Ultra-stable cooling system: very promising results

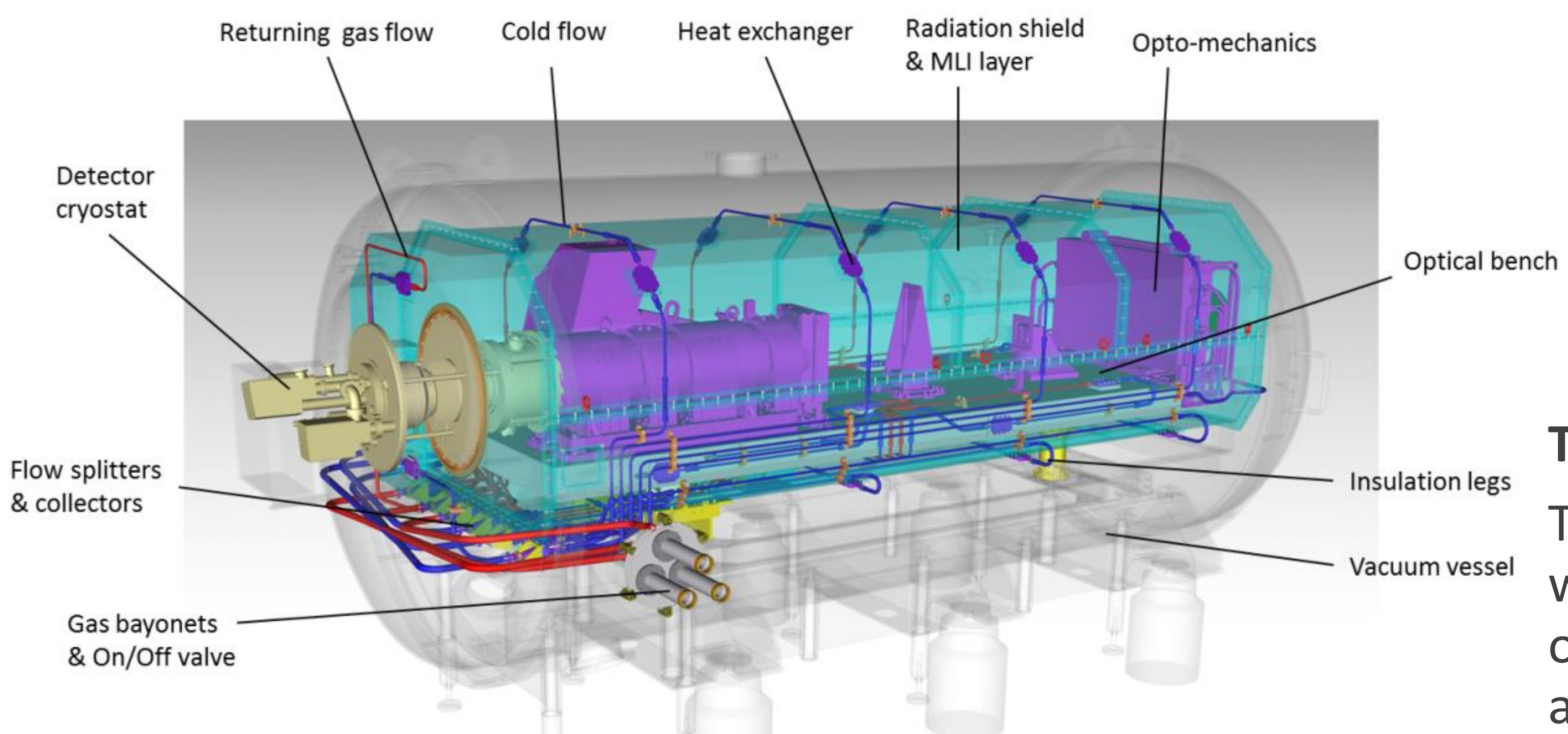
E. Mirabet[1] (emirabet@iaa.es), P. Carvas[2], J.-L. Lizon[2], S. Becerril[1], E. Rodríguez[1], M. Abril[1], M. C. Cárdenas[1], R. Morales[1], D. Pérez[1], M. A. Sánchez-Carrasco[1], P. J. Amado[1], W. Seifert[3], A. Quirrenbach[3], J. A. Caballero[4], I. Ribas[5], A. Reiners[6], S. Dreizler[6] and the CARMENES Consortium[1,3,4,5,6,7,8,9,10,11,12]

