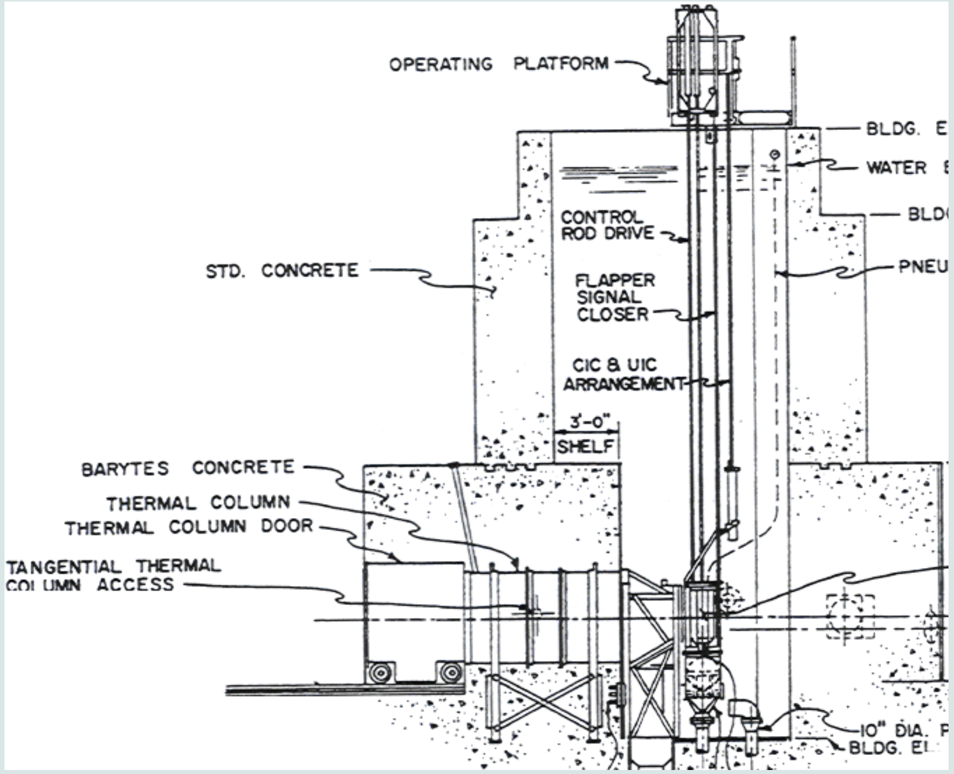
PULSAR UCN source: studying solid deuterium growth and evolution

E. Korobkina

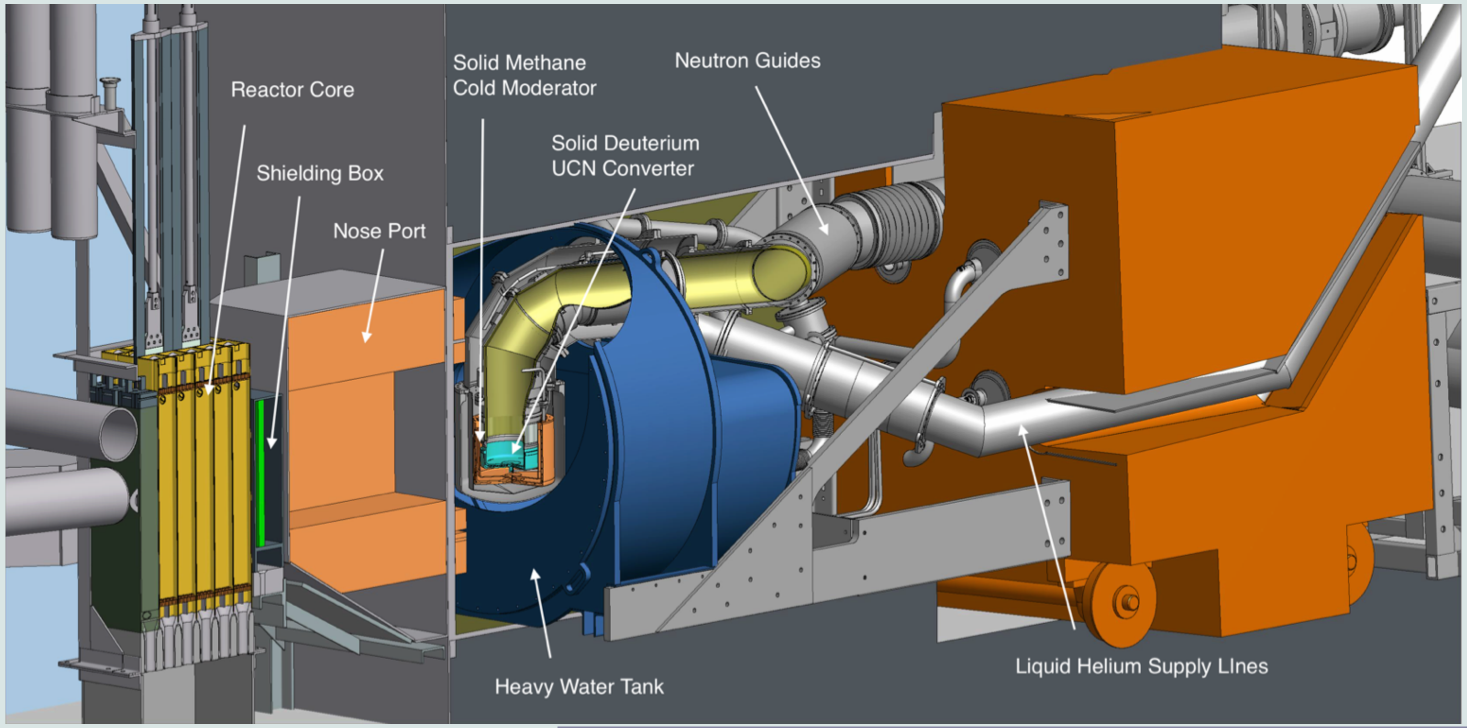
NC State University

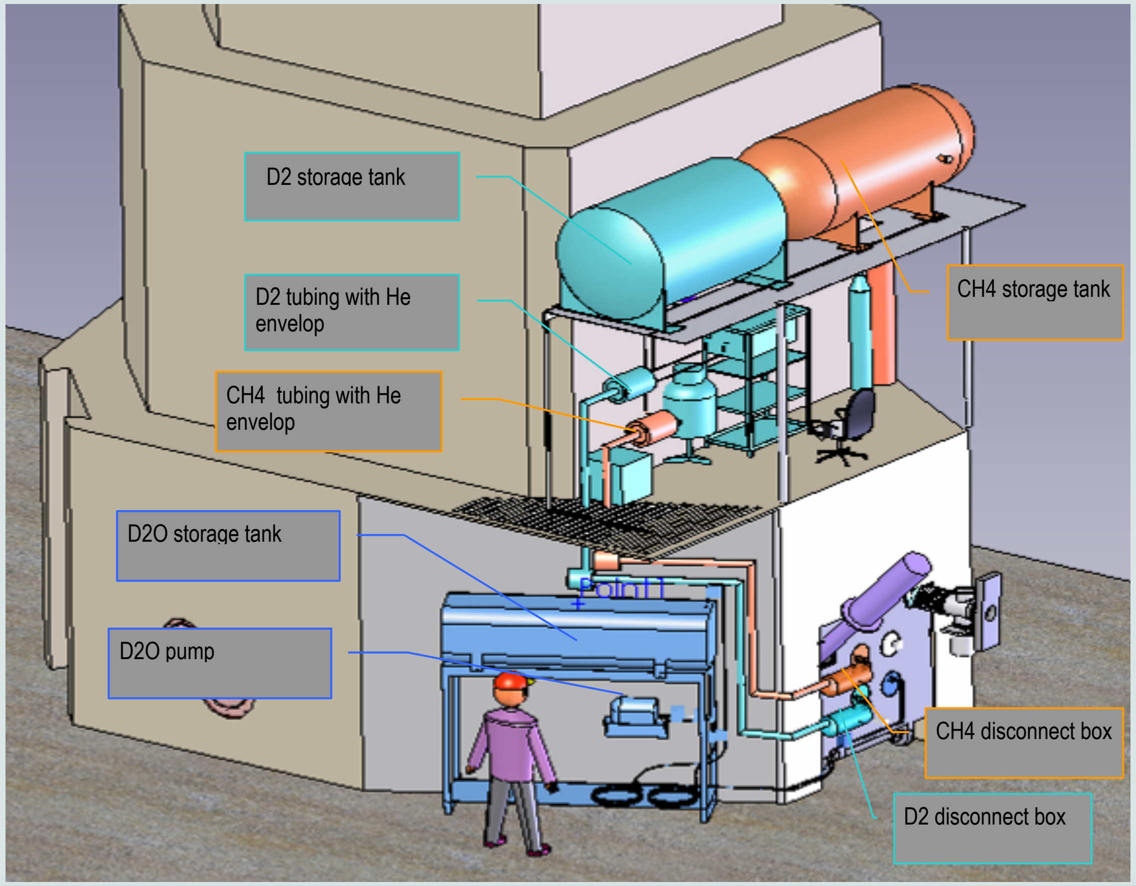


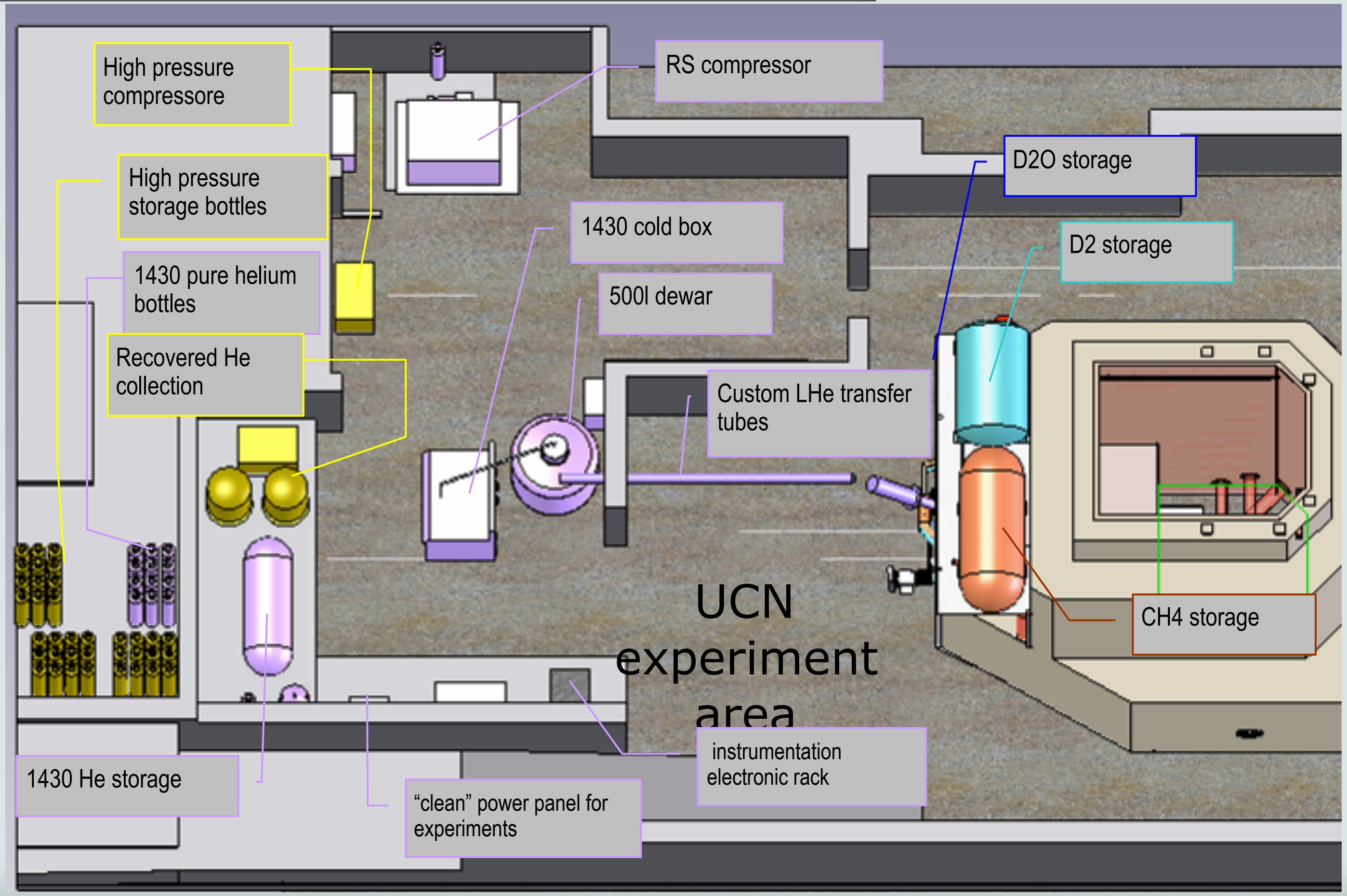
Outlines

- Brief reminder of PULSTAR source design and status
- Overview of test instrumentations
- Brief overview of runs
- Discussion: temperature dependence of crystal shapes and quality
- Conclusions and Outlook

Overview of PULSTART source design







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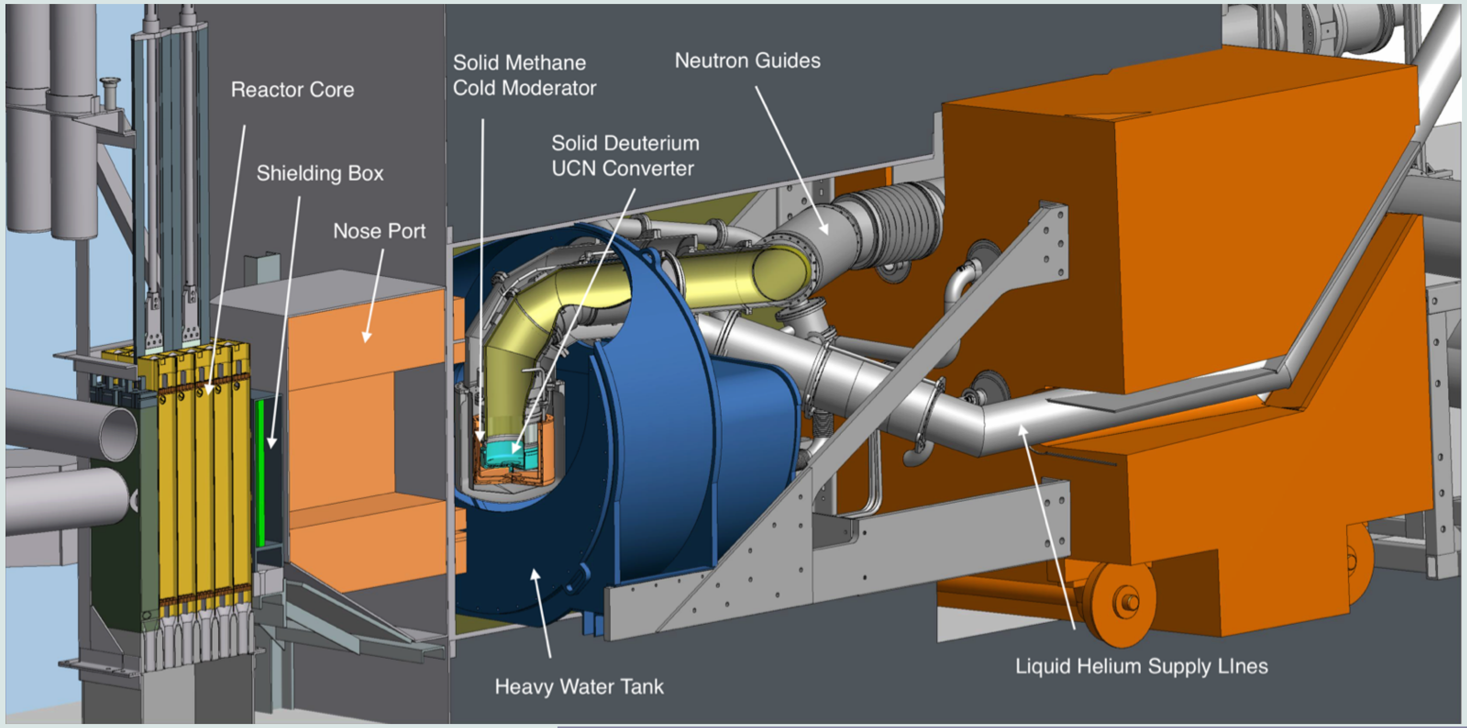

