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On The Performance of Cryogenic Cooling Systems for Optical Elements at Sirius/LNLS

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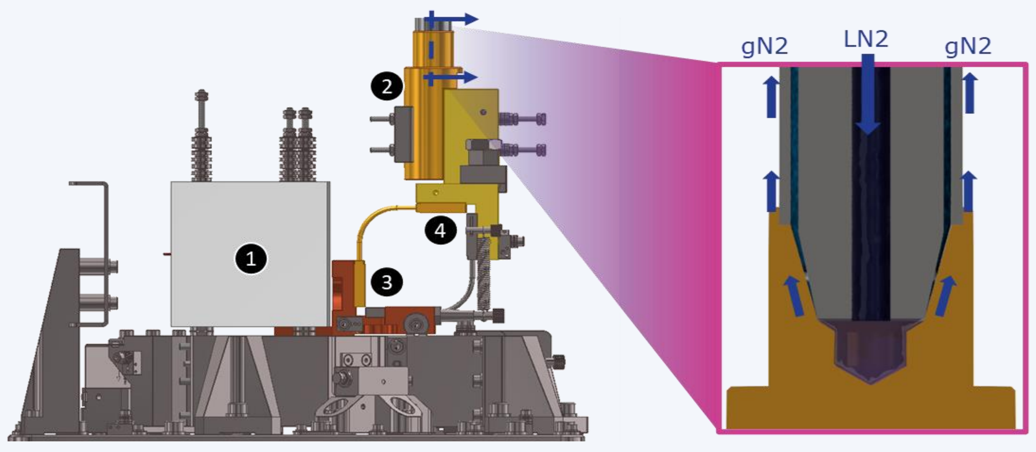
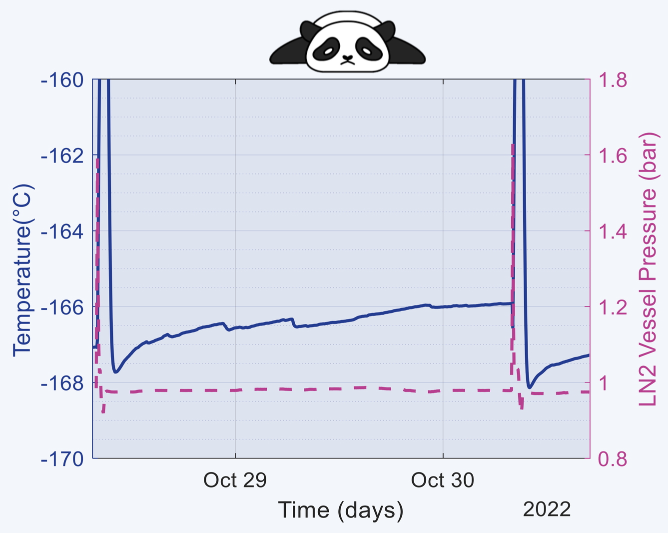
Abstract

Several Sirius' beamlines employ cryogenic cooling optics to take advantage of the Silicon properties at low temperatures. A series of enhancements has been evaluated based on our early operational experience focusing on the prevention of instabilities in the temperature of the optics. This work discusses the performance of the systems after optimizing the pressure of the vessels and their control logics, the effectiveness of occasional purges, cool down techniques, and presents the monitoring interface. Furthermore, we introduce solutions (commercial and in-house) for achieving better beam stability, featuring active control of liquid nitrogen flow. We also propose the approach for the future 350 mA operation, including different cooling mechanisms.