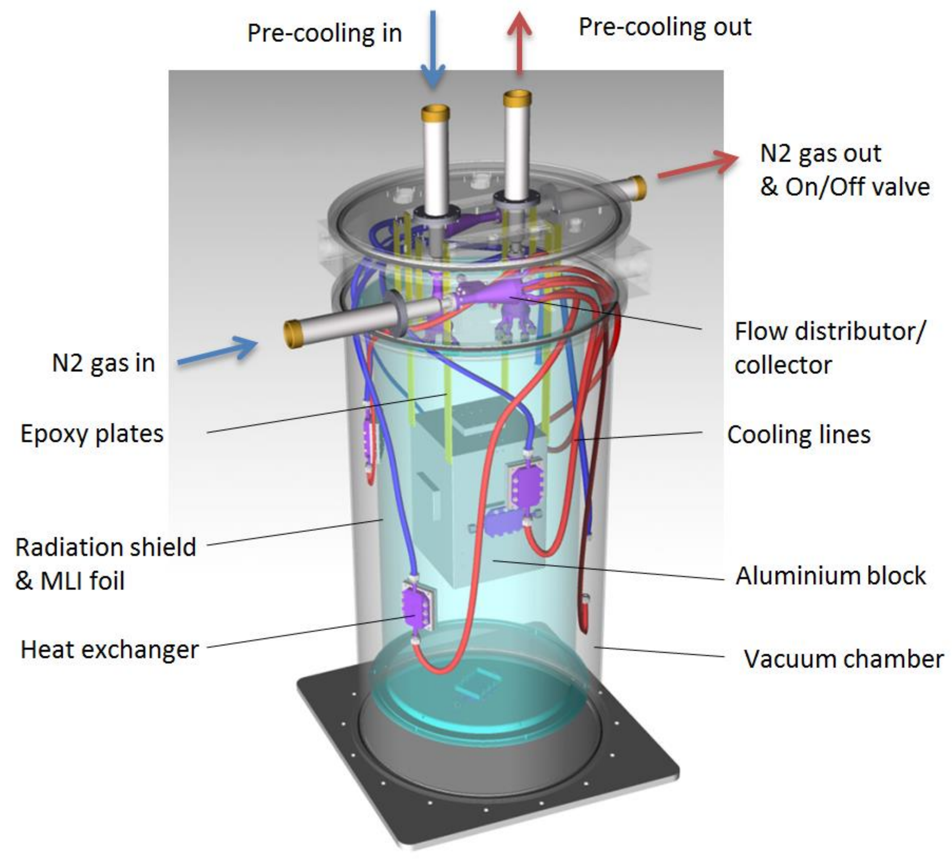
[1]Instituto de Astrofísica de Andalucía (CSIC) · [3]Landessternwarte Königstuhl · [4]Centro de Astrobiología · [5]Institut de Ciències de l'Espai · [6]Institut für Astrophysik Göttingen · [7]Max-Planck-Institut für Astronomie · [8]Instituto de Astrofísica de Canarias · [9]Thüringer Landessternwarte Tautenburg · [10]Universidad Complutense de Madrid · [11]Hamburger Sternwarte · [12]Centro Astronómico Hispano-Alemán – Calar Alto Observatory · [2]European Southern Observatory

The CARMENES NIR channel has an ultra-high stable working temperature requirement of 140K with a 24 hour stability of ±0.1K, goal ±0.01K. Its optical bench is enclosed within a radiation shield actively cooled with nitrogen gas to remove the radiative heat load. An external preparation unit (N2GPU) is responsible for providing thermally stabilized nitrogen gas at a wide temperature range. A test facility has been built to simulate the instrument and enable a full characterization of the N2GPU and the cooling system. The present paper shows the very promising high thermal stability cooling test results and the hardware used.