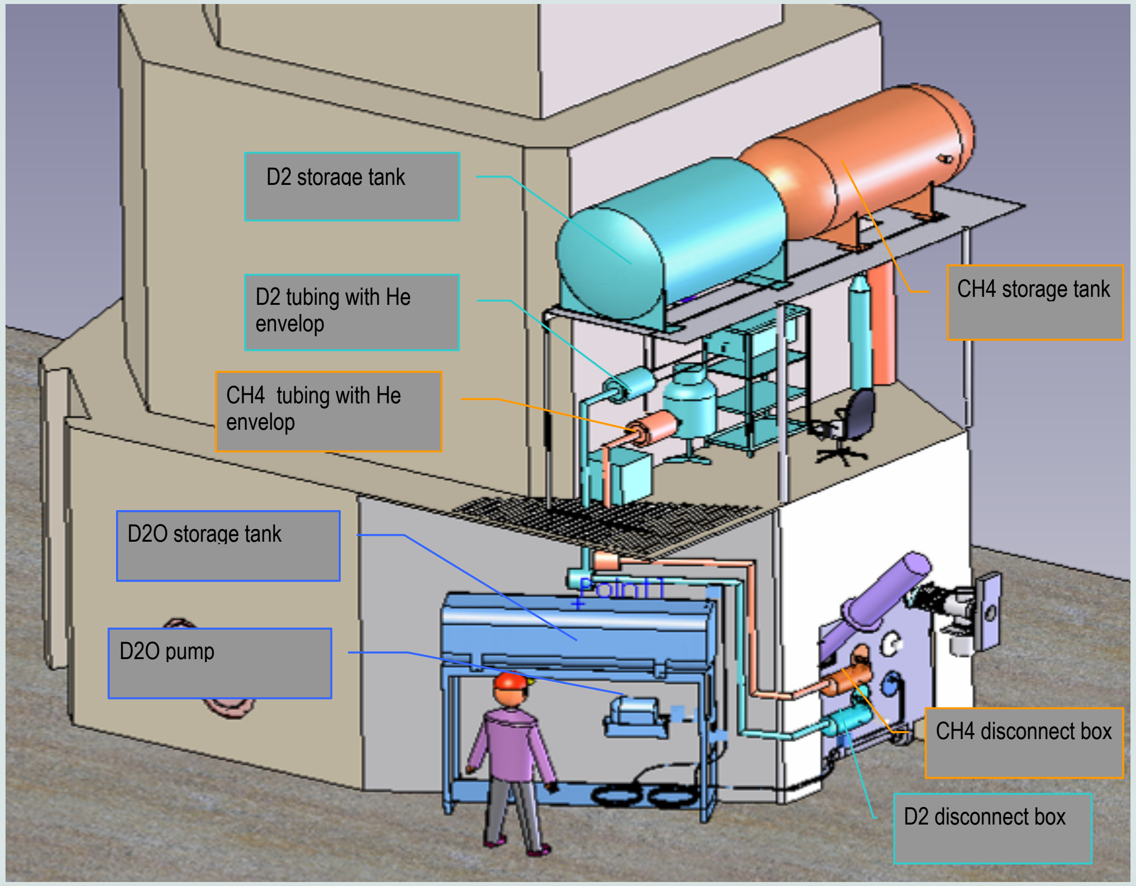

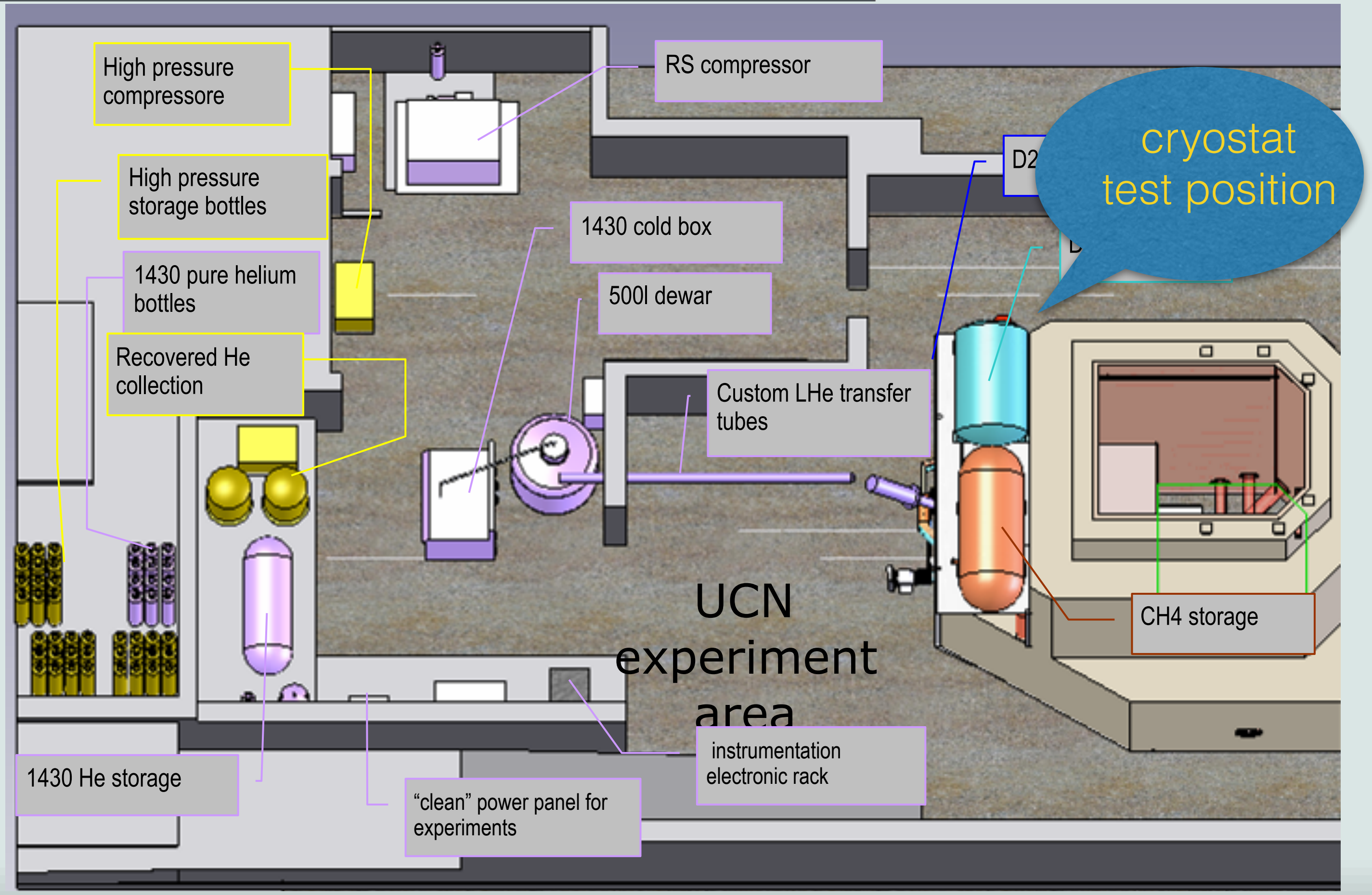

Pulstar UCN source status update

- In 2015 we successfully completed cryogenic commissioning of the source before it is installed in the biological shield of the reactor, everything works as designed
- In 2016 we have added P/O convertor to complete cryogenic tests with ortho-deuterium
- From operational experience of other facilities we are aware of the crucial importance of the solid deuterium crystal properties for good source performance
- Therefore this year we installed special set-up for visual and temperature control of the deuterium crystal growth and performed several runs with different parameters.
- At present we are evaluating our data and preparing for the next round of solid deuterium growth
- summary of main results will be presented today

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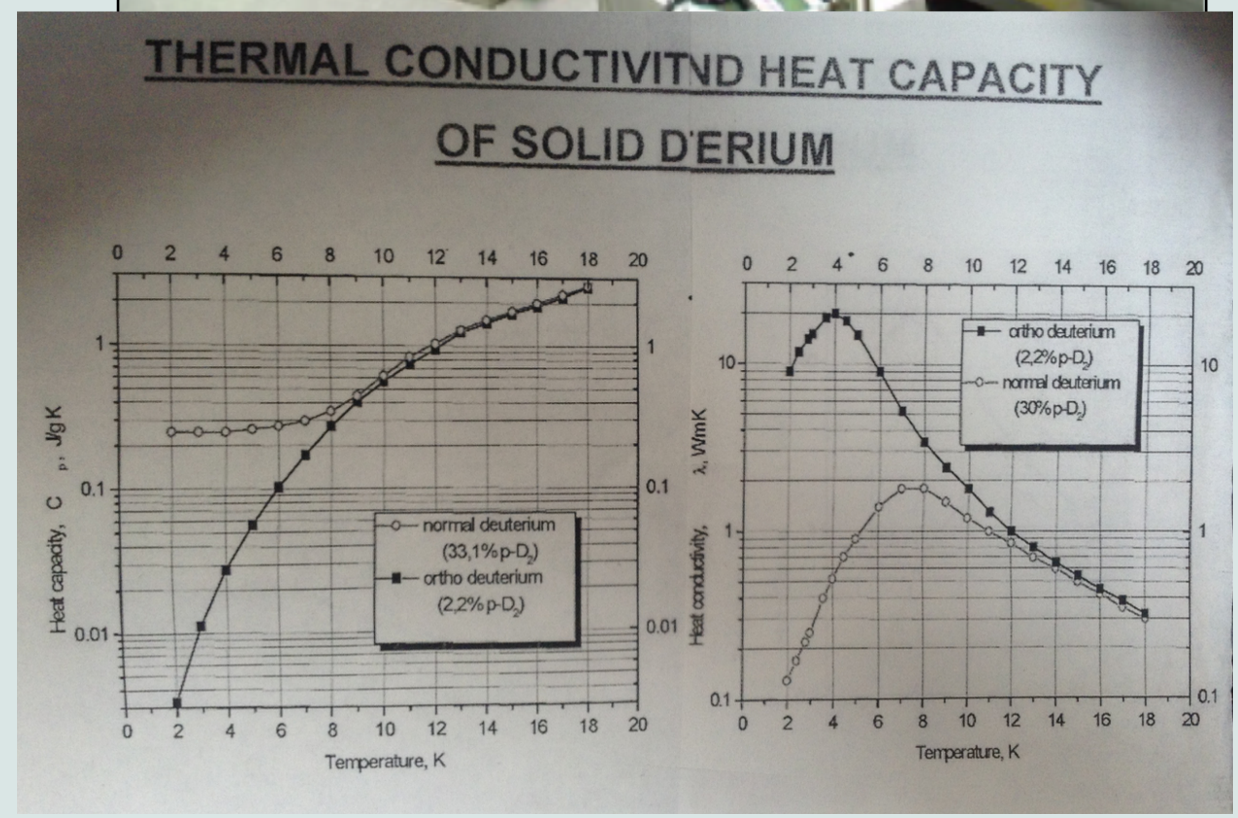
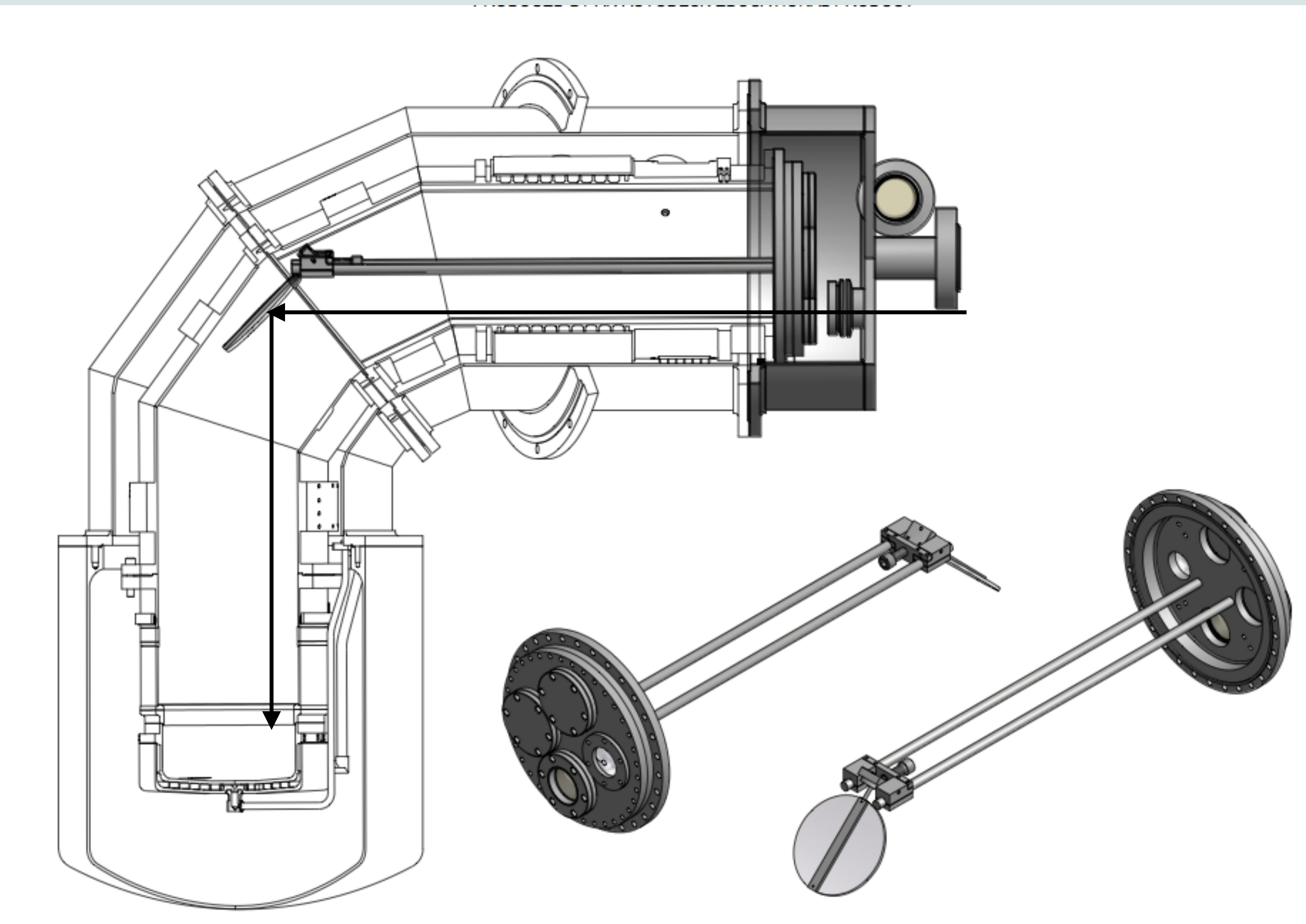
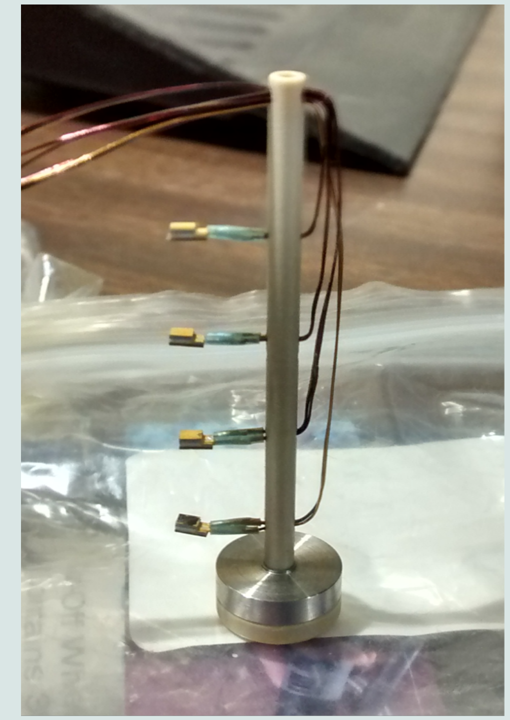
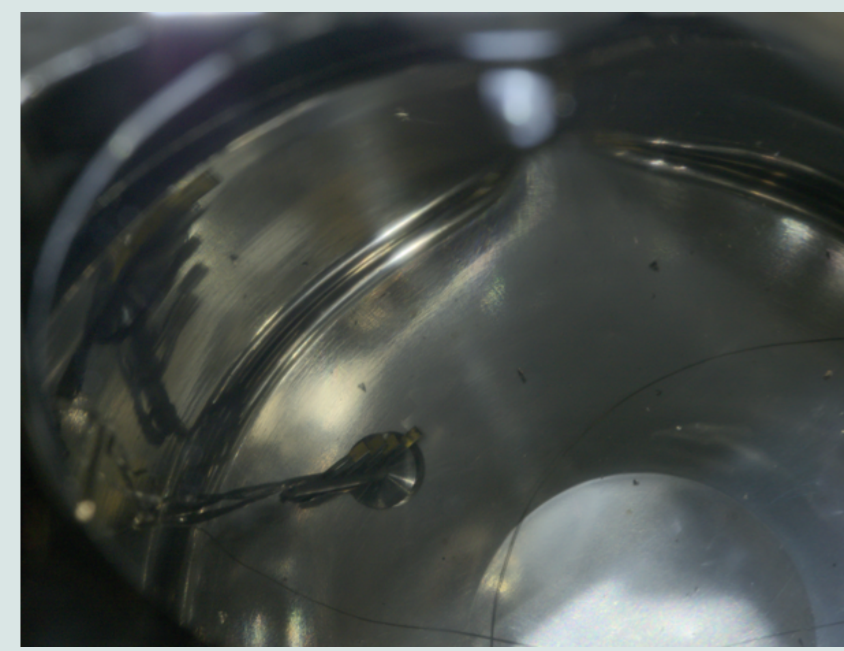


