The REMIR Cryogenics Restyling

F. Vitali*[a], J.L. Lizon[b], G. Ihle[c], M. Accardo[b], L. Gonzales[c], , P. Sinclaire[c], J. Pineda[c], A. Pizarro[c], J. Valenzuela[c], P. Conconi[d], F. D'Alessio[a], V. De Caprio[d], M. Riva[d], E. Molinari[d], G. Chincarini[e], F.M. Zerbi[d], M. Rodonò[f], S. Covino[d], V. Testa[a], G. Tosti[g], L.A. Antonelli[a], G. Malaspina[d], E. Palazzi[h]

[a] INAF-Osservatorio Astronomico di Roma, Via Frascati 33, I-00040, Monte Porzio Catone – Italy
[b] European Southern Observatory, Karl-Schwarzschild-Strasse 2, 85748 Garching bei München, Germany
[c] European Southern Observatory, La Silla Observatory, Chile
[d] INAF-Osservatorio Astronomico di Brera, Via Bianchi 46, I-23807 Merate (LC) – Italy
[e] Università di Milano Bicocca, Piazza dell'Ateneo Nuovo 1, I-20126 Milano – Italy
[f] INAF-Osservatorio Astrofisico di Catania, Via S.Sofia 78, I-95123 Catania – Italy
[g] Università di Perugia, Piazza Università 1, I- 06100 Perugia – Italy
[h] INAF-IASF, via P. Gobetti 101, I -40129 Bologna – Italy

ABSTRACT

REMIR is the NIR camera of the automatic REM (Rapid Eye Mount) Telescope located at ESO-La Silla Observatory (Chile) and dedicated to monitor the afterglow of Gamma Ray Burst events. During the last two years, the REMIR camera went through a series of cryogenics problems, due to the bad functioning of the Leybold cryocooler Polar SC7. Since we were unable to reach with Leybold for a diagnosis and a solution for such failures, we were forced to change drastically the cryogenics of REMIR, going from cryocooler to LN2: we adopted an *ad-hoc* modified Continuous Flow Cryostat, a cryogenics system developed by ESO and extensively used in ESO instrumentation, which main characteristic is that the LN2 vessel is separated from the cryostat, allowing a greater LN2 tank, then really improving the hold time. In this paper we report the details and results of this operation.

Keywords: Near Infrared Instrumentation, Cryogenics, Continuous Flow Cryostat.

1. INTRODUCTION

REM (Rapid Eye Mount) is a fully robotic fast-slewing telescope primarily designed to follow the early phases of the afterglow of Gamma Ray Bursts (GRB) detected by Space-borne-alert systems such as HETE II, INTEGRAL AGILE, Swift. Since 2003, REM is in its operating phase at the La Silla Observatory Chile. REM hosts the NIR camera REMIR and the optical camera ROSS (REM Optical Slitless Spectrograph). The overall description and the scientific rationale of the REM project can be found in Chincarini *et al.* 2003 and Zerbi *et al*. 2003, 2004.

REMIR covers the 0.95-2.3 μm range with 4 filters (1*mic*, J, H and Ks) and hosts a one-working quadrant HAWAII array. A detailed description of the camera can be found in Vitali *et al*., 2003 and Conconi *et al*., 2004. Initially the cryogenic temperature needed to effectively operate the infrared array was obtained through the Leybold cryocooler Polar SC-7, a very small and compact device directly attached to the camera. This allowed us to design a very compact and efficient system, without any need of human intervention. The stated performances of the device should allow us to keep the temperature of the array and the optics at 78 K for at least two years of continuous functioning.
Unfortunately, after a short period of functioning, the Polar SC-7 cryocooler showed some under performances and the

* Further author information: send correspondence to Fabrizio Vitali
E-mail: vitali@oa-roma.inaf.it, Telephone: +39 06 94286462

temperature of the array was no longer lower than 100 K. We mounted two spare cryocoolers but both lasted less than one week. Up to now, we could not understand the reason of such a failure: then, to ensure a rapid solution of the cryogenics and a quick return to operability, we were forced to change the philosophy of our cryogenics system and to return to the classic (and reliable) liquid nitrogen. This operation was not really simple because a camera born to be cooled via cryocooler cannot be easily turned to LN_2. Moreover, the small dimension of the camera allowed a very small LN_2 vessel, then allowing a very short hold time. This was a very stringent constrain, due to the robotic nature of the system.