CARMENES - NIR channel requirements and design

Working temperature of 140K±2 K · Temperature stability of ±0.07 K (±0.01 K goal) in the timescale of 1 day · Pre-cooling time of 48 h (goal) · Cool-down and warm-up rate for the optics <10 K/h · Liquid nitrogen consumption <150 l/day · Environment temperature 285±0.5 K · Vacuum level ~10^{-6} mbar.





Test facility to simulate the CARMENES NIR channel

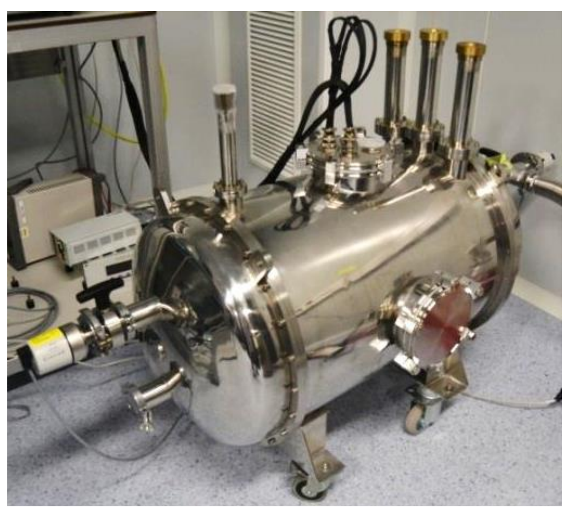
This uses the same hardware: heat exchangers attached to the radiation shield, wrapped with multi-layer insulation, and to the 34 kg aluminium block, which represents the optical bench, flow distributors/collectors, inlet/outlet gas bayonets, epoxy-fiberglass and everything enclosed into a vacuum chamber. It has two independent cooling lines: the pre-cooling of the aluminium block and the active cooling of the radiation shield during the steady state controlled with a cryogenic on/off valve at the end of the circuit.

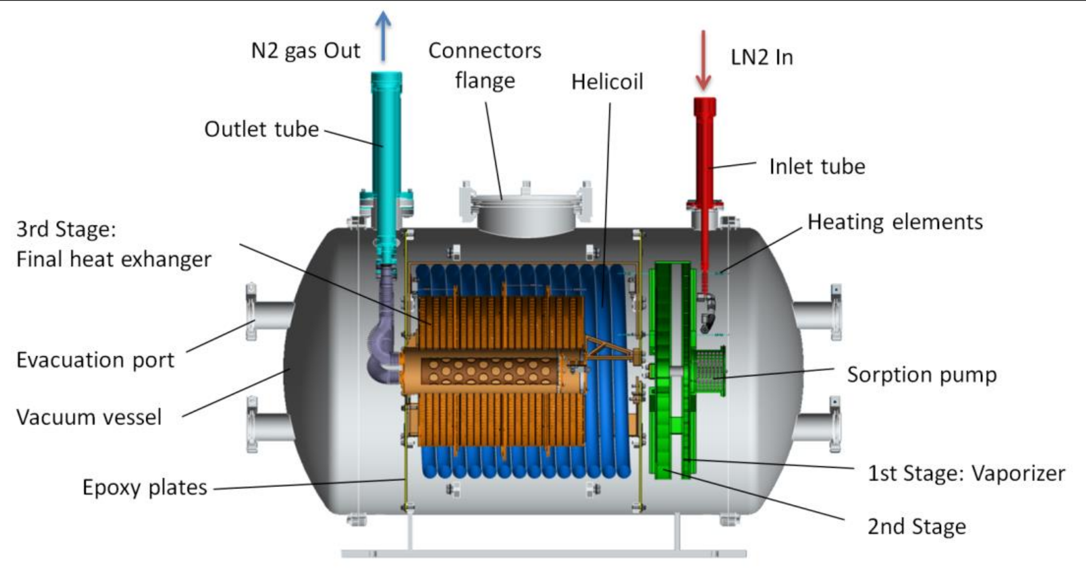
Nitrogen Gas Preparation Unit - N2GPU

A three stage gas production unit fed with LN2: 1st stage: LN2 gasification, 2nd and 3rd stages: gas thermal stabilization · Each stage is controlled by a three-term controller (PID) wit a 240W power supplier to warm up the gas using heaters.

