CRYOGENIC COOLING SYSTEM BRAYTON

Cryogenic Cooling System Brayton (CSB) for 10 J/10 Hz Yb:YAG multi-slab based laser system at ELI-Beamlines project

Company ATEKO delivered a cooling system based on Bryton's cycle for 10J/10Hz Yb:YAG multi-slab laser system at ELI-Beamlines project. Where, the laser was designed to operate on absolute temperature 150 K and with maximum heat load of 300 W to be removed from the laser crystals. At this temperature, the CSB is capable of dynamically removing the waste heat arising in the Yb:YAG active medium as a result of optical pumping, while keeping the temperature stability within +/- 0.1 K.

Description of Cooling System Brayton:

Standard multistage compressor refrigeration system is economically acceptable to the temperature level –90ºC (183 K). Cooling System Brayton (CSB) operating with corresponding gas, compressor, heat exchanger and turbine is economically acceptable in the temperatures range 183 – 20 K. In this temperature range, it is necessary to respect all cryogenic conventions like materials, system tightness condition, gas and all elements purity and vacuum reflexive insulation application.

The presented CSB is based on 2 turbomachines, cold box with water and He-He heat exchangers, vacuum insulated pipes and control system. Turbomachines are situated in fully aerodynamic radial / axial gas bearings to correspond the conditions of extremely long-life time. As a cooling medium, helium-gas is used. The requirements put on the CSB in the scope of cryogenic cooling of the multi-slab laser amplifier (MLA) designed for 10J / 10Hz operation are summarized in Table 1:

Requirements for the CSB system

Helium Flow Rate	30 g/s
He pressure at the MLA inlet	10 bar(a)
He temperature at the MLA inlet	150 K
Temperature stability	+/- 1 K
Pressure drop at MLA	0.03 bar
Heat production at MLA	min. 300 W
MLA insulation vacuum	10^{-5} mbar

CSB is possible to design for temperatures 170 – 20 K and cooling power to 5 kW.

Basic CSB scheme (P&I Diagram) is shown in following picture.

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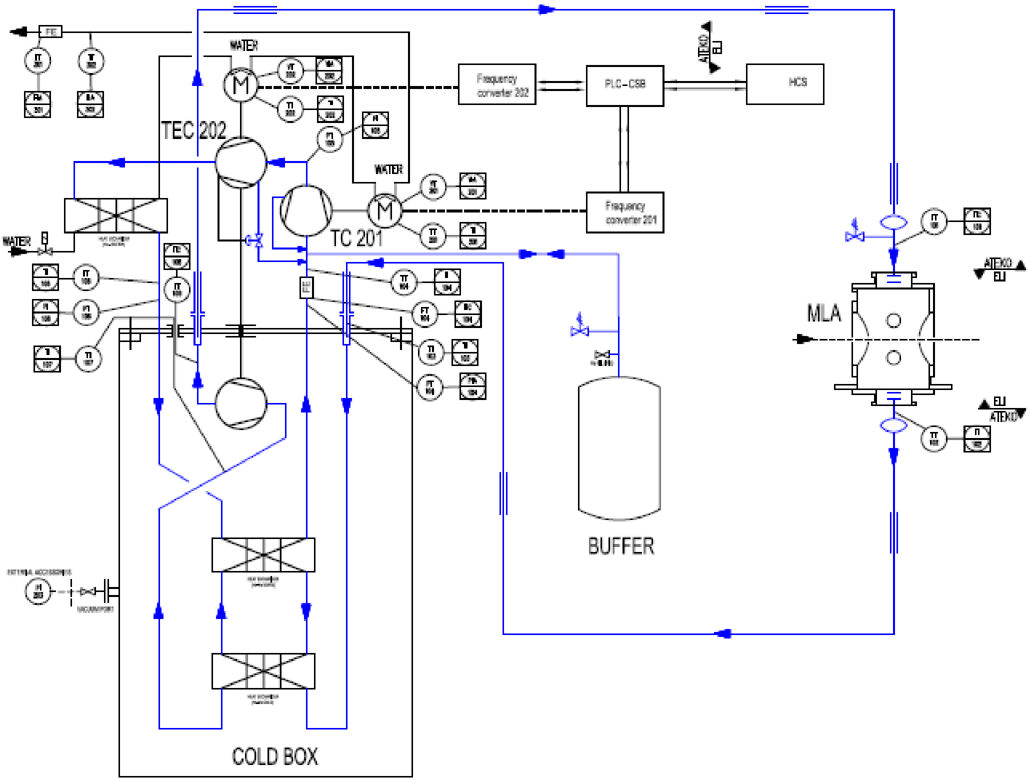