The solution of the problem was found adopting the Continuous Flow Cryostat (CFC) that ESO routinely uses in its instruments. This cryostat solves the problem of the LN_2 vessel dimension because it simply separates the vessel from the instrument.

In the following we will briefly describe the CFC system, the modification adopted to implement it to the REMIR camera and the performances of the current cryogenics system of REMIR.

2. THE NEW CRYOGENICS

The failure of the Leybold POLAR SC 7 cryocooler , forced us to search for an alternative solution, effective and reliable. After a study of the possible solution, we decide to change the cryogenics from cryocooler to LN2, the major problem being to adapt an adequate LN2 vessel to an instrument built with a different philosophy.

Then, JLL suggested to modify and adopt a Continuous Flowing Cryostat (CFC, Figure 1), a cryogenic system developed by ESO and widely adopted in ESO instrumentations to cool down different type of instruments. It consists essentially in a cryostat, in which a heat exchanger, i.e. the cold finger (label 1) is continuously fluxed with LN2, controlled through a set of OMEGA CN76000. The LN2 vessel is separated from the instrument, and the cryogenic liquid is filled through a rotating joint, allowing to derotate the instrument at the Nasmyth focus.

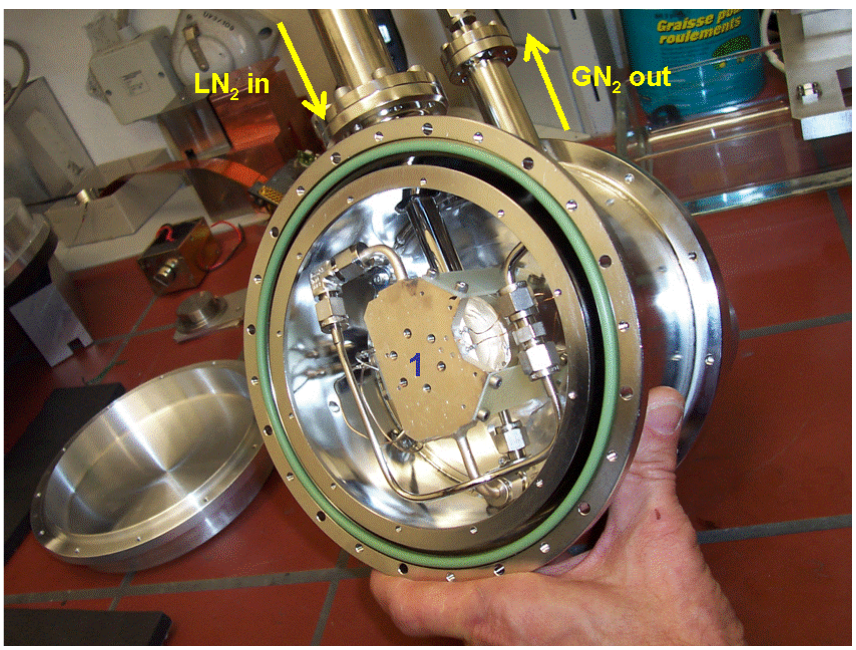


Figure 1 -The CFC system at ESO, it is clearly visible the heat exchanger (label 1).

We made some modification to adapt the system to our needs, both on the CFC (Figure 2 and 3) and on the REMIR camera (Figure 4).

With reference to Figure 1, the major modification was the LN_2 input line, that was moved from the side to the rear (Figure 4), to align the axis of rotation of the REMIR camera with the derotator of the telescope.

