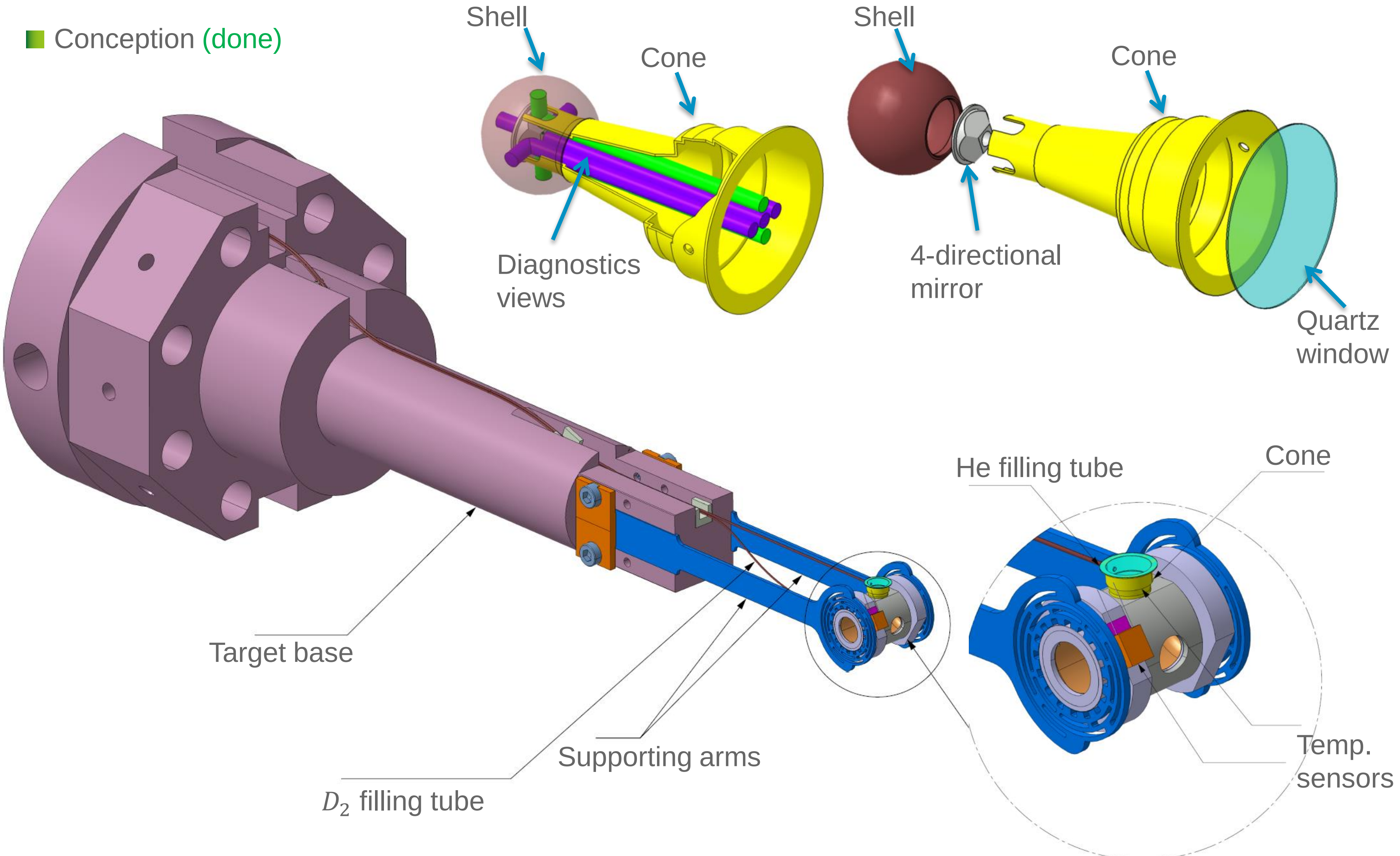
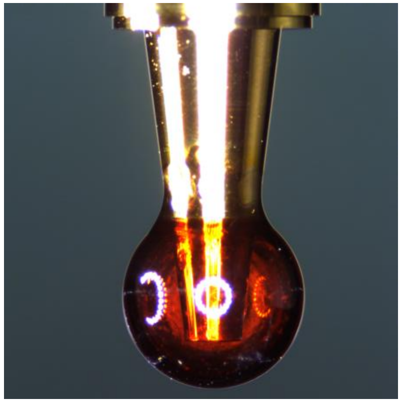
Keyhole target prototype development (1/2)