The main parts of the CSB

- Cold Box (CB) – inside the CB there is insulation vacuum and the set of plate fins heat exchangers which are insulated by multi-layer vacuum insulation.
- Turbo machines - are situated on the top of CB. TC 201 machine is 1st stage of turbo-circulator, TEC 202 machine is 2nd stage of turbo circulator and expansion turbine situated on the same rotor.
- VIP (Vacuum Insulated Pipe) – connect the CSB with MLA.
- Buffer – CSB operates as closed circuit and Buffer allows to start operation at pressure 15 bar(a) at warm (ambient) conditions
- Control System – is based on standard SIMATIC system and control:
  a. Communication with higher control system
  b. START of the CSB system
  c. OPERATION of the CSB system at specified temperature thanks to the turbo machines speed variation
  d. STOP of the CSB system
- Power system as a part of Control System is based on two frequency converters which drives motors of turbomachines

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Operational experiences and results

Diode Pumped Laser Amplifiers (MLA) system is cooled down by gas helium circulating in CSB. It is required to cool the laser crystals to a defined temperature level and remove a waste heat MLA. This waste heat is arising in the active medium temperature due to the “optical pumping”. Since the laser output properties can be strongly dependent on the crystal temperature, a cooling system has to keep the set temperature with minimum oscillation amplitudes all the time. In addition, the CSB cooling system intended for commercial use and/or daily operation should be as much as possible simple for handling.

The operational results of the CSB unit ELI are shown in following graphs. In first graph, there is possible to see that the CSB cooling capacity is sufficient to reach crystal temperatures even bellow the required 150 K (set temperature was 145 K). Dynamics of the CSB while the temperature was set to 150 K is shown in second graph. If the 150 K is reached (after approx 3.5 hours from the room temperature), the control system dynamically tailored the revolution of the turbo-machines in such a way that the temperature fluctuation is kept within +/- 0.1 K. Moreover, while the amplifier head was (laser) pumped at maximum energy and repetition rate (approx. 300 W of additional heat load), there were no sign in change of the fluctuation behavior. It can be explained by the big thermal inertia due to the big mass of the stainless steel He-He heat exchanger (165 kg).

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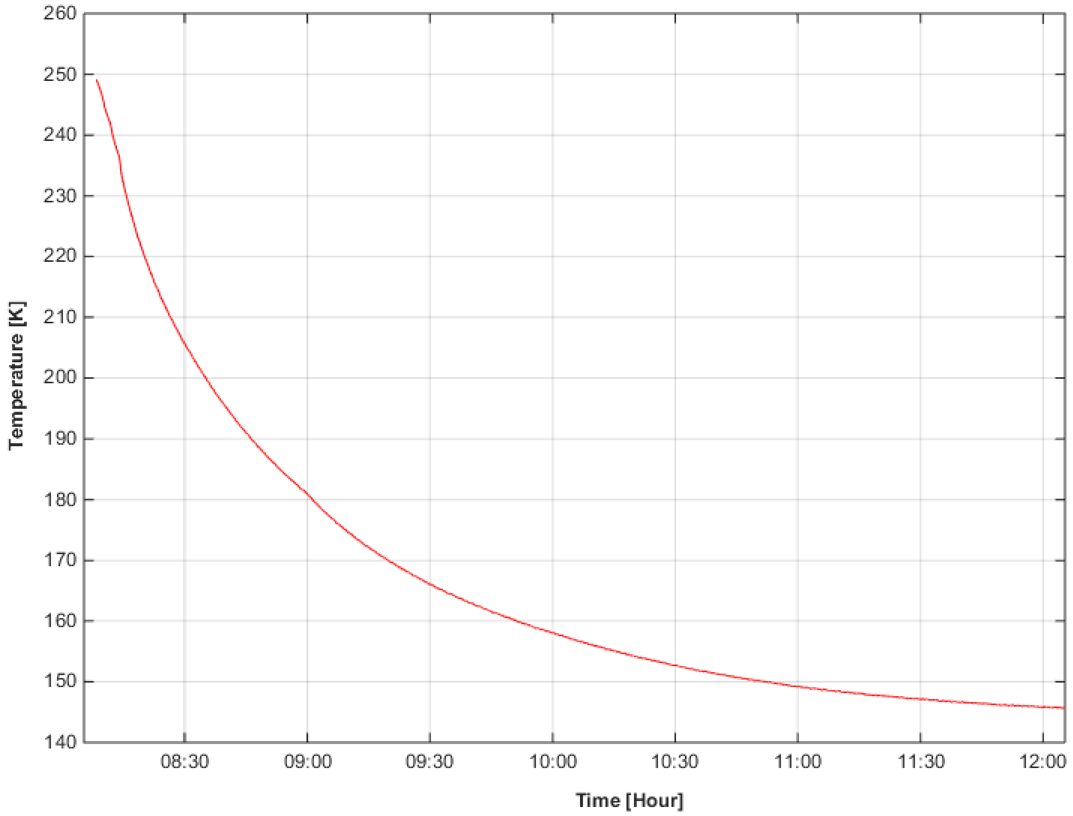