With reference to Figure 2, the modified CFC essentially consists in :

- A modified ESO CFC, with the entrance LN2 port moved from side to rear, to be implemented in the REMIR camera;
- 2 vacuum ports (DN25), on the rear of the CFC;
- 1 LN2 Fill port with the rotating joint (label 1), on the rear of the CFC;
- 1 Vent Line with the electro-mechanical valve (label 2), on a side of the CFC;
- 1 ex Fill port (DN40), on a side of the CFC complete with vacuum valve (it can be closed with a blind flange or used for vacuum pumping);
- 1 overpressure safety valve, on a side of the CFC (label 3);
- 1 Housekeeping connector (Amp19) for the three PT100 (Heat Exchanger (HE), Sorption Pump and Nitrogen Gas) and the two resistors (the Sorption Pump and the Gaseous Nitrogen Heater) (label 4);
- 1 electronic box with 3 OMEGA CN76000 controllers (See Section 4) for the monitor and control of the Heat Exchanger temperature, the Sorption Pump Heater and the Gaseous Nitrogen Heater (Figure 8);
- 1 Power Supply (12V-3A) for the resistors.

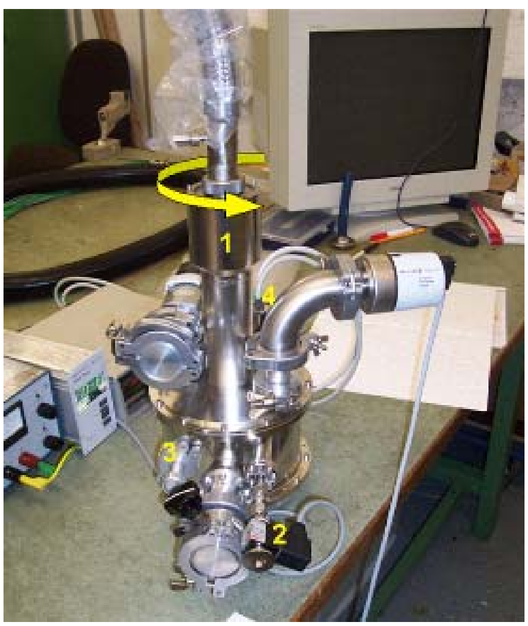


Figure 2 - the modified CFC with the new LN_2 fill port and the rotating

joint (label 1).

The LN2 flux is regulated through an electro-valve on the exhaust N2 gas line, whose status (open/closed) depends upon the temperature of the heat exchanger (read through a PT100 and the CN76000): if the temperature is higher than the set temperature, the valve is open and let the LN_2 flux through the line. The other two Omega CN76000 monitor the temperature of the Sorption Pump Heater and the Gaseous Nitrogen Heater, this latter needed to avoid that the exhaust gas line gets frozen.

The CFC cold finger is thermally linked to the REMIR cold plate through a series of copper straps (see Figure 3). The modified CFC has been mounted on the rear of the REMIR camera, removing the old cryocooler and the vacuum valve and pressure sensor group, see Figure 4 for a comparison.

The REMIR array is then currently cooled via LN_2 since June 2005. During this period, the LN_2 consumption has been monitored and optimized. As we will see in Section 5, an upgrade of the system is envisaged to lower the array temperature and optimize the LN_2 consumption, that currently is about 50 *l* LN_2/3days.

Figure 3: the modified CFC, while mounting the cold finger and the thermal straps.

Then, the new CFC system has been added to the rear of REMIR (Figure 4), and the new REMIR mounted again at the REM telescope (Figure 5).

Figure 4: REMIR before (left) and after (right) the CFC implementation.