- Conception (done)

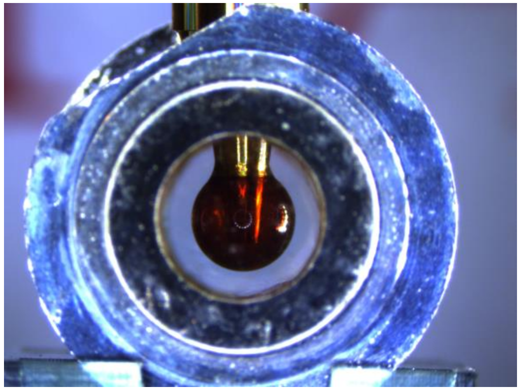


Keyhole target prototype development (2/2)

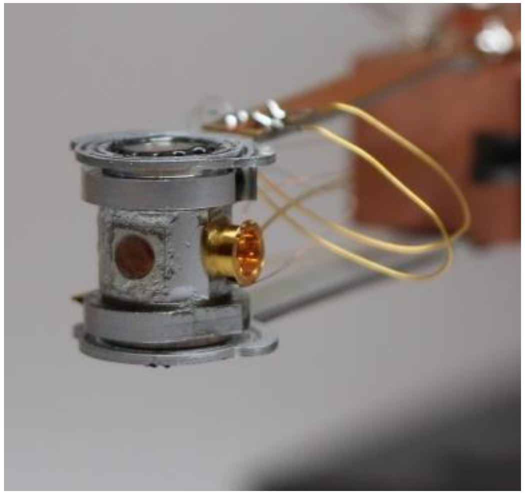
- Machining (done)
- Assembly (done)
- Characterizations (done)
- Temp. sensors calibration and tightness controls (in progress)
- First liquid D_2 filling (coming soon)
- Validation of the target design and assembly (coming soon)



Keyhole cone and shell



Keyhole cone and shell through the hohlraum

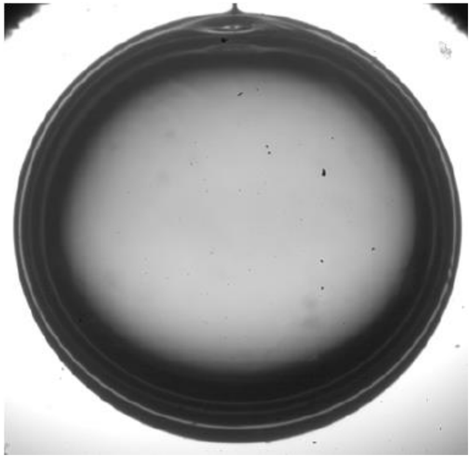


Assembled Keyhole target prototype

Skills under development (state of the art)

Filling and layering characterization

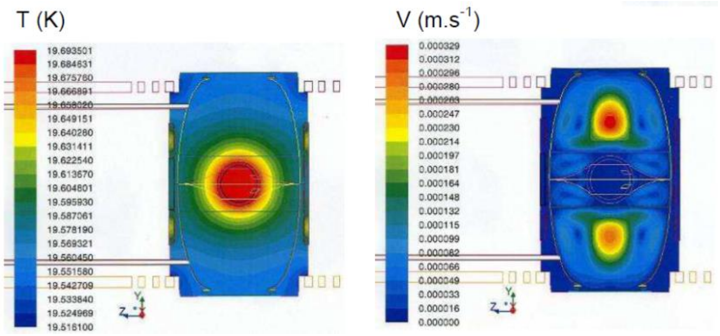
- Backlit shadowgraphy can readily be used for the observation of :
  - Liquid filling
  - Crystal growth
  - Roughness and defects
- For opaque shells, X-rays will be used for DT layer characterization
  - CEA's target department studied X-ray phase contrast
  - Integration for DT layer characterization is currently being studied



D_2 solid layer

Numerical simulations

- Optimization of the target design (geometry, materials,…)
- Evaluation of temperature uniformity inside the hohlraum
- DT layer life span
- …



Temp. uniformity study

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Conclusion

- After being stopped in 2013, the cryogenic program was relaunched in 2018
- LMJ cryogenic targets are developed and tested at CEA ‘s target department
- To this aim, the CEA developed two cryostats
  - CRYOTECI for sensor calibrations and tightness control
  - MVT-S for target assembly and design validation
- The MVT-S is designed for achieving DT layering
- A Keyhole target design is being tested with the MVT-S
- X-rays phase contrast is considered for DT layer characterization
- Numerical simulation is integrated to the target fabrication cycle

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