SD2 monitoring system for visual control

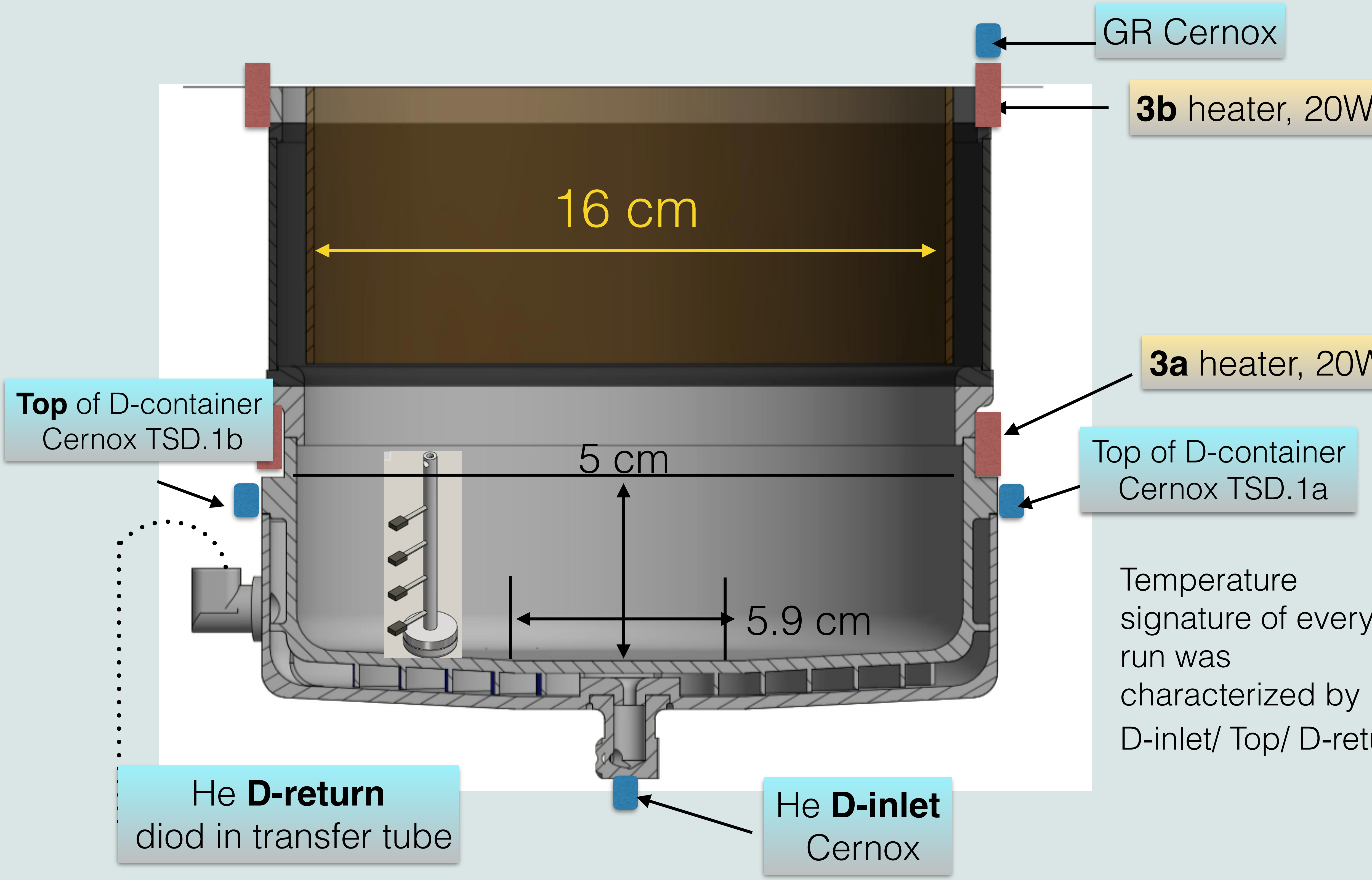
- Graham Medlin designed and implemented a monitoring system which allows to observe D2-container by using camera outside cryostat







SD2 growing tests : instrumentation details



Temperature signature of every run was characterized by D-inlet/ Top/ D-return

Overview of runs

1. Feb 23-26 **condensation**
2. Feb 27-Mar 4 - annealing, **melting-refreezing**; evaporation
3. Mar 15- Mar 25 - **condensation**
4. Mar 25 - 28 annealing, adjustment of cryogenic system
5. Mar 29-31 **heat shooting**
6. Apr 1-4 slow warming/annealing ; evaporation
7. April 11-13 **condensation**
8. April 25 **condensation**

Feb 23-26 condensation

- this run was to simulated Mainz UCN source condensation of SD2 with cold (6K) bottom of container and slow D2 flow rate
- **5.4K/ 8.2K/ 7.2K**:
  - Small flow (0.3 l/m) produced dense multicrystall, optically opaque
  - Higher D2 flow >1 l/m produced snow-flake-like mass
- when T of container was increased (**5.4K/ 11.2K/ 8.3K**) and crystal annealed, D2 flow =>0.8 l/m results in visibly shiny surface

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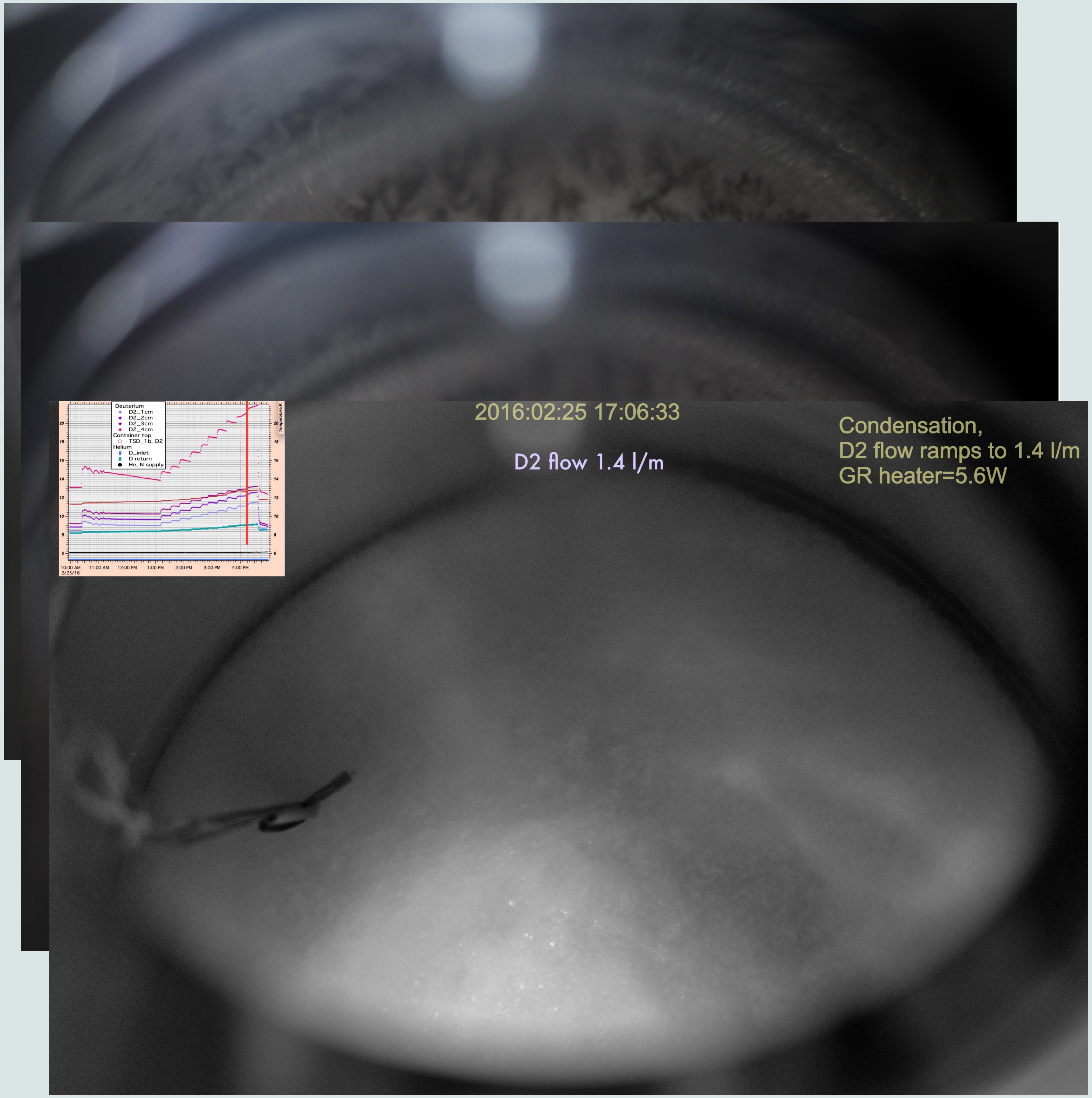

Feb 27-Mar 4 - melting-refreezing

- Melting &re-freezing is routine crystal conditioning procedure at LANL and PSI UCN sources
- it produces reasonable transparent crystal, with some crystal structure visible, no surprises here
- After cooling down to 5K , this crystal was melted and evaporated

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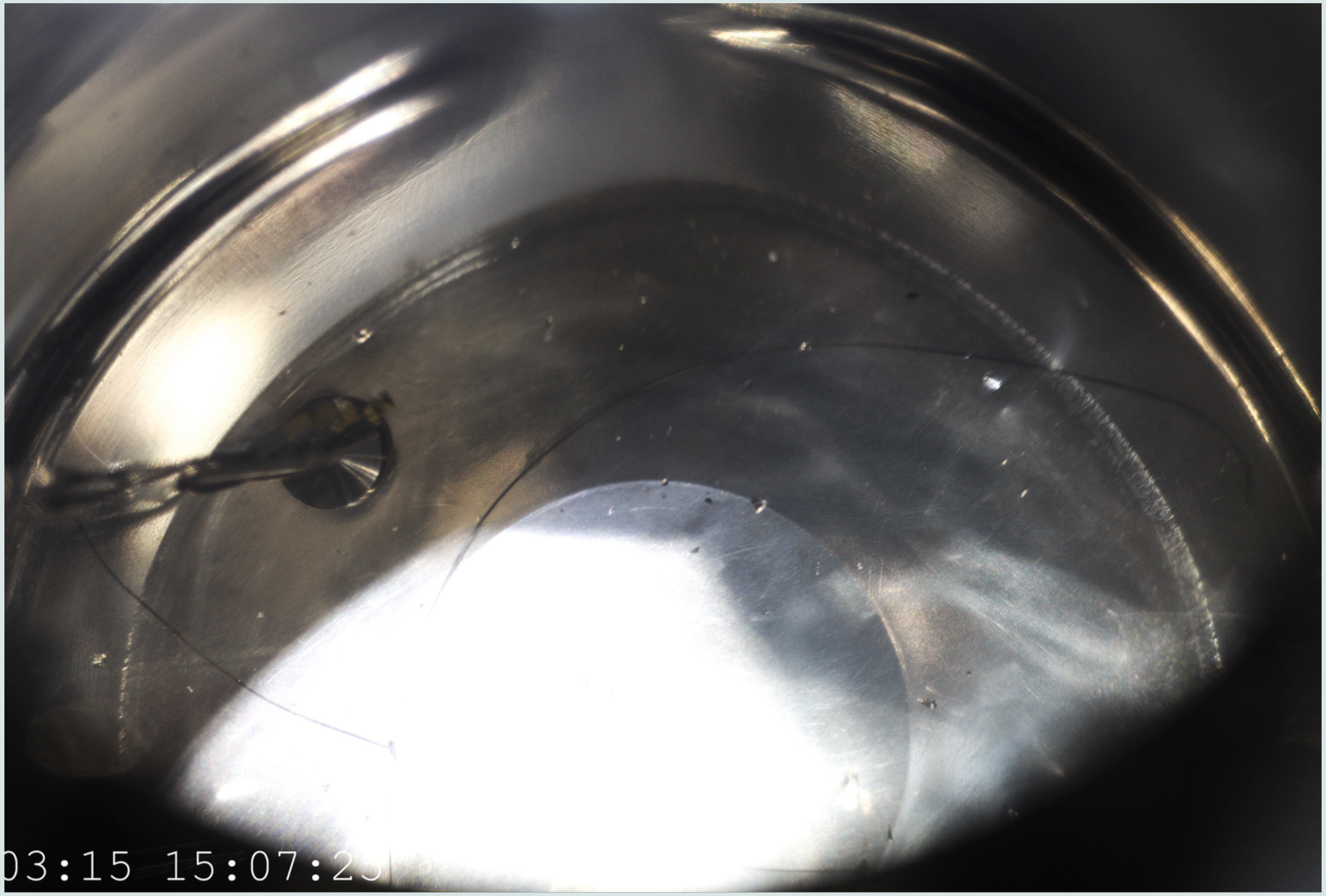
  - ideal transparent crystal
- Mar 15-16-18, evolution to blob:
  - amazing mobility and tendency for avoiding warmer surfaces
- Mar 16 condensation, with heaters on, 8.5/ 18/ 15K, 1 l/m
  - clear crystal



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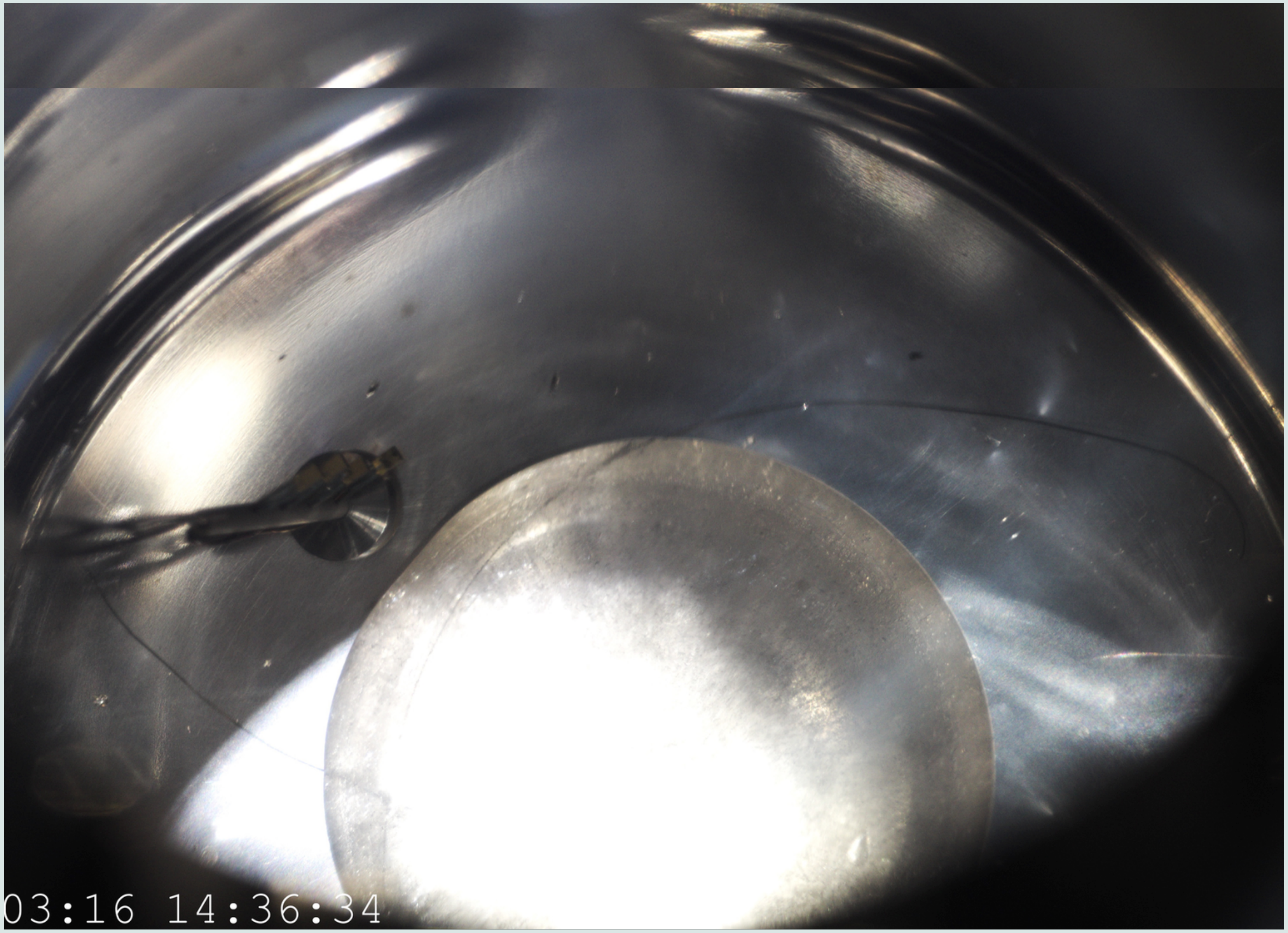

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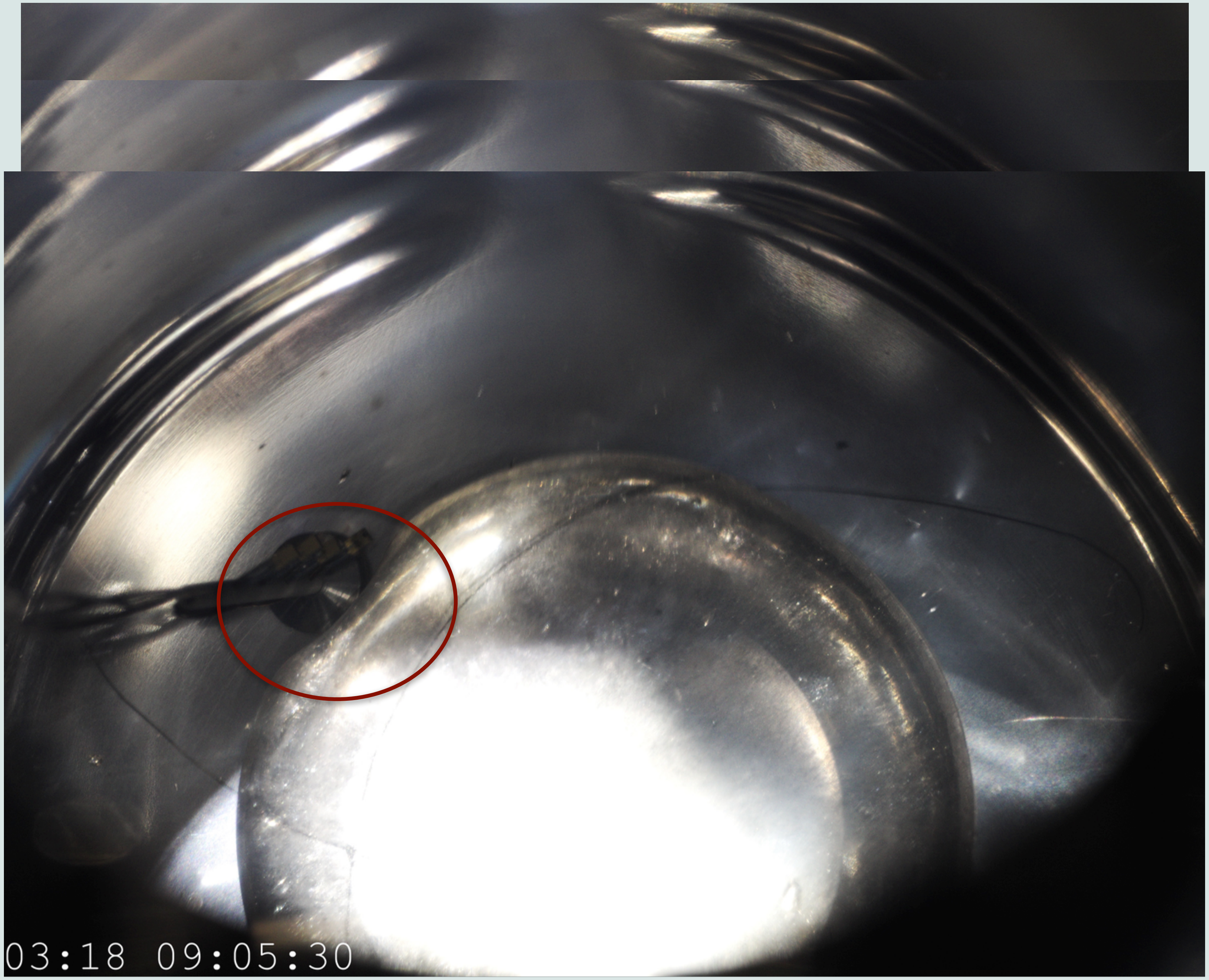