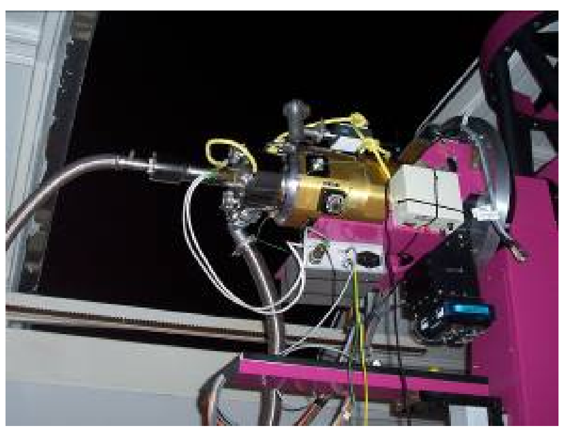


Figure 5: REMIR mounted at the Nasmyth focus of the REM telescope.

3. THE (RE)FILLING SYSTEM AT THE TELESCOPE

The REMIR camera has currently a total LN_2 reservoir of 50 *l*, connected to the CFC through a dedicated cryogenic line.

In detail, the cryogenic refilling system consists in:

- a mechanical frame able to host two CryoDiffusion vessels of 25 l each: it is attached at the telescope fork, opposite to the instrument Nasmyth arm (see Figure 6). It can be moved downward from the upper working position for vessel replacement. The frame allows to change safely two LN_2 vessels empty with two full vessels in few minutes;
- a vacuum cryogenic line from the LN_2 vessels to the rotating joint of the CFC.

The Mechanical Frame

The two LN2 vessels are linked to the telescope through a complex and stiff mechanical interface that allows two positions: i) *working*, with the two vessels at the upper level, which allows the vessels to be connected to the cryo Link line, *ii) change*, lower level, which allows the empty vessels to be easily disconnected from the cryo Link line and be replaced (with other full vessels). As shown in Figure 6, all operations are performed manually: on the left, the vessel are being replaced with the frame in the lower position, in the right panel, the two full vessel are being uploaded to the working position, usually this operation needs only two operators.

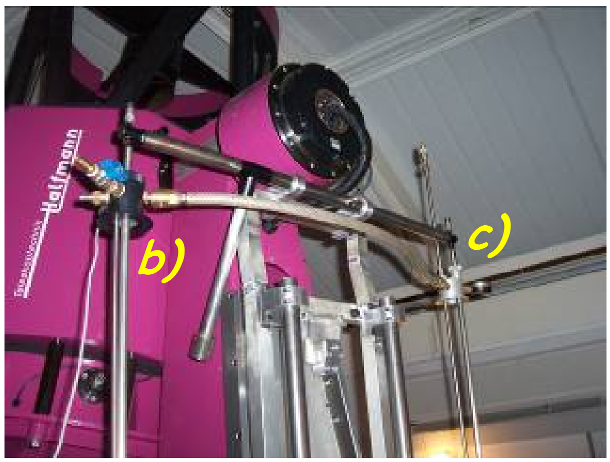
Figure 6 - The vessel change operation.

The Cryo Line

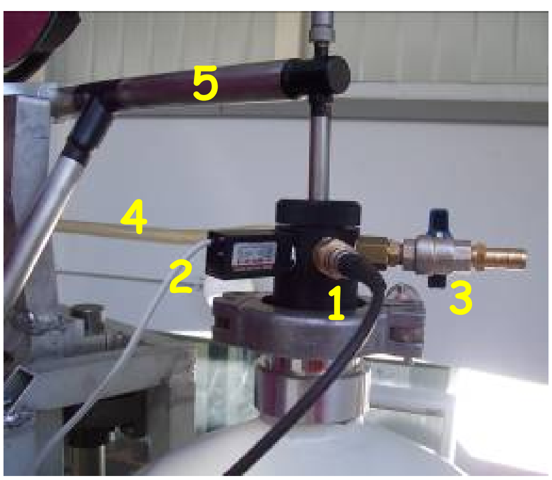
The LN_2 tanks act as one single vessel, via a cryogenic line connecting them together (see Figure 7). It consists in a rigid vacuum line that connects the two vessels and allows the sharing of the internal pressure and, in case, of the LN_2 level (see Figure 7*a*). The cryogenic link line has different devices to monitor and control the LN_2, as showed in the next Figure 7*b*,*c*.

