Cooling system for the OmegaCAM CCD mosaic

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Abstract: For the optimal trade-off between dark current, sensitivity, and cosmetics, the OmegaCAM detectors need to be operated at a temperature of 153 K. The detectors mosaic with a total area of 630 cm^2 directly facing the dewar entrance window, is exposed to a considerable heat load. This can only be achieved with a very performing cooling system.
The paper describes the cooling system, which is build such that it makes the most efficient use of the cooling power of the liquid nitrogen. This is obtained by forcing the nitrogen through a series of well designed and strategically distributed heat exchangers.
Results and performance of the system recorded during the past months of system testing are reported as well.

Key words: CCD cryostat, cooling

1. INTRODUCTION

The 2.6-m VLT Survey Telescope will be equipped with the optical wide-angle camera OmegaCAM, which features a field of view and pixel scale that perfectly match the VST and Paranal seeing, respectively. OmegaCAM will be mounted in the Cassegrain focus, and the focal plane is populated with a mosaic of thirty-two 2K x 4K CCDs plus 4 virtually identical auxiliary CCDs for autoguiding and image analysis. For the optimal trade-off between dark current, sensitivity, and cosmetics, these detectors need to be operated at a temperature of about 155 K.
The detectors fill a total area of 630 cm^2 and for obvious reasons have to face the dewar entrance window which, however, is in direct contact with the ambient air and temperature. Through this window, the detector is exposed to a considerable radiative heat load of roughly 30 Watts. This is the factor dominating the thermal balance. But a detailed analysis shows that all other contributions (thermal conductance through the mechanical support structures and cables, dissipation in the electronics, etc.) add up to the same amount, bringing the total heat load to 60W.
Various cryo-cooling systems were considered but for none of them the suitability to this rather special task was obvious. Eventually, a decision in favor of liquid nitrogen (LN2) was made, not at last because ESO has a

long experience with CCD cooling using bath cryostats. However, from the Wide Field Imager (WFI), OmegaCAM's predecessor mounted on the 2.2-m telescope at La Silla, we knew that in the case of large heat loads, a plain bath cryostat to directly heat-sink the mosaic would not be efficient enough. The most important limitation of such a system comes from the large change in cooling power with nitrogen level in the tank. This required developing a new system. It still uses an internal storage tank but employs a sophisticated flow of liquid nitrogen in order to be independent of filling level and telescope position.

2. DESIGN

Figure 1 schematically illustrates the principle, which permits the heat to be extracted where it is required (at the level of the detector mosaic) and makes optimal use of the enthalpy:

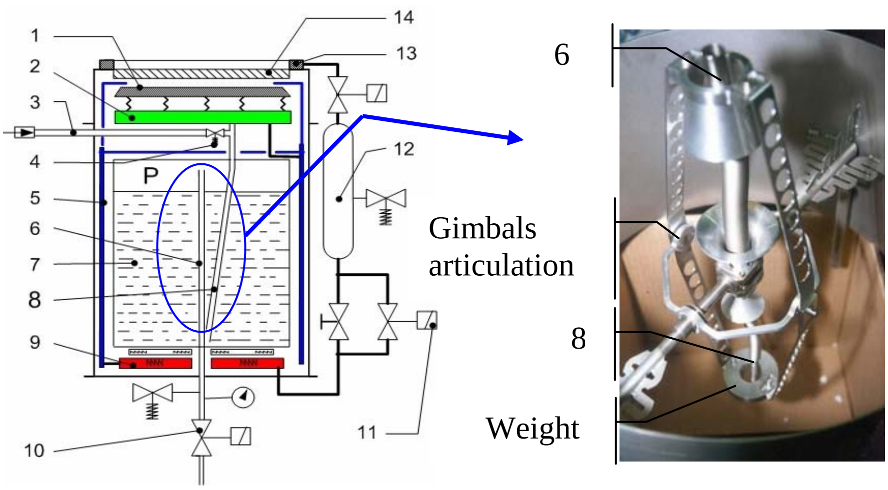

Fig. 1: Cryogenic principle with detail of the anti-overflow

By its own pressure (P), the LN2 is forced to flow from the storage tank (7) through pipe (8) to and through a heat exchanger (2) which is in direct thermal contact with the mosaic base plate (1). The heat exchanger consists of three parallel bars in order to ensure good temperature homogeneity across the mosaic. After having absorbed the heat load, the now gasified nitrogen circulates through a special annular heat exchanger (5) which acts as radiation shield for the storage tank. A final heat exchanger

(9) is used to (electrically) heat the gas to room temperature. On its way out of the instrument, the gas is captured in a small tank (12). Because it is now warm and anyway perfectly dry, it can serve a second purpose and be safely blown over the dewar entrance window to prevent the condensation of air humidity.
The thermal regulation employs a valve (11), which is supervised by a PID controller in order to maintain a constant operating temperature of the heat exchanger (2). The refilling of the internal tank is done from a standard 120 l storage tank via a vacuum-insulated line. When the latter is connected to refilling tube (3), this is detected by a proximity sensor, and valve (10) is opened in order to depressurize the internal tank so that the filling can begin. The valve is automatically closed when the tank is full (which is reported by 1 temperature sensor). The refilling port is fitted with a small spring loaded valve which is activated by the end of the refilling tube. This allows keeping the operating pressure while removing the tube.
The tank has been dimensioned such as to contain some 40 liters in order to reach a hold time of 30 hours so that refilling would be necessary only once a day. Thanks to a special anti-overflow system, which allows the cooling tube (8) to be permanently at the lower position (in the liquid) and the vent tube (6) to be permanently at the highest position (in the gas), 90% of this capacity can be used without spilling (up to the nominal pointing limit of 60 deg zenith distance).
A dedicated thermal clamp has been designed in order to allow an easy separation of the detector head from the cooling system it-self. Figure 2 shows (on the left side) the top of the cooling system with the 12 thermal clamps and (on the right side) the bottom of the mosaic plate with the 12 thermal heat-sinking points.

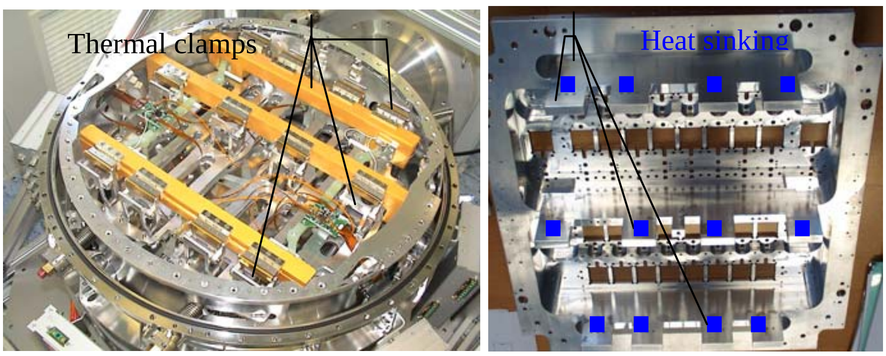

Fig. 2: Thermal clamps

3. STATUS AND PERFORMANCE

The integration of the cooling system was essentially completed one year ago (Fig. 3). Before integration of the science array, it was intensively tested stand-alone (flexure, leaks, spilling, LN2 flow, etc.). The results are very satisfying. The performance is well within the specifications with the mosaic reaching a temperature to within ±1 K even below the nominal operating temperature (128K for 155K specified). The hold time is well over 24 hours (~40 hours).

Fig. 3: Cooling system

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