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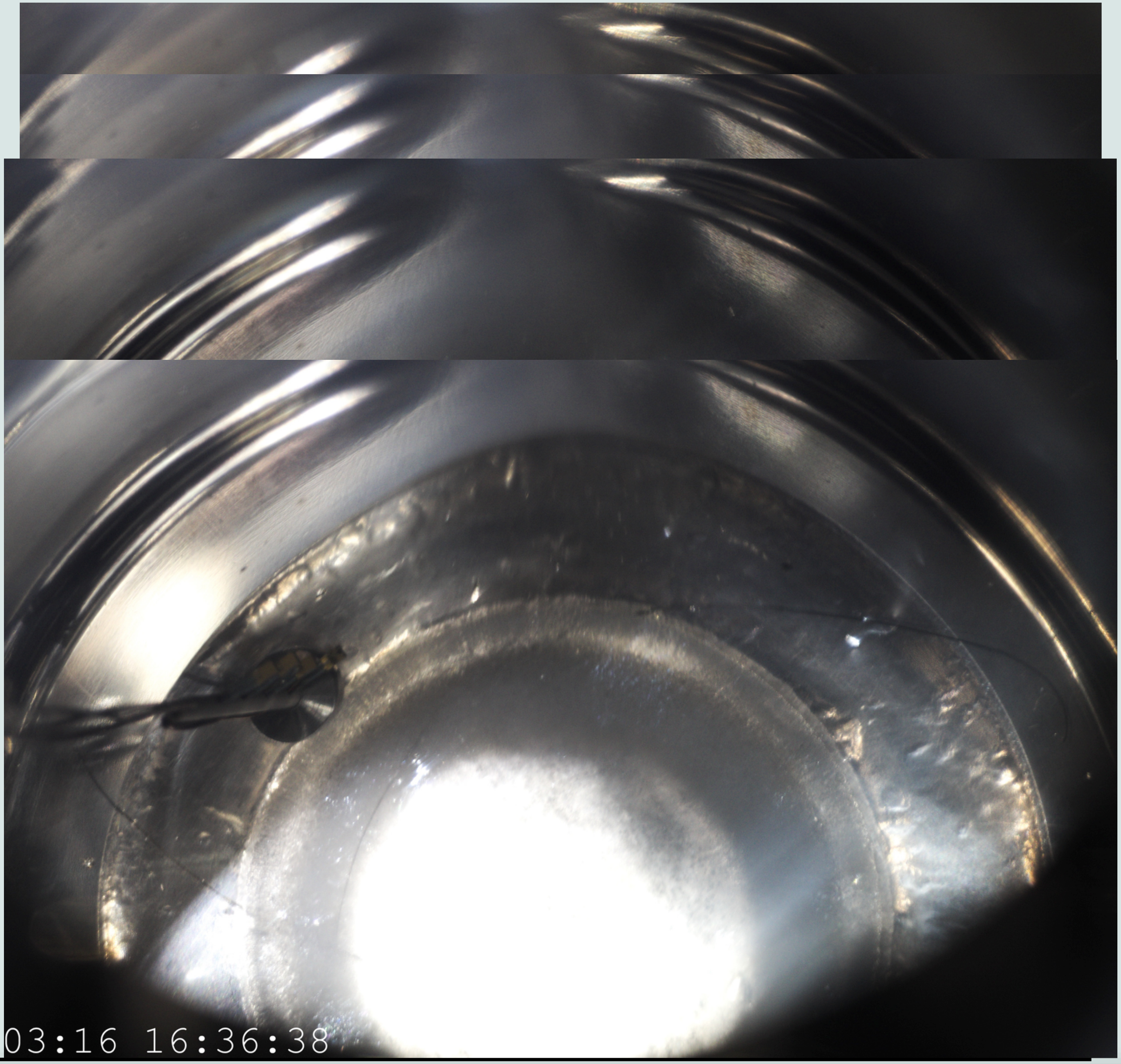

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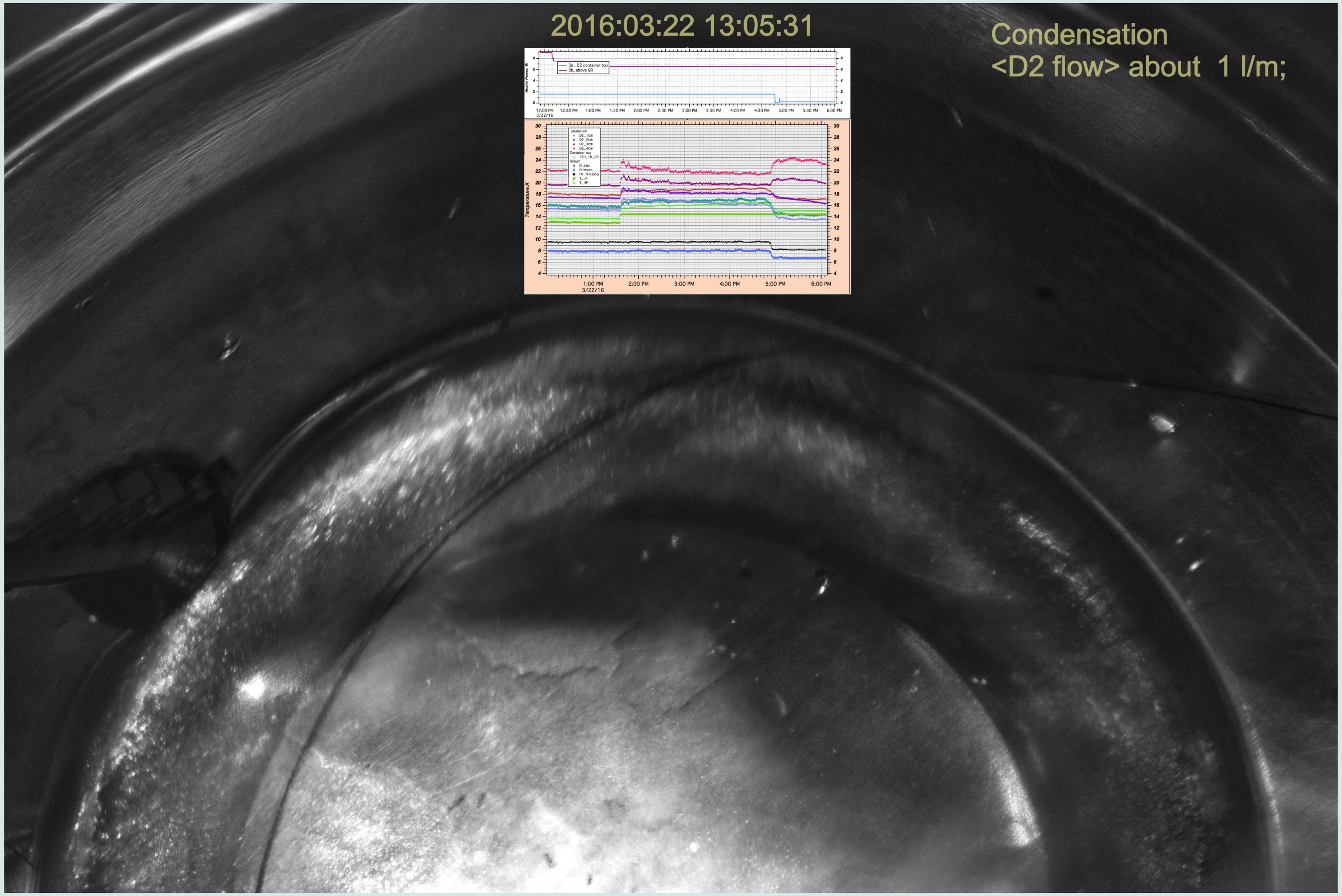
- Mar 22 condensation, with heaters, 7.75/ 17/ 18.5-19, 1 l/m
  - transparent crystal
  - 1 cm diod covered

- Mar 24, 25 - all probe sensors covered, about 1050 cc total
- Main conclusions from Mar run:
  - it is possible to grow optically good crystal from vapor at warmer temperatures and flow 0.8-1 l/m
  - need to be concerned about crystal shape evolution with time



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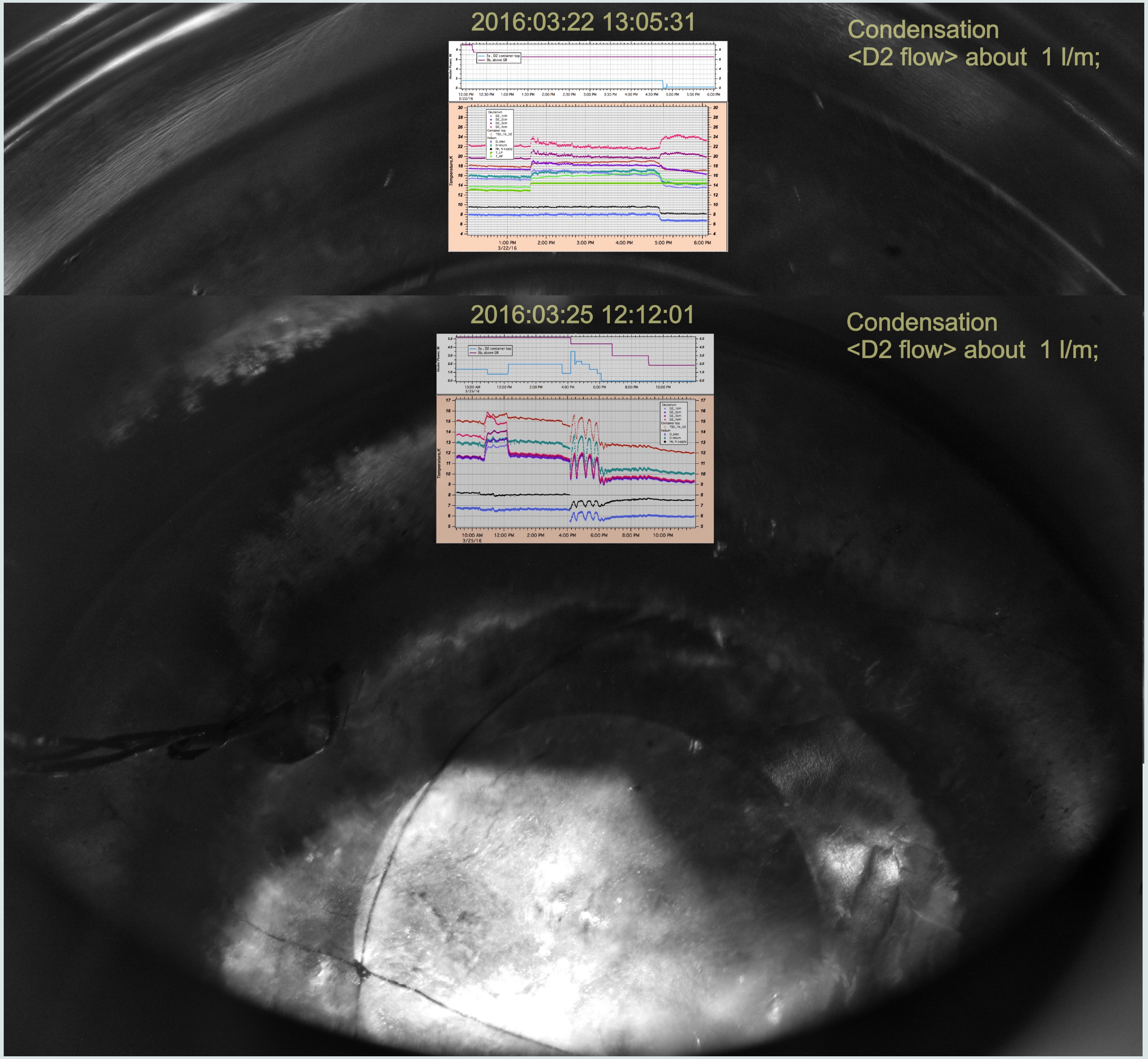
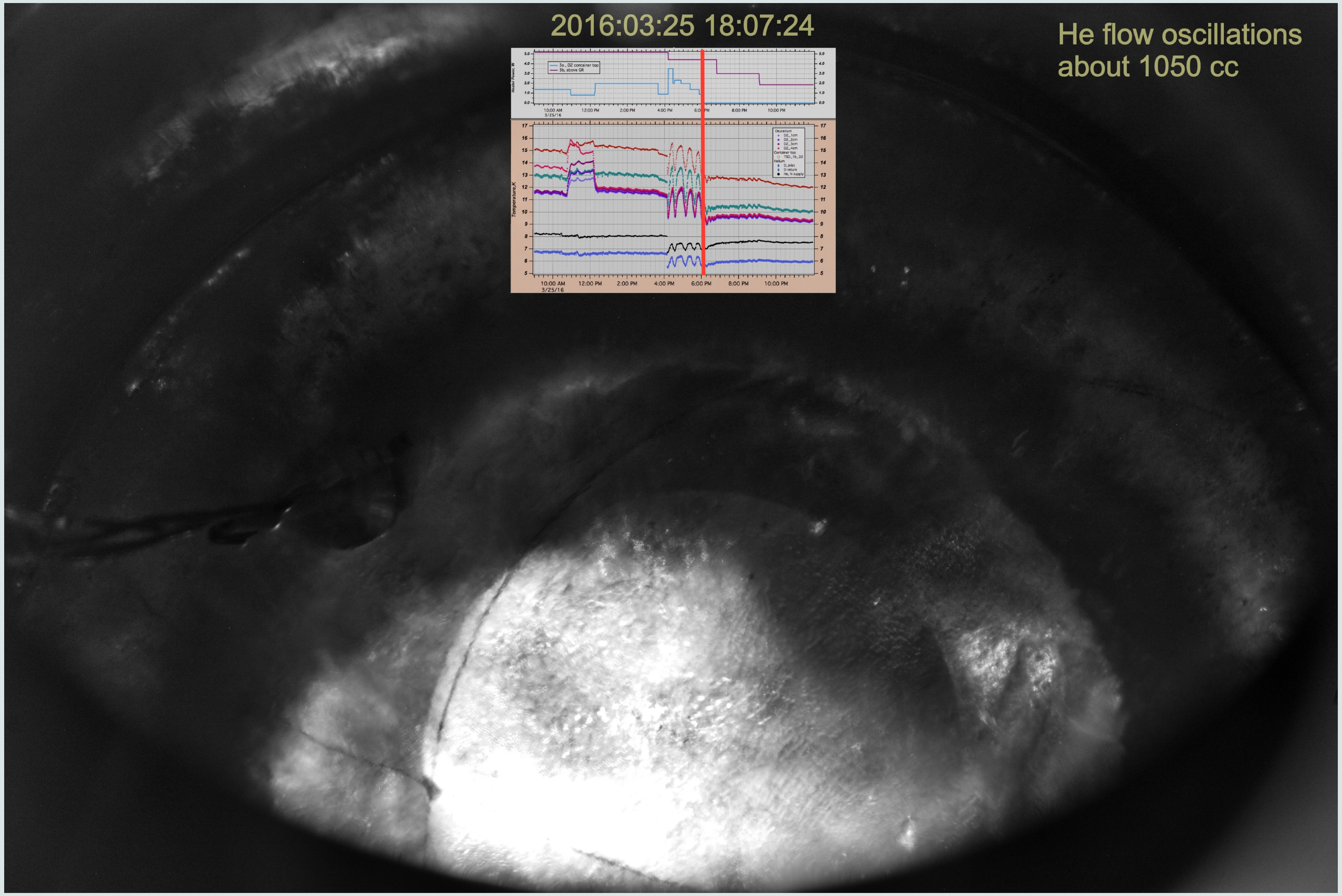


Mar 29-31 heat shooting

- Accidental He flow oscillations on Mar 25
- Mar 29-31 heat shooting
- Conclusions: we need also to be concerned about crystal surface evolutions when temperature is not stable