With reference to Figure 7*b*,*c*, you can see:

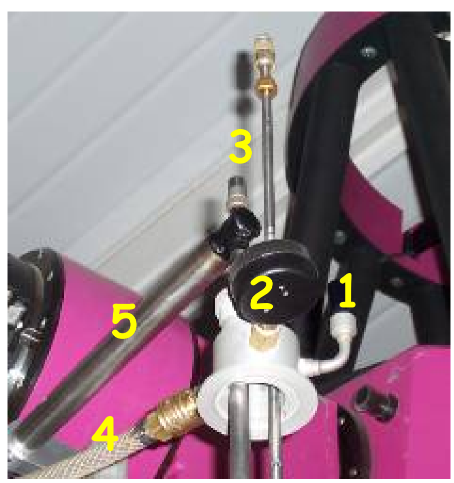
	b)	***c)***
1.	Connector for N_2 Heater:	Security overpressure valve, set at 0.5 *mbar* ;
2.	Electronic Pressure gauge:	Pressure gauge ;
3.	N_2 gas valve:	LN_2 level probe ;
4.	Inter-vessel Pressure equalization hose:	Inter-vessel Pressure equalization hose ;
5.	LN_2 line to CFC:	LN_2 line to CFC.



a)



b)



c)

Figure 7 - *a)* The LN_2 line between the tanks and *b)* the right and *c)* left vessel control devices

Once the LN_2 tanks have been closed on the cryogenic line, an heater *(b-1)* can be switched on to make the internal pressure to rise fast: the heater is controlled through a electronic pressure gauge (*b-2)*. The inter-vessel pressure equalization hose (*b-4)* allows keeping the same pressure in both tanks. Having the same pressure, the LN_2 flow is equal provided the two LN_2 lines have the same flow impedance. Thus, it is important to keep the impedance matched on both lines. For instance, if ice clogs one of the LN_2 lines input filters, the LN_2 flow and consumption in one vessel will be higher than the other with the clogged line, resulting in shorter holding time. The latter because the total holding time is the time to empty the first vessel (since N_2 gas will enter the system at this moment. It already happened once in January 2006). Ice entering on the CFC filling system is a show-stopper as it will decrease the LN_2 flow enough to prevent normal cooling, or stop the flow all together. The removal of the ice most of the time requires a full warm up of the system (two days off-line). During summer time, when the relative humidity is high, this is a real problem since ice develops rapidly on the exposed cold filling tubes at changeover time. It needs careful cleaning to avoid the ice getting through to the CFC, which anyway happened several times during last summer.

A cryo vacuum line from the two LN_2 vessels to the REMIR camera (Figure 14) was built by LG and AP, who assembled several short pieces and couplings. This line work well but it is not optimized and is prone to thermal leaks. A good part of LN_2 consumption could happen on this line. A one piece transfer line made of the exact length (3m for the flexible part and on straight coupling in one end, and one 90 degrees coupling on the other end) would be the best option here. Also, a spare LN_2 hose would be available making easier to regenerate the vacuum by simple exchange while warming up the other hose and pumping it.

4. THE CFC CONTROL

The overall functioning of the CFC is controlled through a series of three OMEGA CN76000 controllers (Figure 8), which monitor and control the LN2 flux, the temperature of the N2 gas exhaust and the temperature of the cryopump during the CFC warming (for a scheme, see Figure 9). The parameters can be set manually or remotely, via a dedicated software that will be soon upgraded (see D'Alessio *et al.,* this conference, 6274-62).

The final cold finger temperature can be set and the CN76000 can control the approach to the set temperature with different PID algorithms: then, the system is stabilized around the set temperature with a precision of about 0.05 K, through the control of an electro valve that allows or stops the flux of LN_2 through the CFC. Also the temperature of the exhaust N_2 gas line can be set and controlled, in order to avoid the freezing of the out line.

During the warm up of the instrument, a resistor on the cryopump can be switched on to warm and regenerate the zeolite.