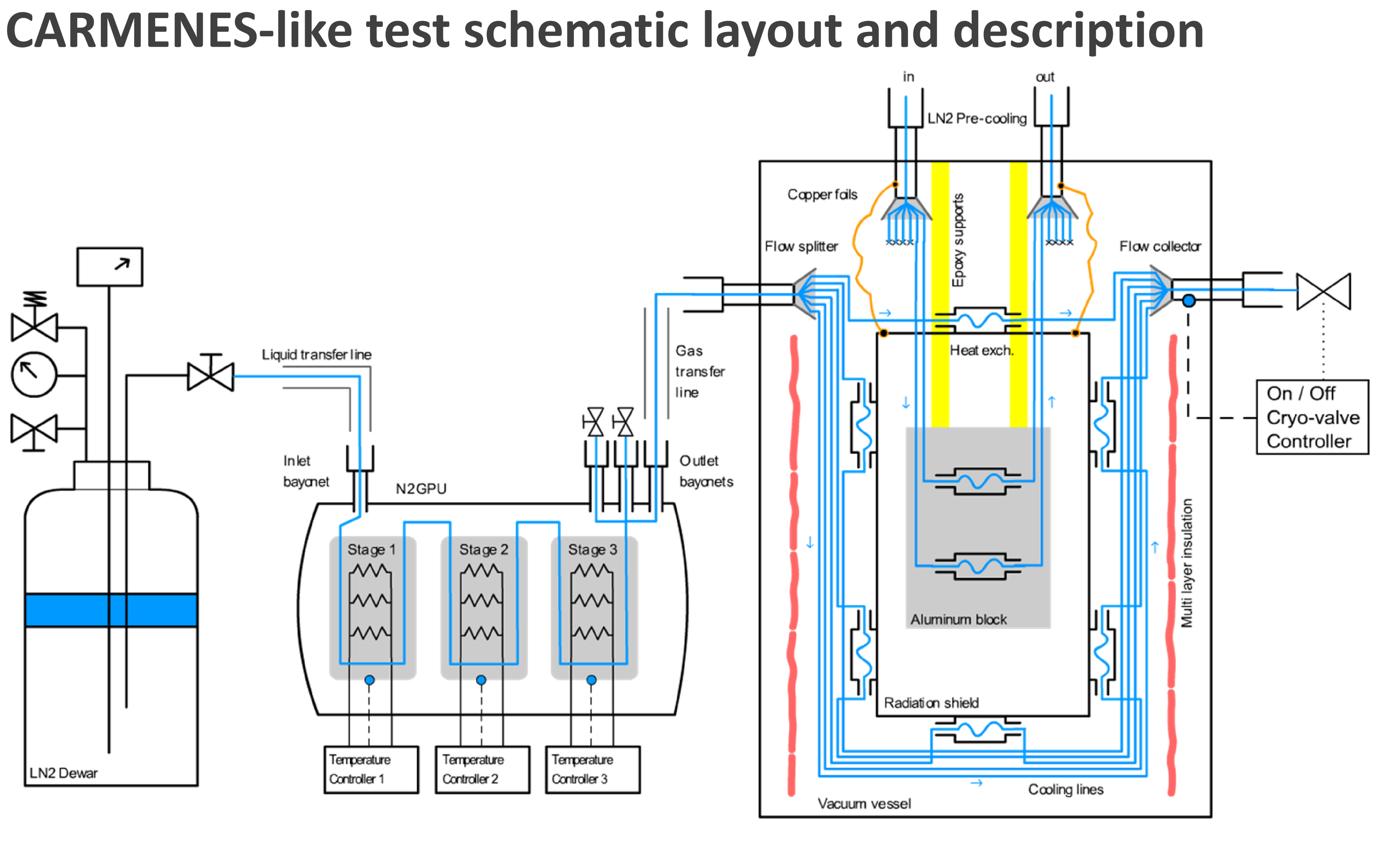
Control inputs to adjust the gas production

Overpressure in the LN2 storage tank that makes the nitrogen circulate · Power supplied to each stage · Continuous or non-continuous flow mode using a cryogenic on/off valve at the end of the cooling circuit controlled by its own PID.