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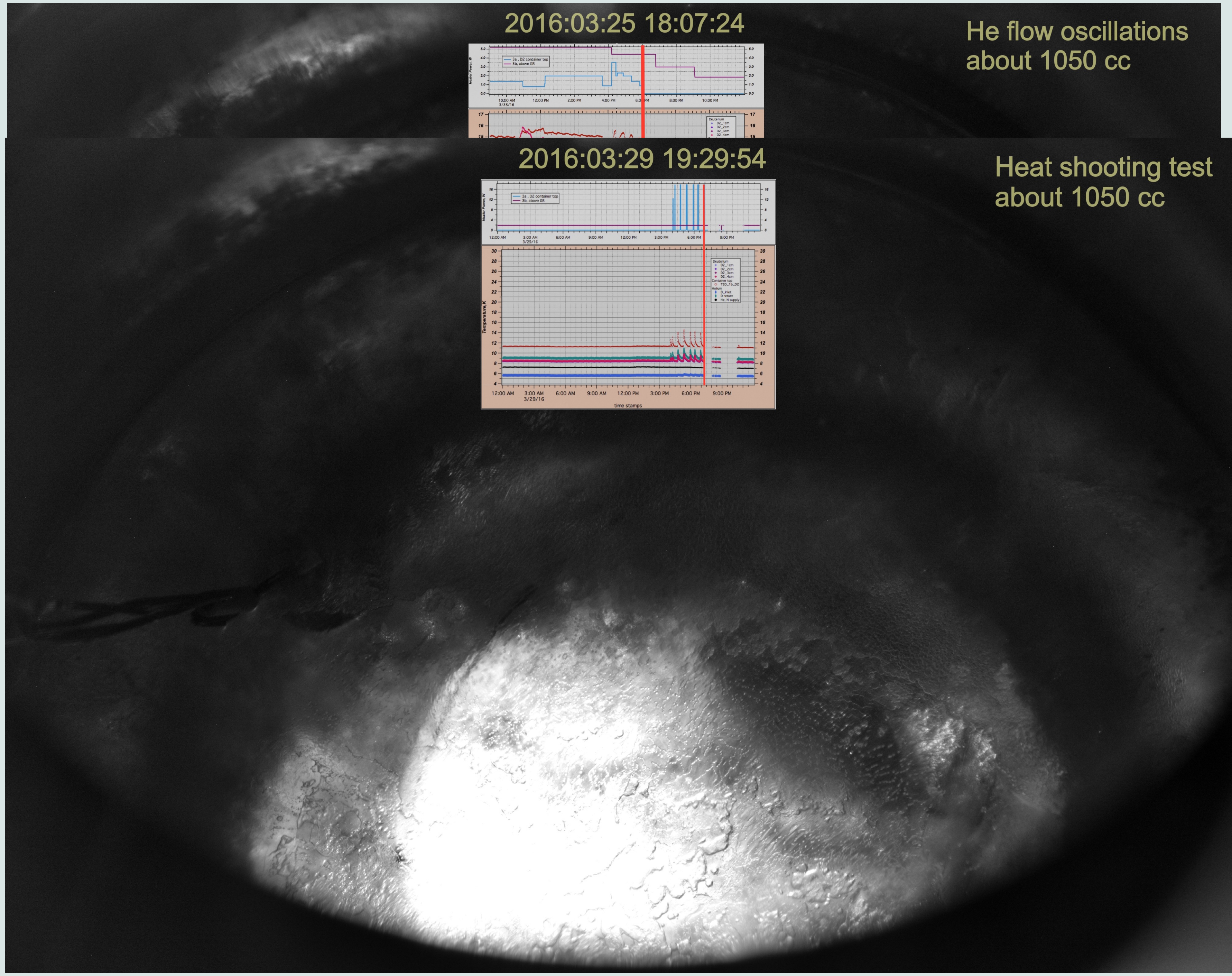

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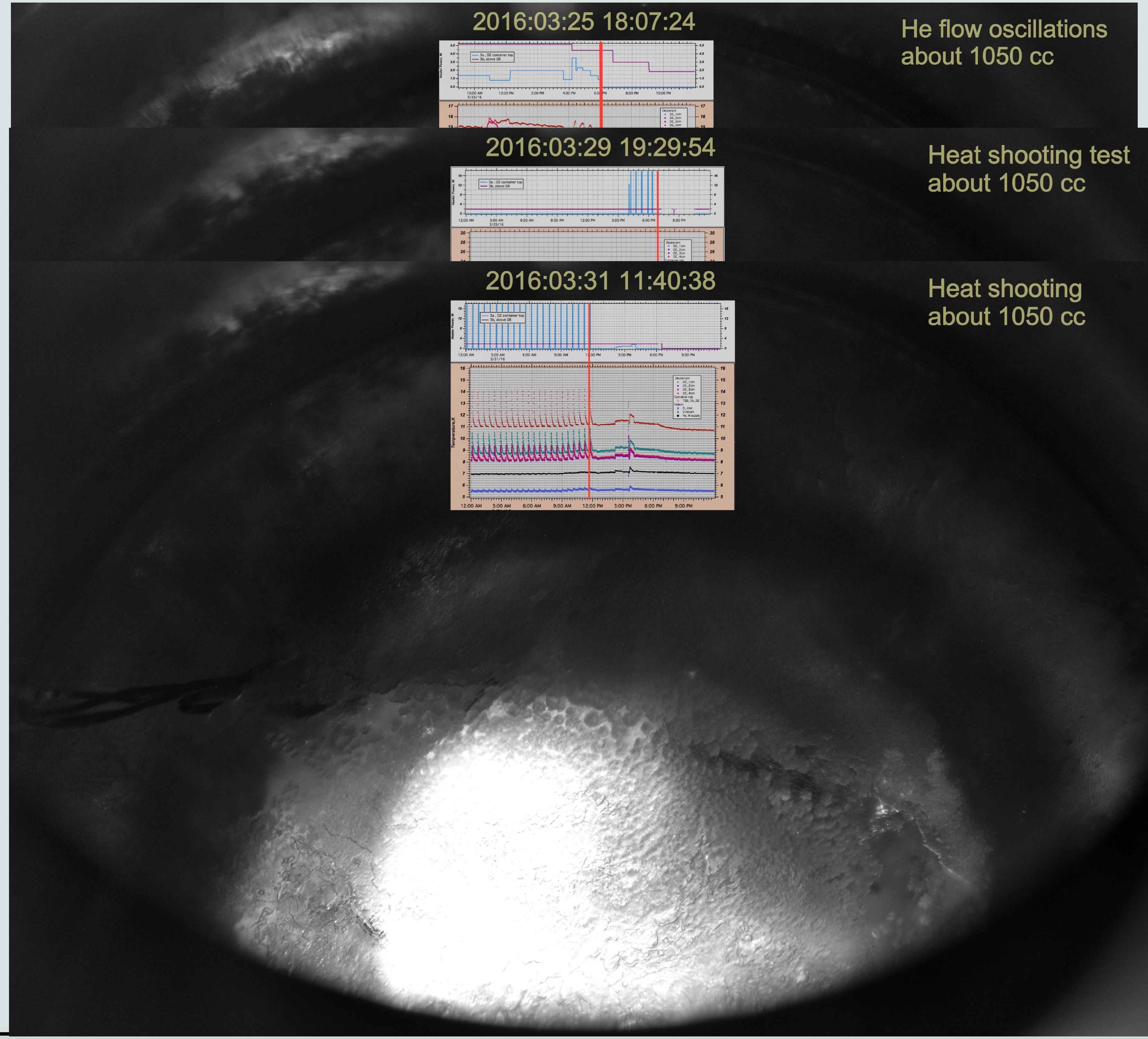

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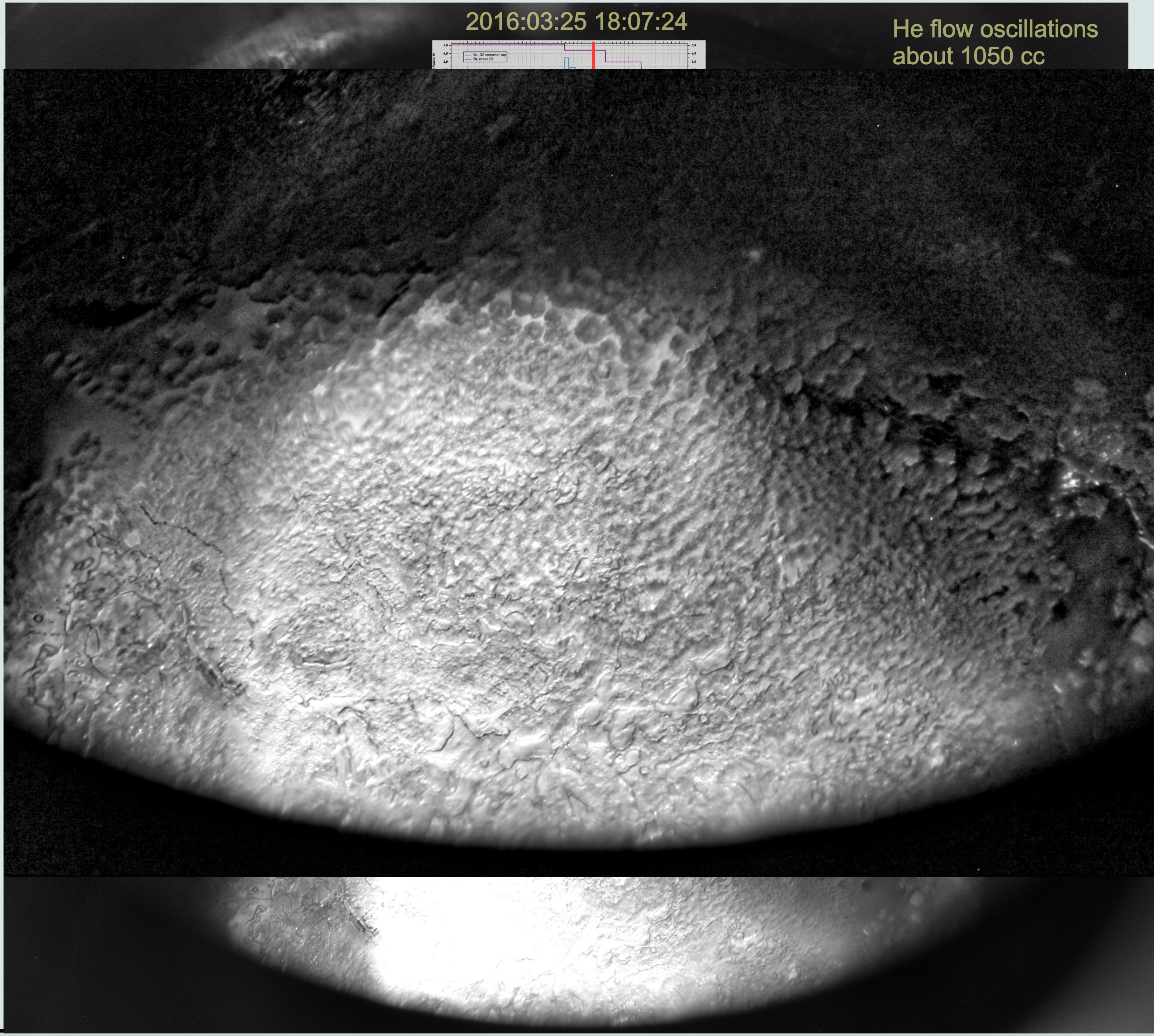

April 11-13 condensation

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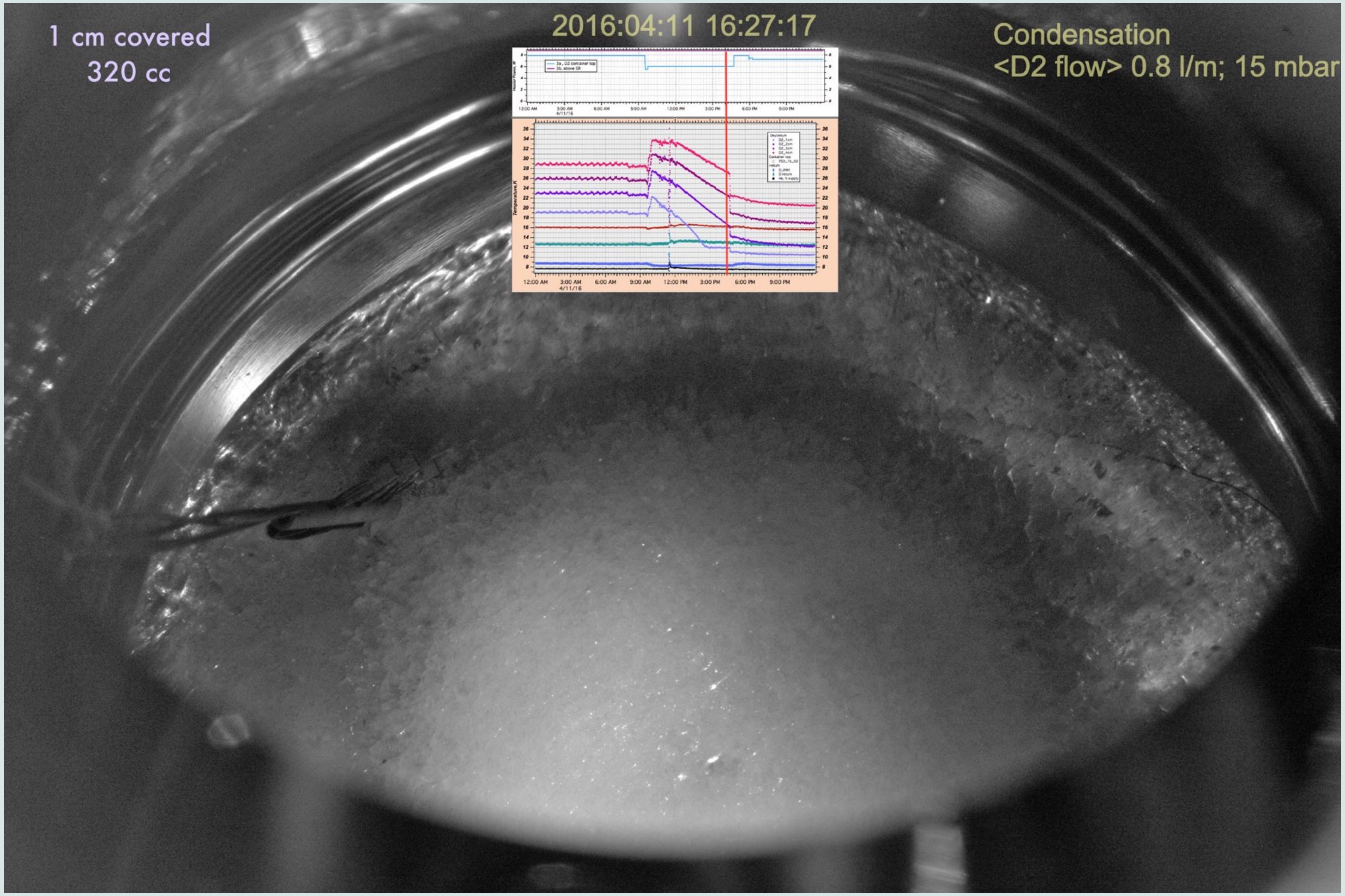
- attempt to reproduce Mar 15 condensation from scratch, unsuccessful, because D-return was nor taken into account and container was too cold
- very interesting run for discussion of crystal properties vs T and crystal shapes



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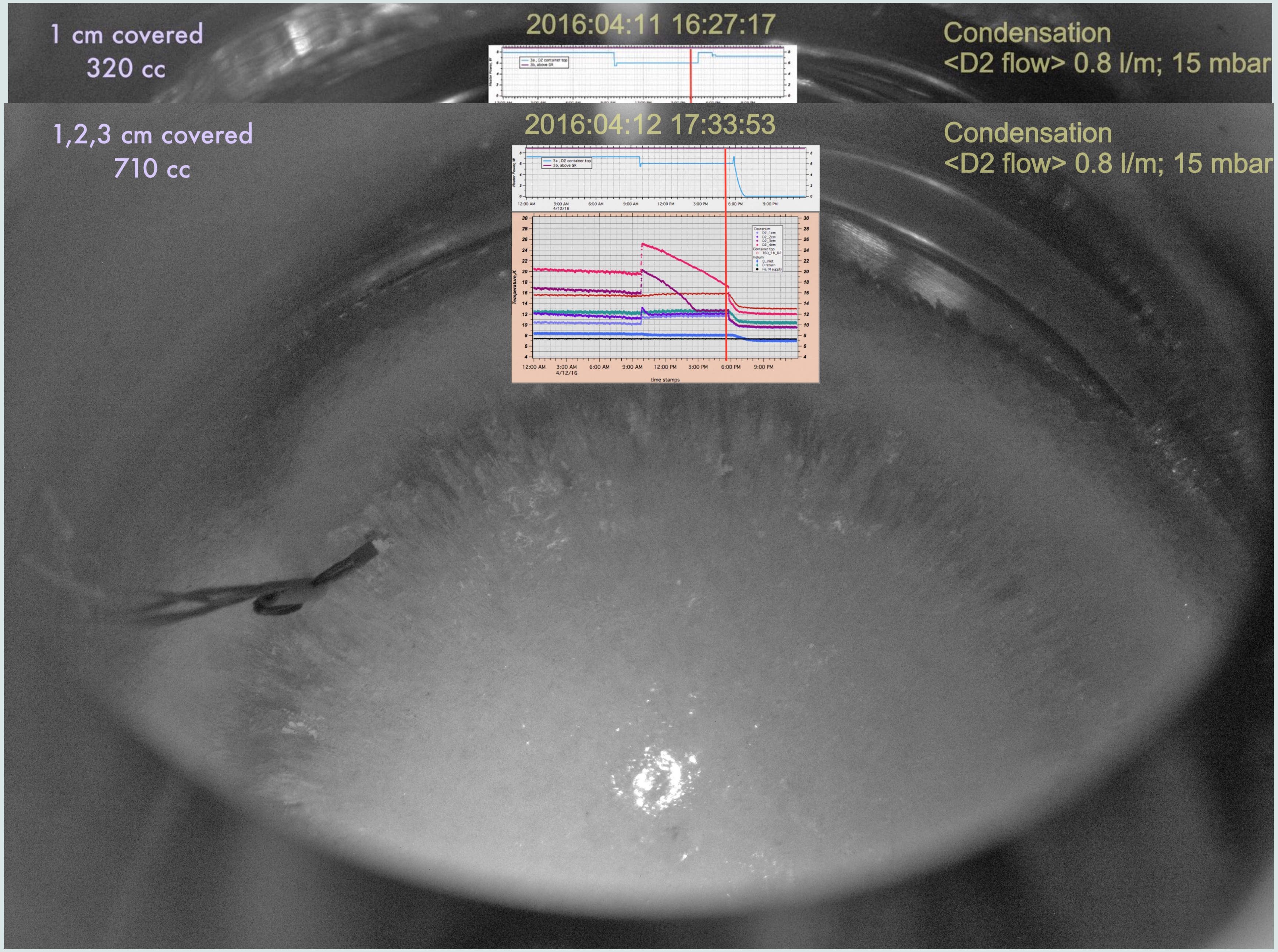