Figure 8 - The OMEGA controllers box

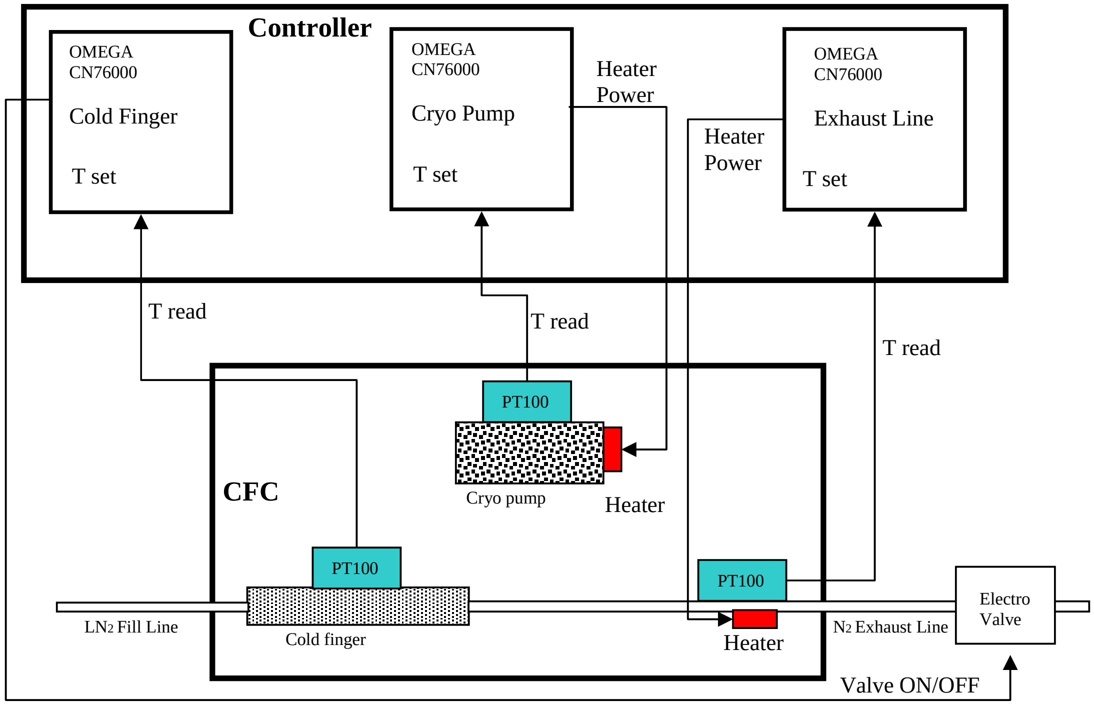


Figure 9 - A scheme of the CFC controller.

Since the first tests in July 2005, the CFC was able to cool the array down to about 93.2 K (with the CFC cold finger at T= 77 K) in about 24 hours (Figure 10, *left*), with a temperature stability *at regime* of 0.05 K (Figure 10, *right*). The CFC is currently set at about 80 K, resulting in an array temperature of about 95 K, with a LN_2 consumption of about 50 *litres per* 3 *days*.

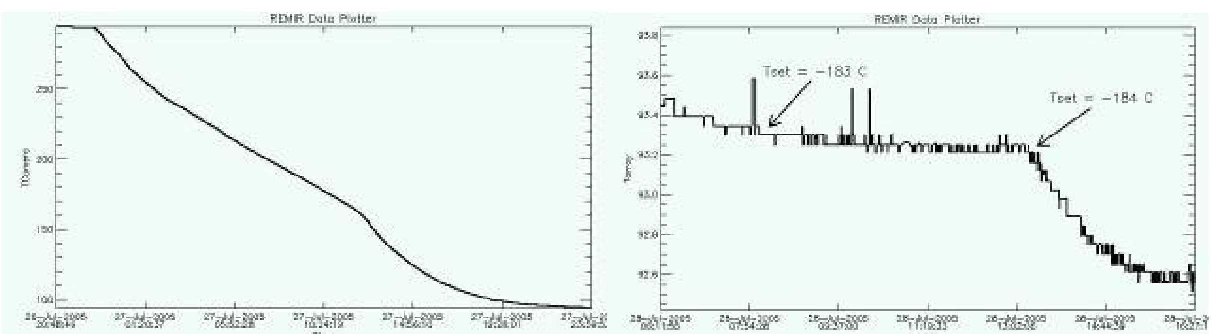


Figure 10 - The overall cooling curve of the array (left) and a detail of the array temperature almost at regime (right).