Motivation

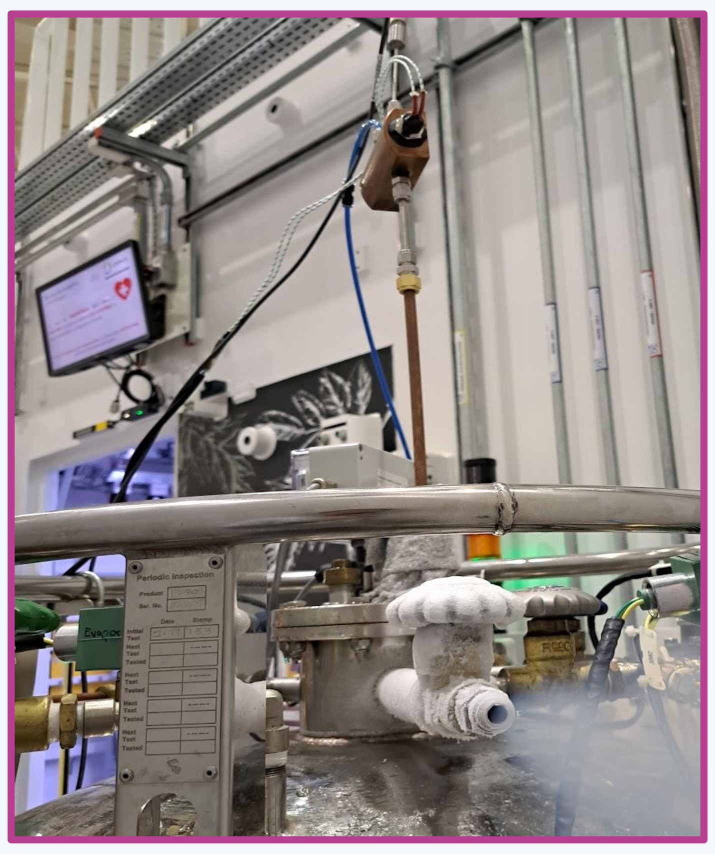


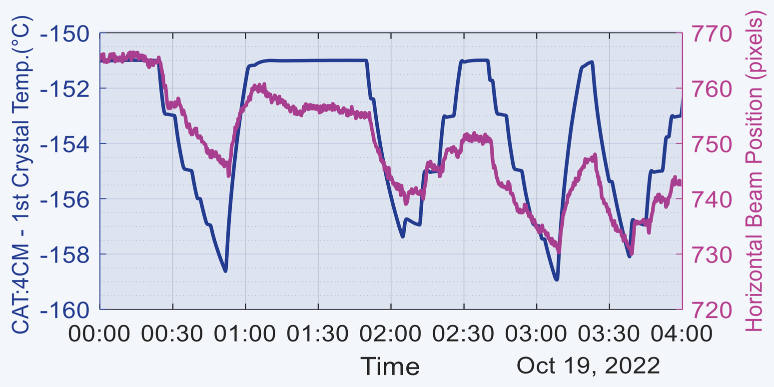
The second mirror of CATERETE beamline is thermally connected to a cryostat by a copper braid (3-4).



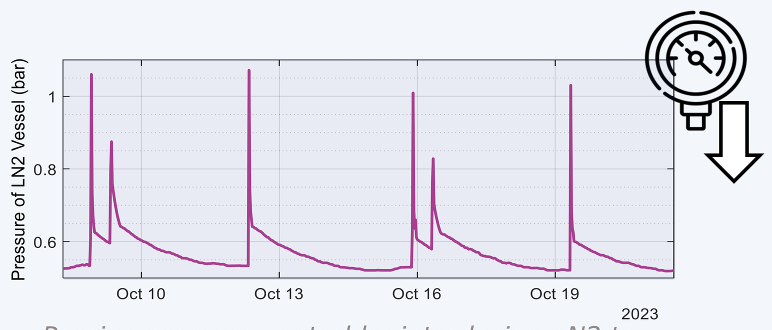
Temperature at the end of a copper braid between first mirror and cold finger at CARNAÚBA beamline presenting drifts.

Open-cycle cryostats operating 24/7 at CARNAUBA and CATERETE beamlines are susceptible to temperature instabilities due to LN2 supply variations, directly affecting the X-Ray beam quality. Active LN2 vessel pressure control, in addition to causing mechanical disturbances, proved incapable of resolving this issue. Therefore, several actions were taken to address it:


Hot gN2 purging process.