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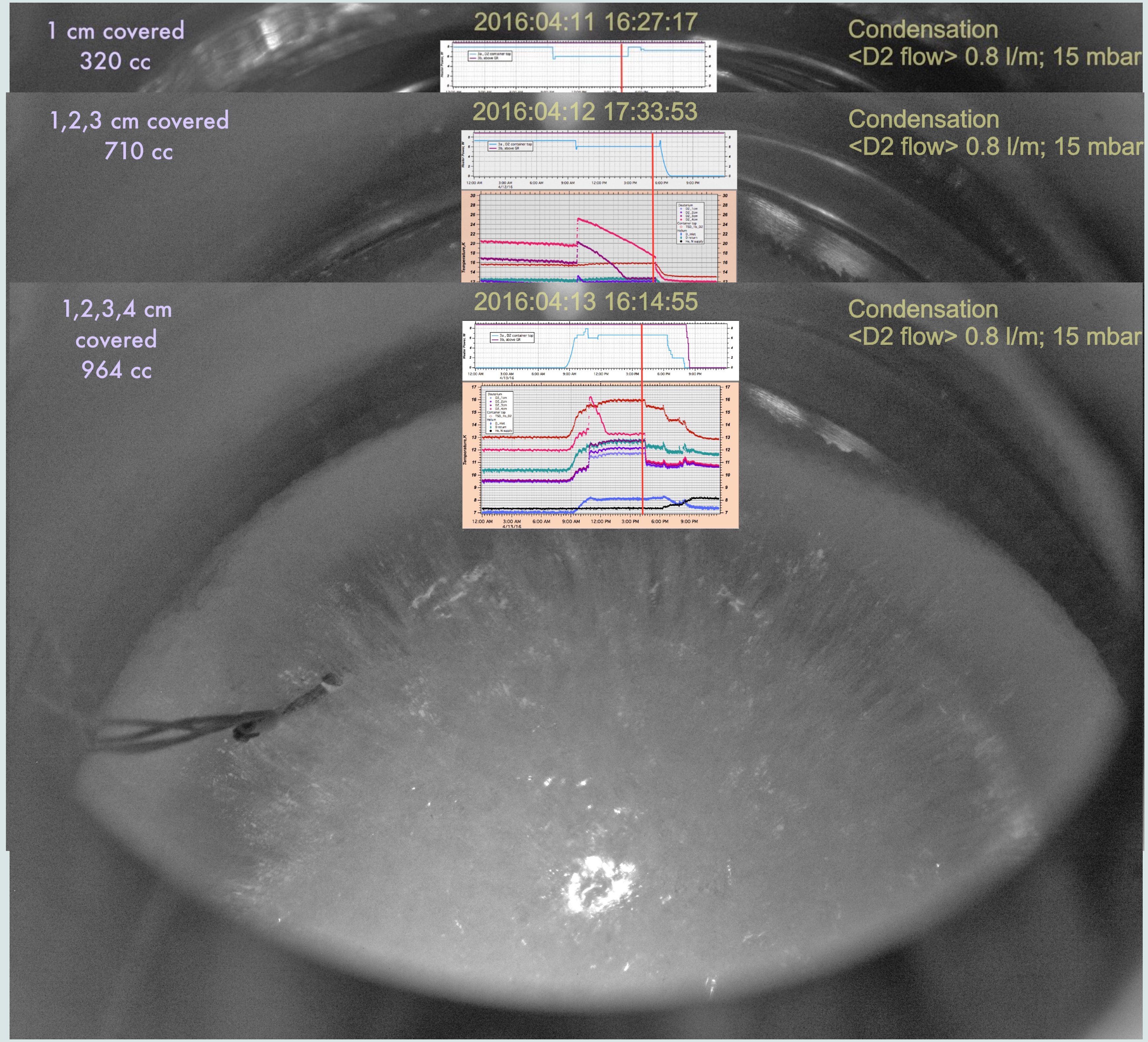
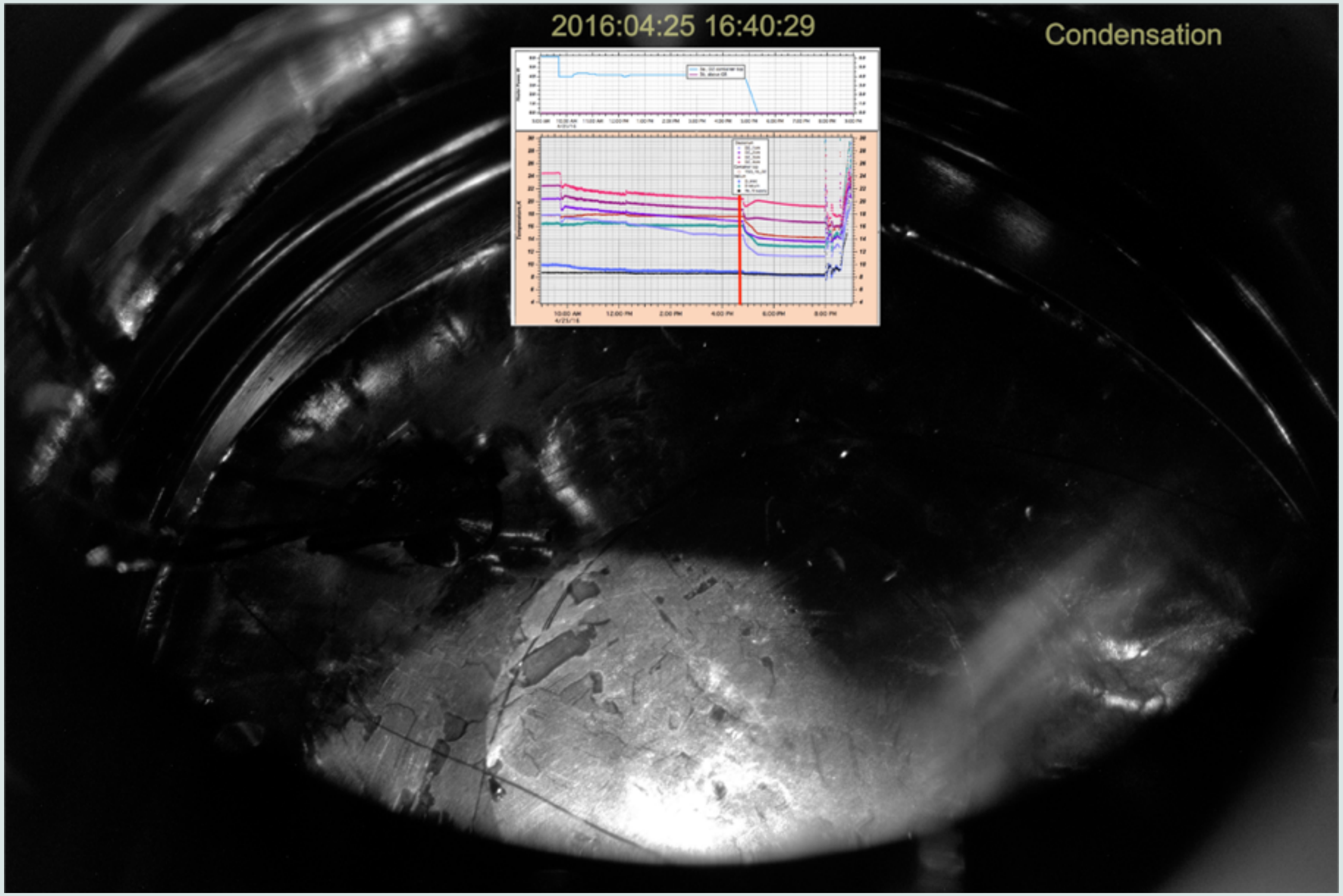


Lessons learned: April 25 condensation

- April 25 condensation, 10-9/18/ 16.2 , 0.8 l/m
- attempt to reproduce Mar 15 condensation from scratch, quite successful.



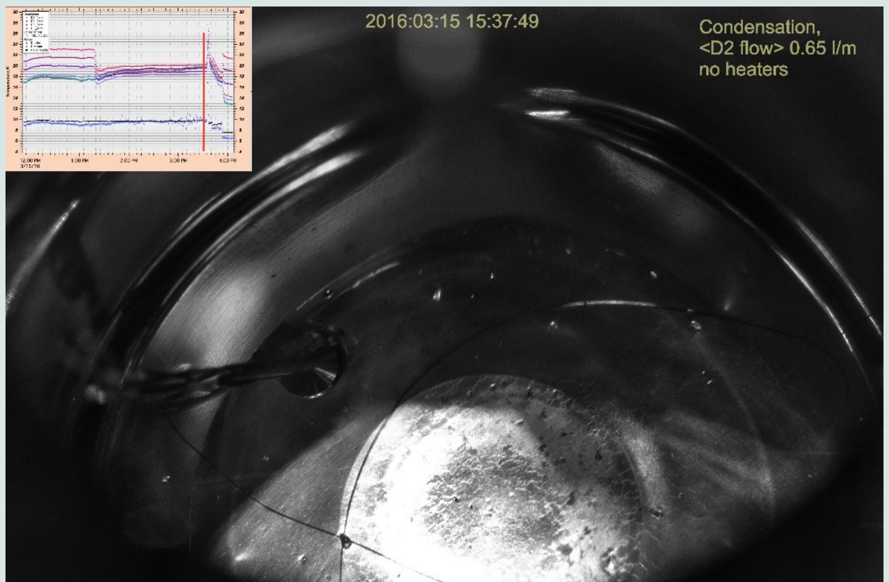
Discussion

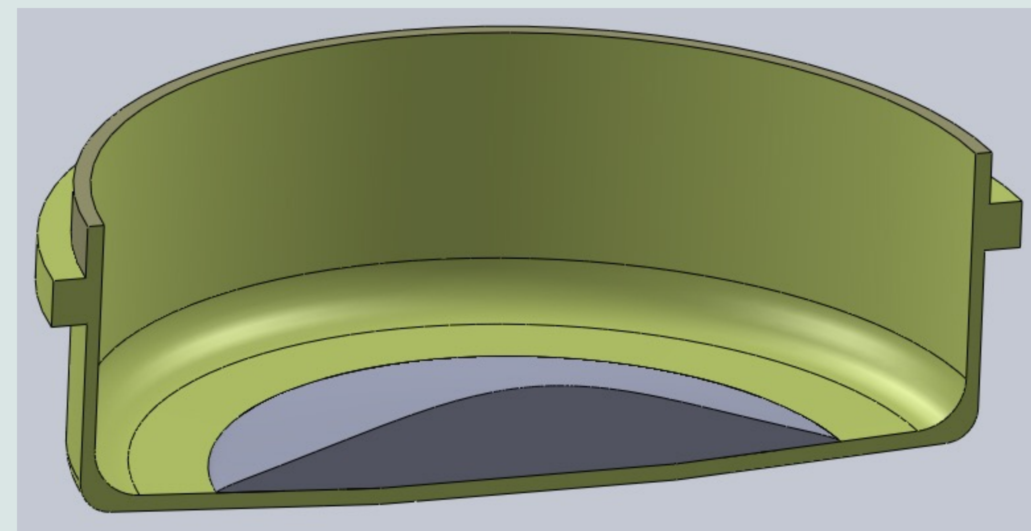
Temperature dependence of Crystal shapes and transparency

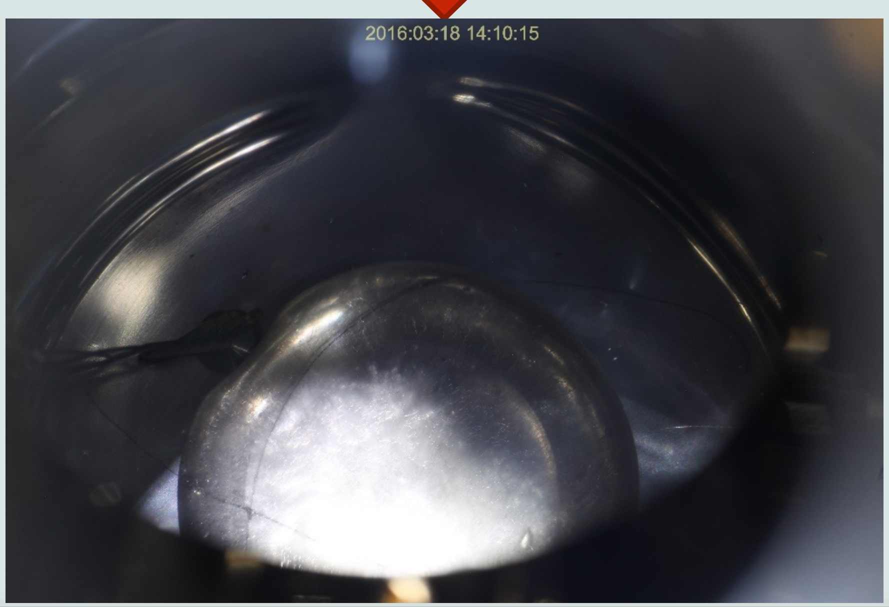
- The main question we want to answer to is what is temperature dependence of the crystal quality?
- We can not measure temperature distribution of the inner wall of SD2 container
- It possible to simulate it using our measured temperatures and reconstructed SD2 shapes

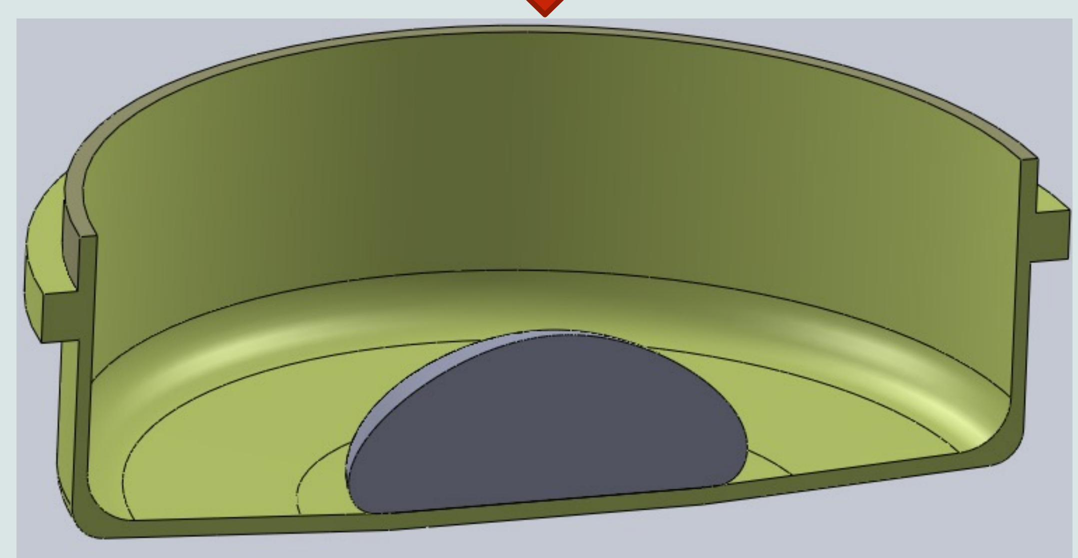
Shape reconstruction

Mar 15, Annealed overnight at 12K. High mobility



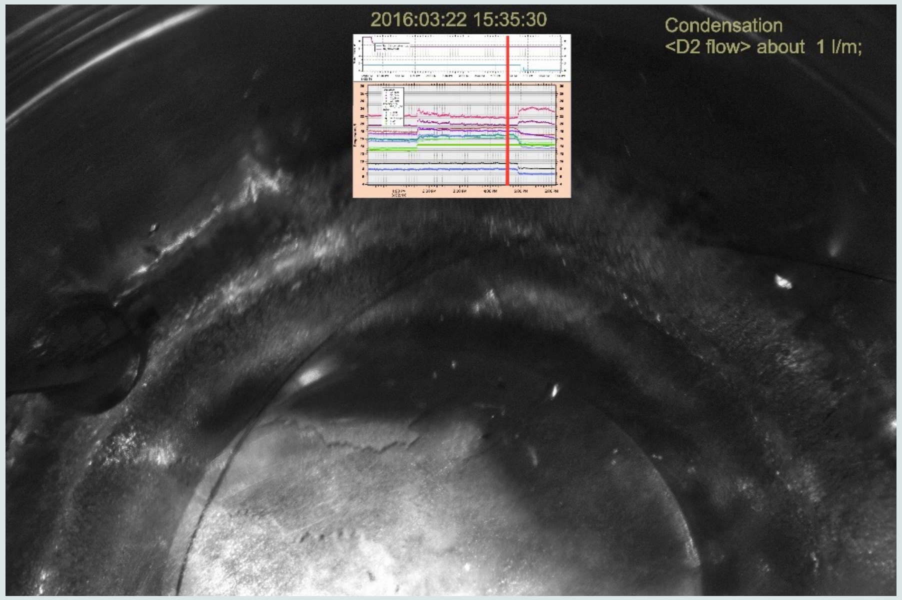


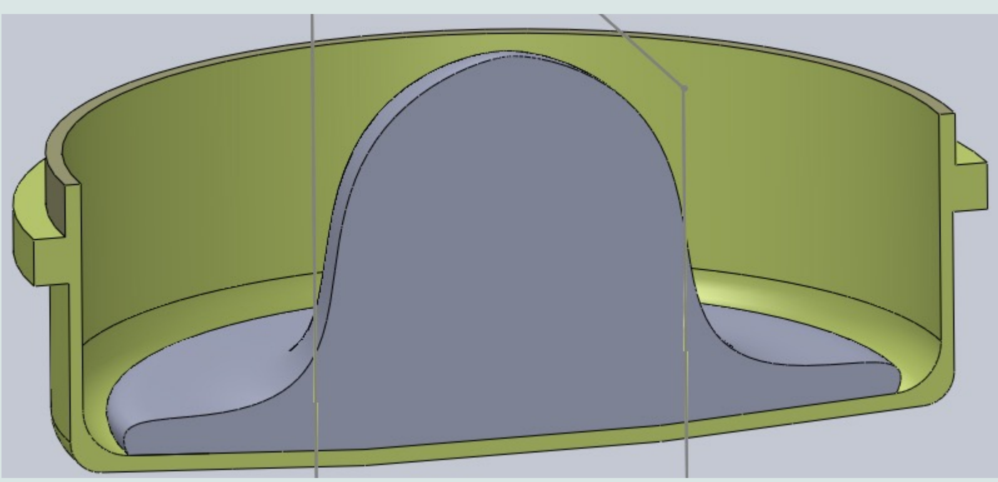




Shape reconstruction (about 350cc)