5. THE NEXT UPGRADE

Thermal Link

The thermal gap between the CFC heat exchanger and the array is quite high, more than 15 K, likely due to a bad thermal contact in between, currently made of a copper link (see Figure 11) made of several straps, with 6 mechanical interfaces, which are likely to be the most responsible for the thermal gap. Moreover, the straps are about 12 cm long and the copper is not thermally optimized and coated. Studies are in progress to effectively reduce the gap: it essentially consists in moving the CFC heat exchanger toward the REMIR cold plate and/or optimize the materials.

In the current configuration (Figure 11, right panel) we have a distance between the CFC and REMIR cold plates of about 70 mm, and we have 6 interfaces. We are currently studying two different solutions, as shown in Figure 10: in the right panel, the thermal link is provided through a solid finger of annealed oxygen-free high-conductivity copper (OFHC-Cu), with the link with the cold plate of REMIR made of pure Ag foils. In the left panel, we envisage to move the heat exchanger of the CFC very close to the cold plate and then adopt a solid cold finger (still in OFHC Copper) for the thermal link. In both cases, the reduced distances and interfaces and the optimized materials should ensure an improvement in the thermal link of at least one order of magnitude.

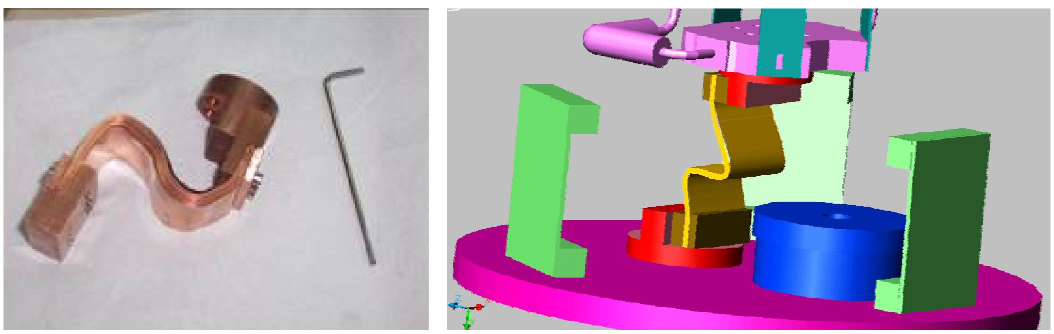


Figure 11 - The current copper strap connection between the CFC and REMIR cold plate and the 3D drawing of the current configuration.