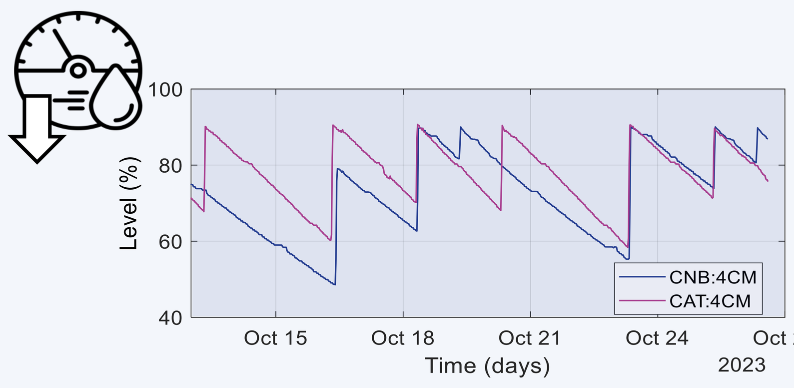
Beam position is directly related to the incident heat load on some optical surfaces. So, top-up operation also contributes significantly to beam stability.



Passive pressure control by introducing gN2 to a vent valve.

Improvements

A pre-cooldown purging standard procedure was implemented, pressure control became passive and was configured to lower values, the maximum level of the liquid nitrogen tank was restricted, and flow control modes were tested. Email notifications are triggered in case of timeouts or system faults for faster issue response. All data is archived in EPICS, and a centralized system enables swift monitoring of levels, pressures, and alerts



The maximum level of the LN2 vessels is limited to 90% to prevent ice formation near the needle valve.

Conclusion

This study focused on the actions taken to improve the performance of open-circuit cryogenically cooled systems at Sirius/LNLS, addressing temperature drifts, pressure variations, and temperature spikes during refilling. We implemented automatic flow control, enhancing system stability. The use of a Phase Separator was explored, but further investigation is needed. Now, even looking ahead to 350 mA operation, non-cryogenic solutions like Peltiers have been contemplated as viable options for some mirrors. In the other hand, motorizing transfer lines emerge as a promising solution for the optical instruments that will remain cryogenic.

Acknowledgements

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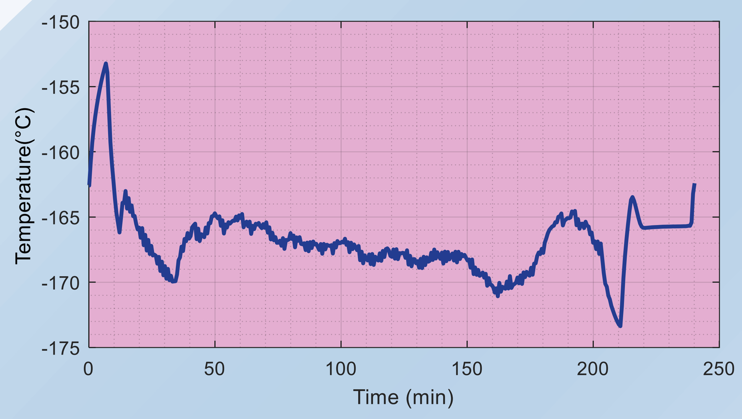
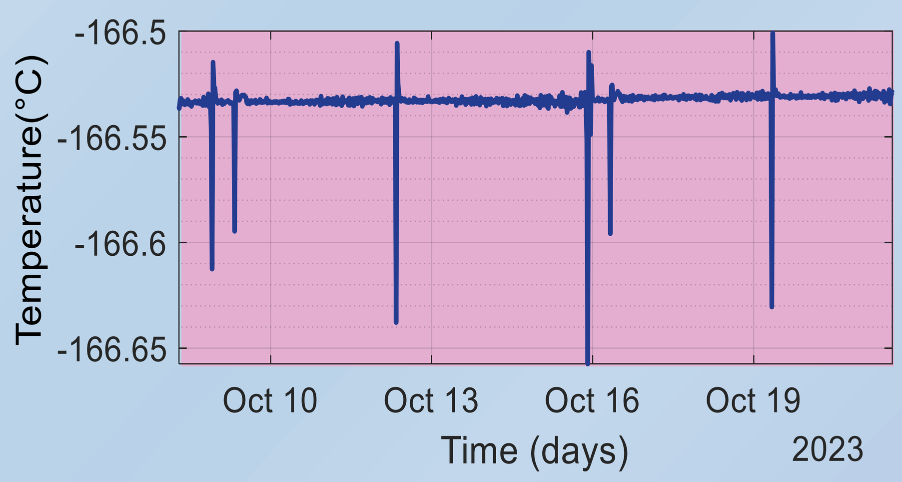
Phase Separator