March 22





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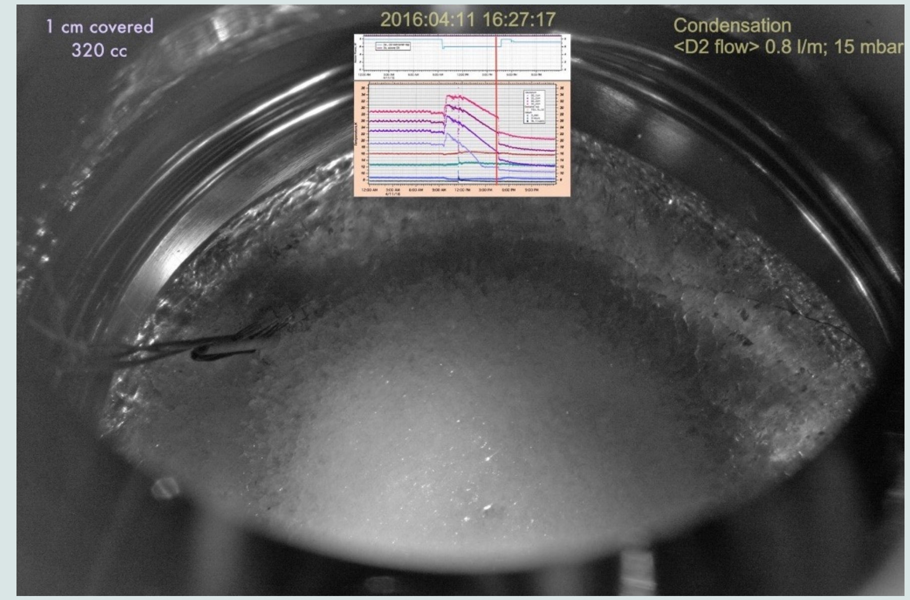
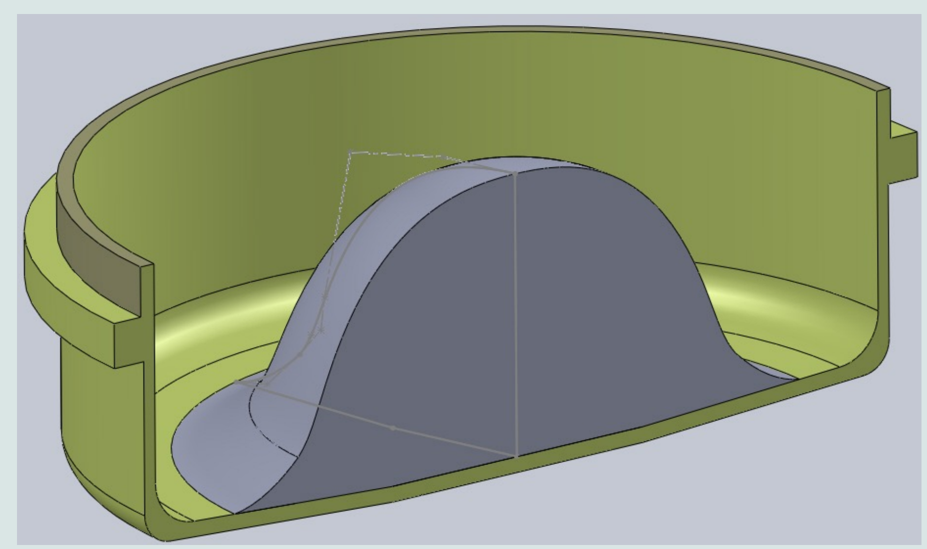
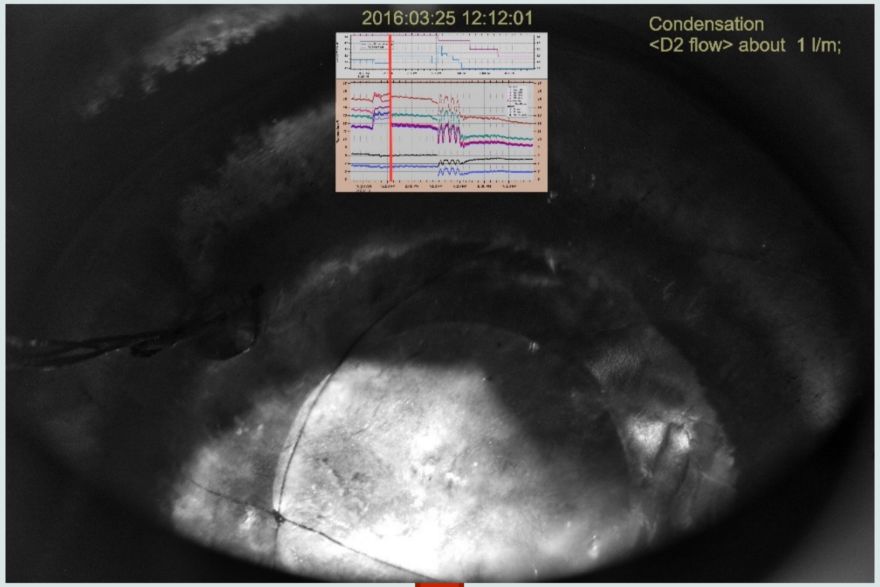
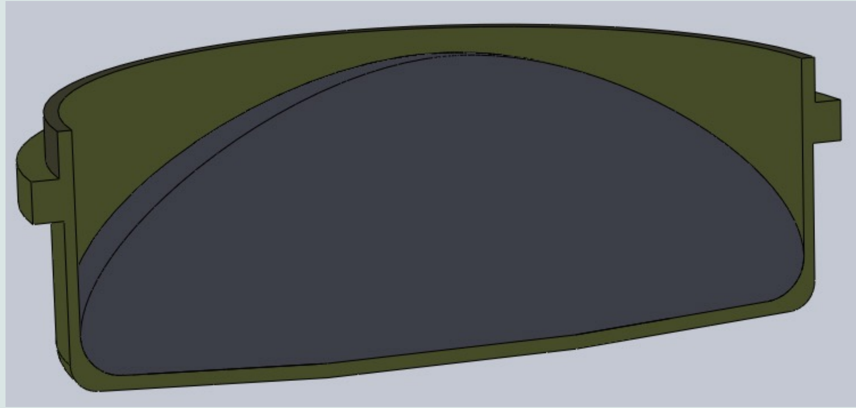




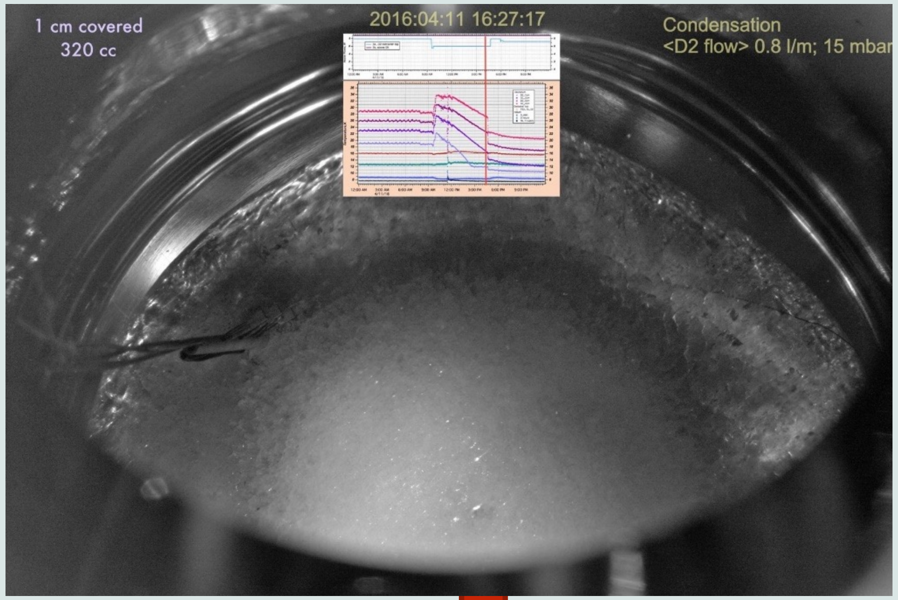
Shape reconstruction (1050cc vs 964cc)

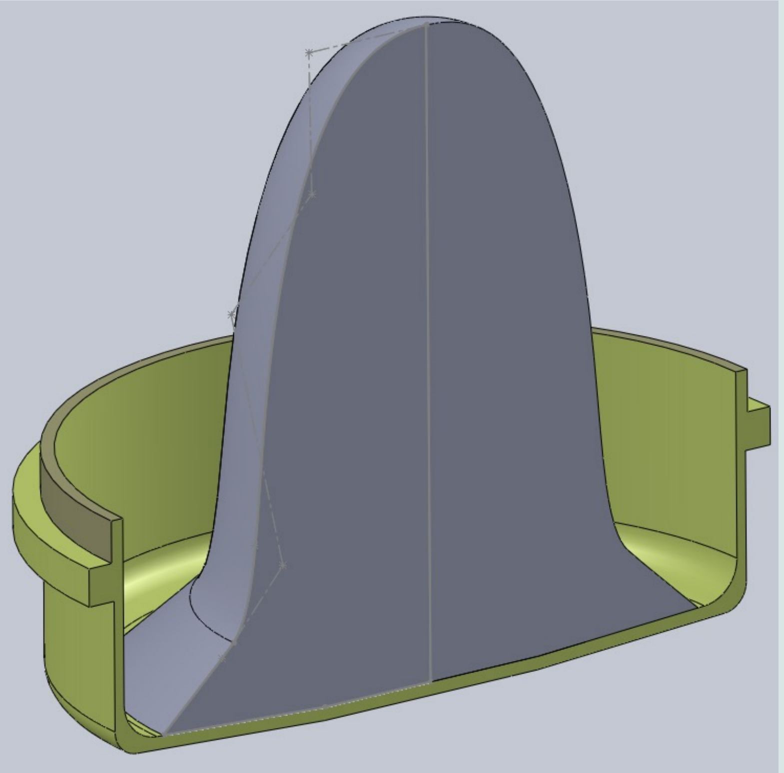
March 25





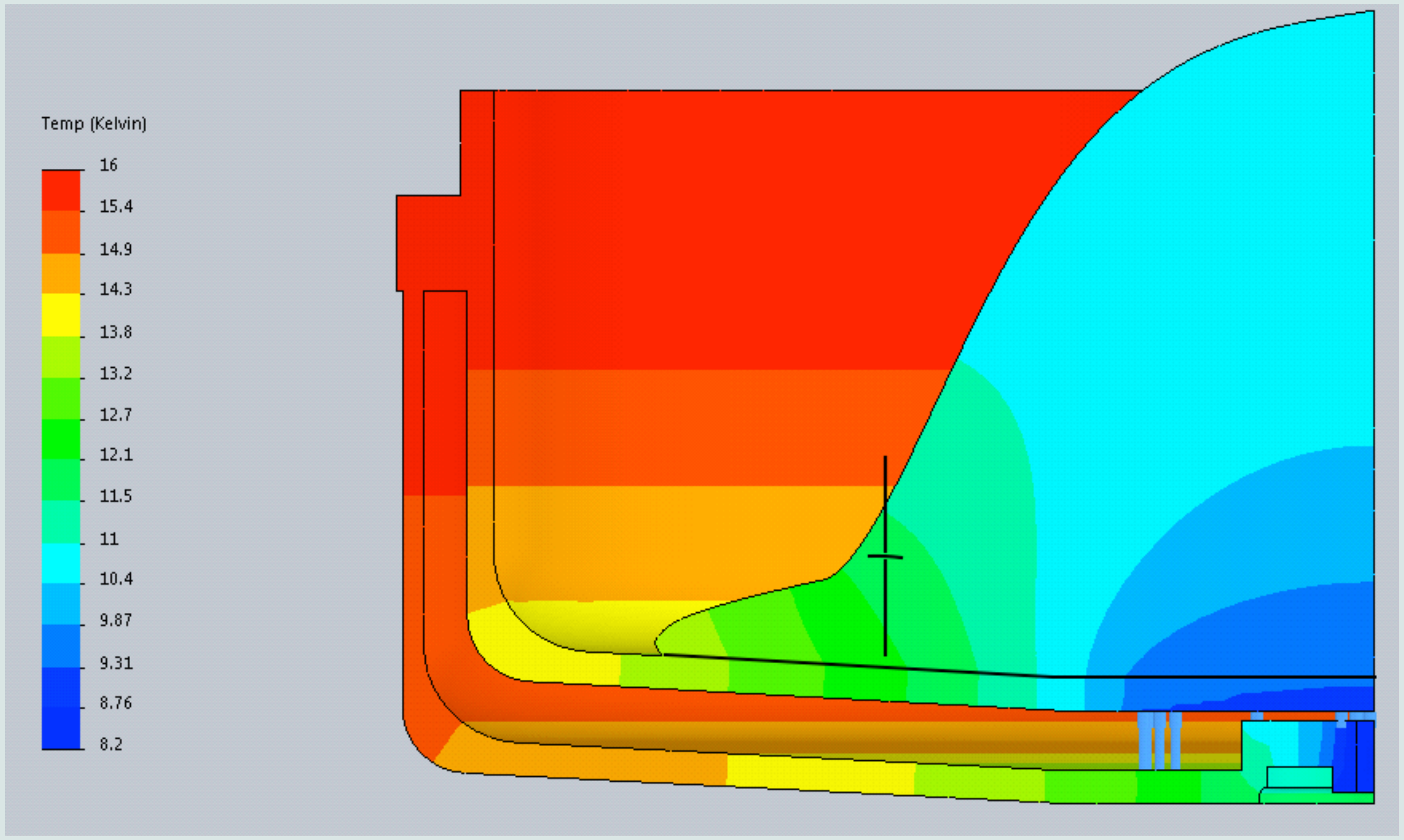
April 13





April 11 simulation, D2 flow on and off

- 1cm temperature can be reproduced only when assuming that bottom circle is at 9.3K
- Transparent region start from above 12K