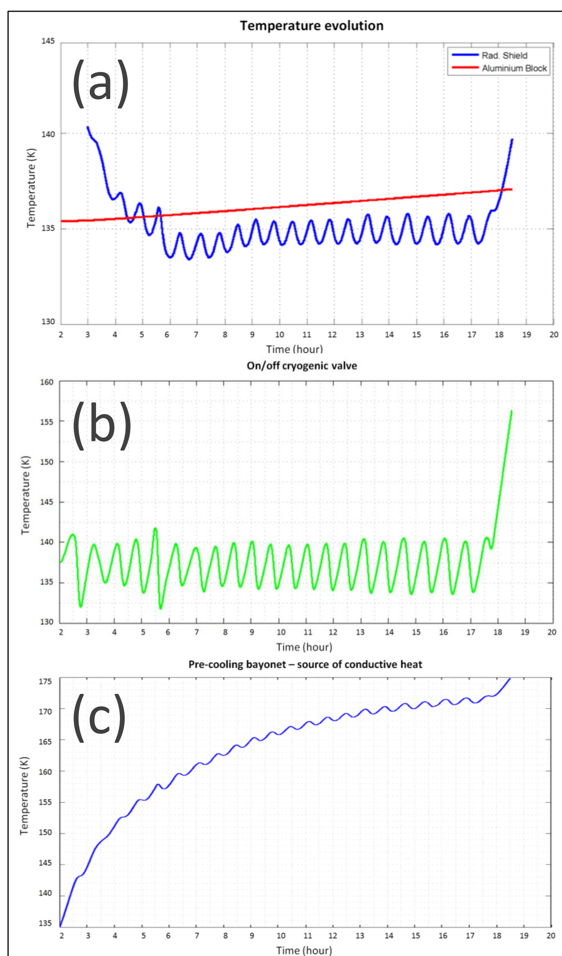




CARMENES-like test schematic layout and description



By establishing the temperature of the radiation shield and the aluminium block close to 140K and then measuring the temperature evolution over time, it is possible to analyze the thermal amplitude response that the optical bench receives when it is cooled only by the radiation of the radiation shield.



Test parameters and results

Cryogenic on/off valve set point at 138K · Non-continuous flow · 0.35 bars overpressure · 1st stage 230 W · 2nd stage average 70 W · 3rd stage 216 W · Test length of 12.5h after pre-cooling · LN2 consumption of 9.5 l/h · Aluminium block at 136.1K with 1.7K increase · Radiation shield at 134K ±0.75 K within 45 min period · The on/off valve is really stable (b) · A source of conductive heat to the aluminium block (c) produced a temperature shift with the radiation shield (a).

Conclusions and future work

This innovative cooling method can provide long term stabilized nitrogen gas at 140K · By setting the control inputs it can also cover a wide temperature range · The non-continuous flow mode is more reliable · The instrument has been designed to be very well isolated against heat conduction · Tests done so far confirm the successful thermal concept for an ultra-stable optical bench, thermally conditioned only by an actively-cooled radiation shield · They show the impressively high stability of the aluminium block even though no steady state was reached, as no oscillation in the drift was detected · Longer tests will be done to achieve the steady state and reduce the LN2 consumption · The AIV phase of the CARMENES NIR channel at IAA has already started and it is foreseen to achieve its first light by fall 2015.

Acknowledgements: MINECO AYA2011-30147-C03-01, CSIC i-Link 0867, Junta de Andalucía FQM-7363

Unión Europea
Fondo Europeo de Desarrollo Regional
"Una manera de hacer Europa"

SPIE. CONNECTING MINDS. ADVANCING LIGHT.

http://carmenes.caha.es/