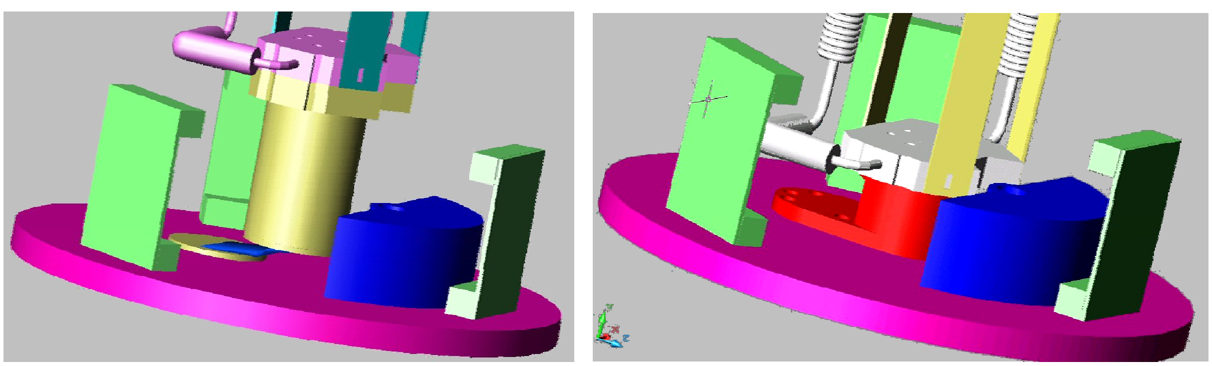


Figure 12 - The 3D drawings of the different optimized configurations under study.

The LN_2 Level Control

As a manner of keeping known the LN2 level, a new level sensor shall be installed on the thanks, as is shown in Figure 13. This sensor issues an analog voltage signal which is proportional to the LN2 level inside of the tanks. This signal shall be converted to RS232 protocol and sent to an monitoring PC. In this way, a complete follow-up shall be performed on real time and an eventually alarm system could be triggered when the LN2 level is low , for example , to 30%. For its implementation, an electronic board used in other designs (CES, SINFONI , FEROS, etc) must be inserted onto the level sensor.

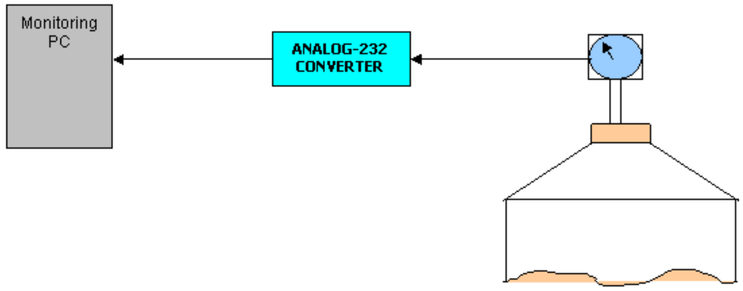


Figure 13 - The new LN_2 level control.

6. THE NEW REMIR CAMERA AT THE REM TELESCOPE

Since the first REM installation in the Summer 2003, the telescope and the installed instrument setup changed drastically. Currently, the configuration of the REM telescope is shown in Figure 14, where you can see the LN_2 vessels system, the cryogenic line, directly connected with the REMIR camera at the opposite Nasmyth of the telescope. For the most current view of the REM telescope, please link to http://remwbc1.ls.eso.org/view/view.shtml or http://remwbc2.ls.eso.org/view/view.shtml .

Figure 14 - The new looks of the REM telescope.

REFERENCES

- Chincarini, G., Zerbi, F.M., Antonelli, L.A., *et al*. 2003, ESO Messenger 113, 40;

- Conconi, C., Cunniffe, R., D'Alessio, F., Jordan, B., Mazzoleni, R., Molinari, E., Vitali, F., Zerbi, F.M., Chincarini, G., Antonelli, L.A., Covino, S., Cutispoto, G., Nicastro, L., Tosti, G., 2004, , SPIE vol.5492, p. 1602.

- D'Alessio, F., Vitali, F., Testa, V., Antonelli, L.A., Molinari, E., Chincarini, G., Zerbi, F.M., Rodonò, M., Covino, S., Tosti, G., Conconi, P., Malaspina, G., Palazzi, E., 2006, SPIE *this conference*, 6274-62.

- Vitali, F., Zerbi, F. M., Chincarini, G., Ghisellini, G., Rodono, M., Tosti, G., Antonelli, L. A., Conconi, P., Covino, S., Cutispoto, G., Molinari, E., Nicastro, L., and Palazzi, E., 2003, SPIE, 4841, p. 627;

- F. M. Zerbi, G. Chincarini, G. Ghisellini, et al. 2003, SPIE vol. 4841, p. 737;

- F. M. Zerbi, G. Chincarini, G. Ghisellini, et al. 2004, SPIE vol. 5492, p. 1590.