Significant fluctuations also observed when cooling by gravity


Phase Separator.

Commercial Bayonet

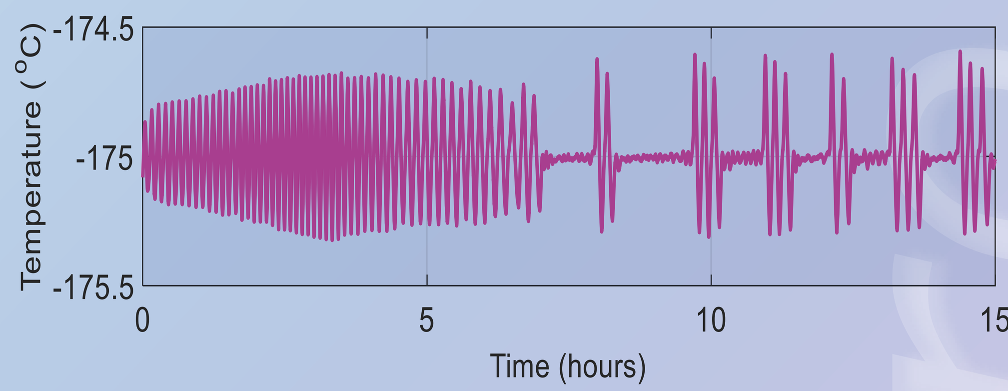


Constant temperature achieved by LN2 flow control valve.

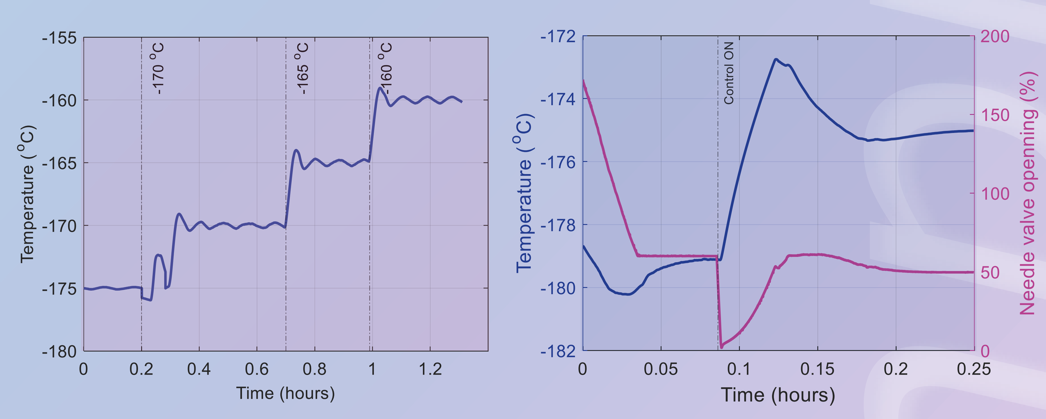

Commercial bayonet.

It was observed that a phase separator did not effectively resolve the temperature instabilities; however, the implementation of an automatic flow control system provided a solution. Then, a local prototype was developed for the existing transfer lines. The mechanics were validated, and preliminary tests shown it was able to keep the temperature controlled. The next steps are PID tuning and enhancement of the homing procedure.

In-House Actuator




Motorization of standard transfer-line.



Initial tests demonstrated sustained stability over hours, setpoint adjustment capacity, and the moment when the first setpoint adjustment occurs following cooldown.