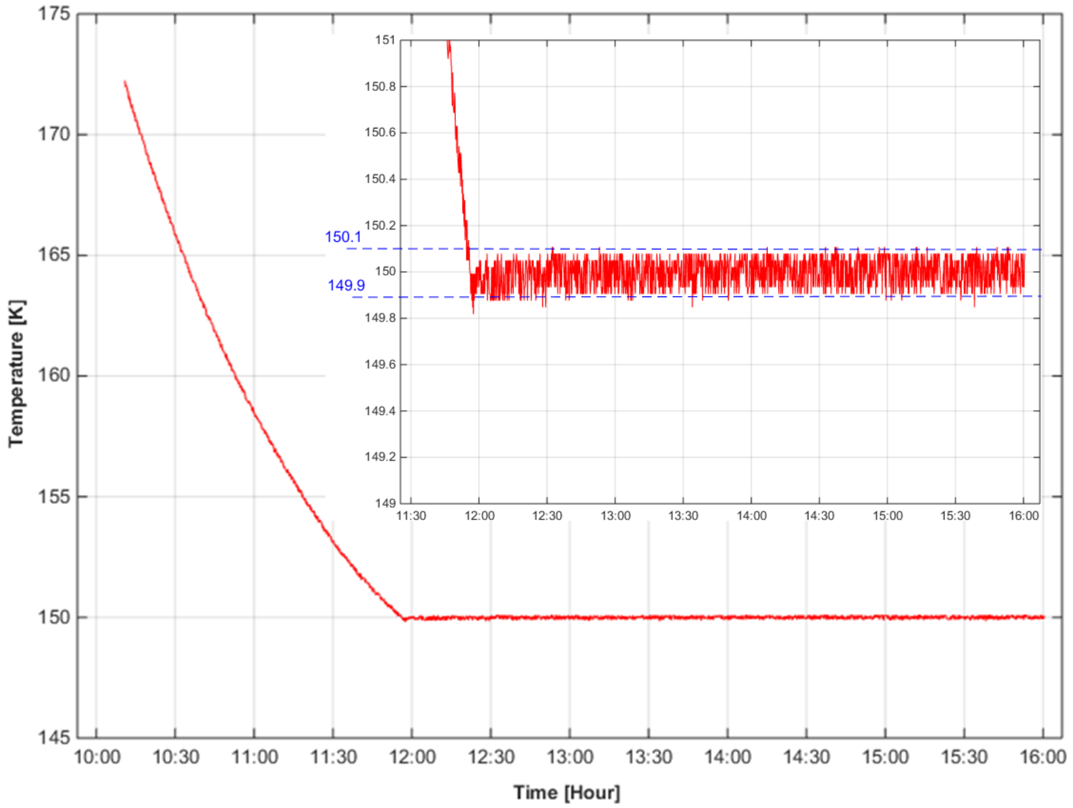

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