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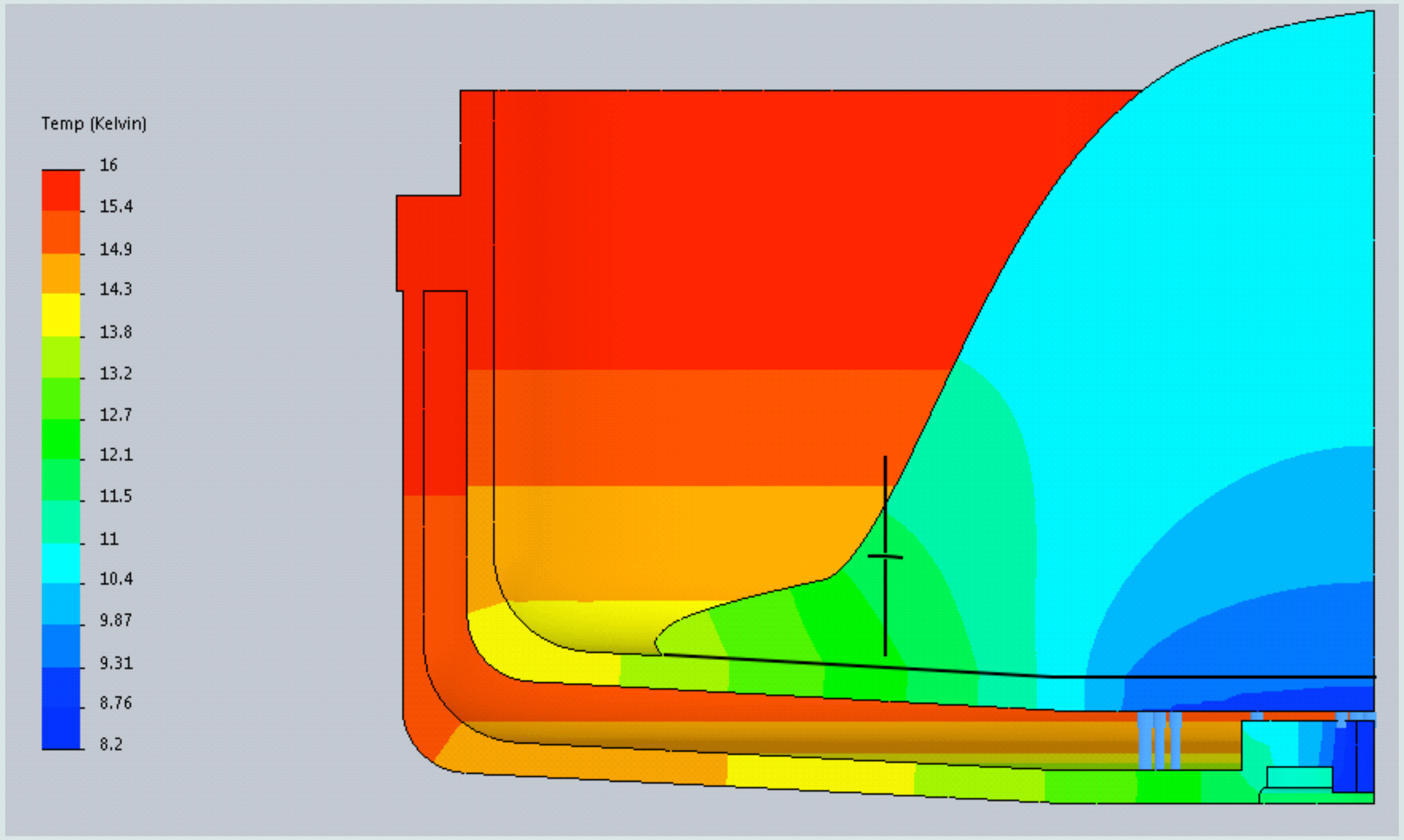
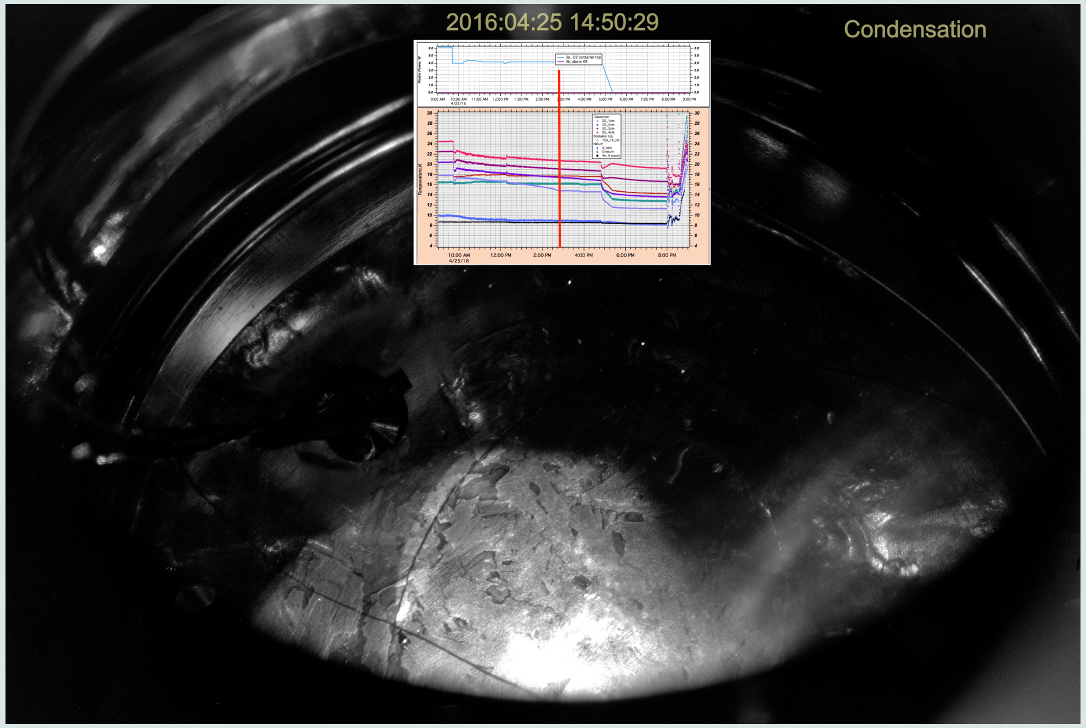
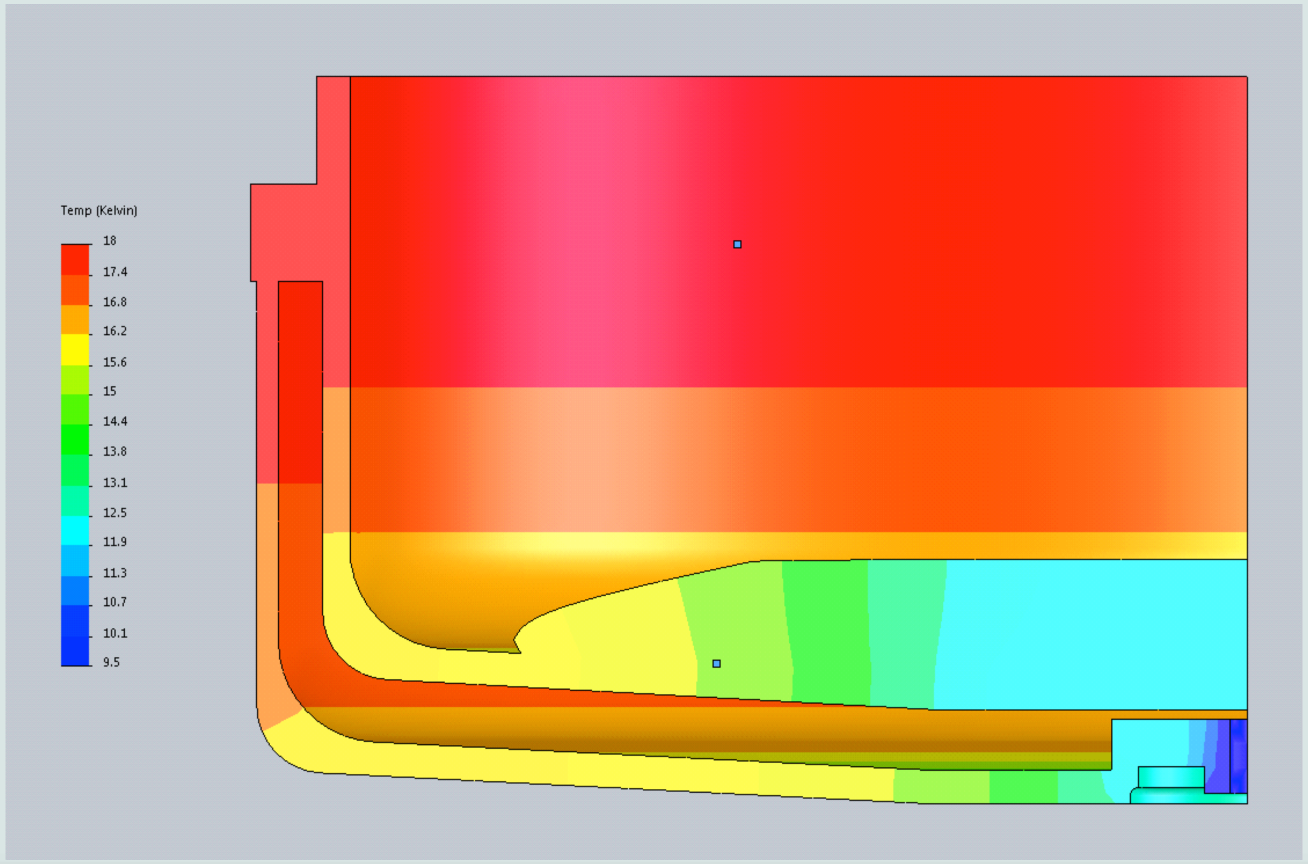


- **Conclusion:** From SD2 NMR studies it is known that below 10K there is no vacancy diffusion, so this is where crystal preferably grows in presence of warmer region

April 25, 9.5/ 18/ 16.2,1cm=14.5K, about 340cc total

- 1cm temperature can be reproduced only when assuming that bottom circle is at 12K
- **Conclusion:** to grow transparent crystal, cryostat walls needs to be above 12K

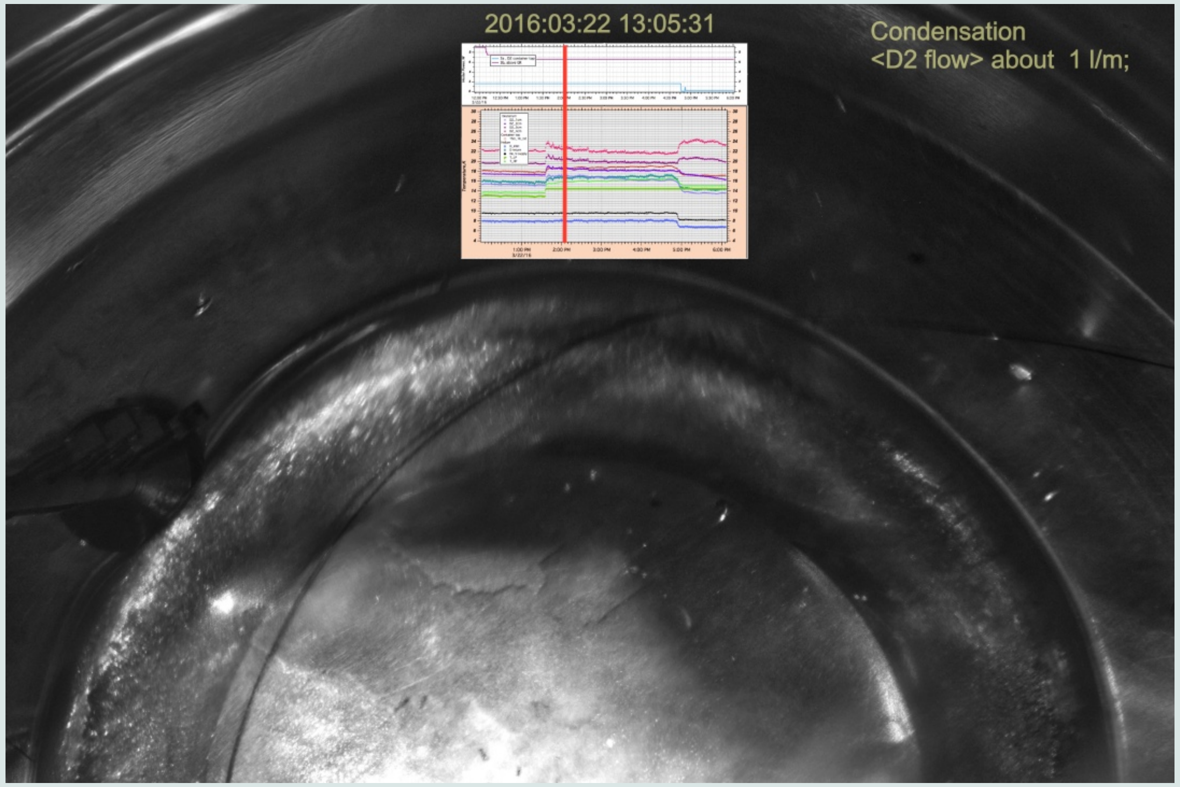


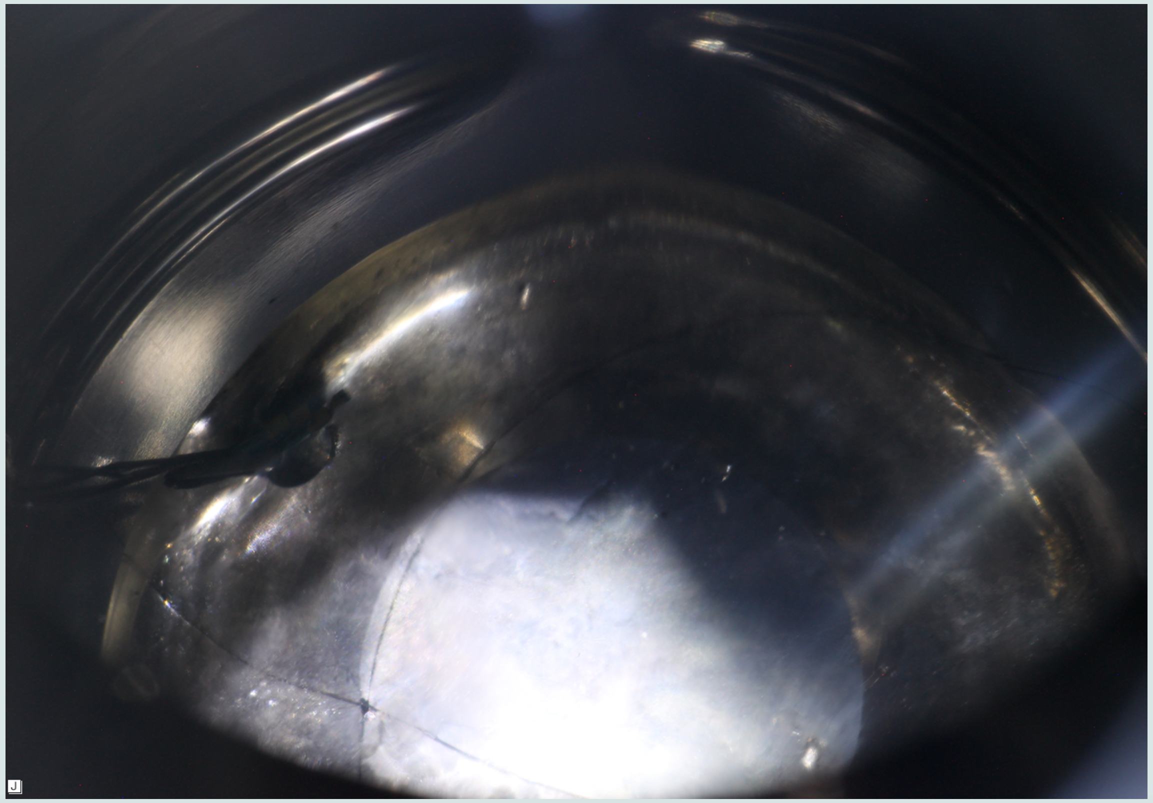


Mar 22 condensation, 1cm=16K; 7.75/ 17/ 18.5-19K; from simulations bottom centre =14K;

- 1cm temperature can be reproduced only when assuming that bottom circle is at least 14K

- **Conclusion:** to grow really good transparent crystal, cryostat walls needs to be above 14K





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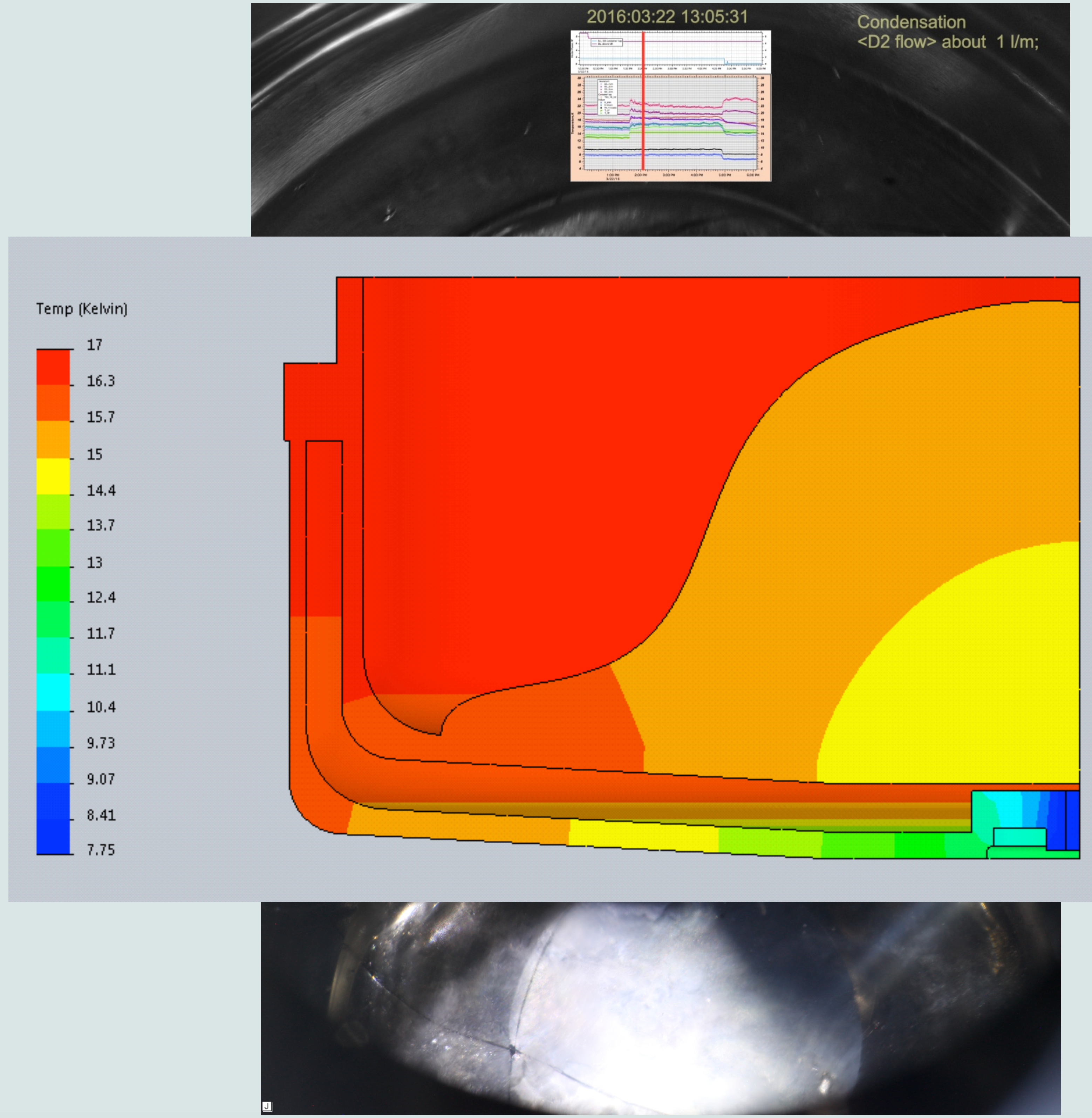

Conclusions

- Both, transparency and shape of the crystal are very temperature dependent
- Not only condensation, but crystal evolution with time needs to be tested in real conditions.
- Strong gradients and temperature oscillations should be avoided
- UCN transport can be affected by different crystal shape and needs to be evaluated

Outlook

- 2017 :
  - another round of SD2 growth
  - install temporary shield
  - assemble cryostat and external neutron guide on the bio-shield
- 2018 :
  - first tests with neutrons on small reactor power

Our team

A. Young, P. Huffman, R. Golub, A. Hawari

Graham Medlin

Grant Palmquist

A. Cook and reactor staff

our new members: Kent Leung and Christian White (author of shape reconstruction slides)