E U R O P E A N   S O U T H E R N   O B S E R V A T O R Y

Organisation Européenne pour des Recherches Astronomiques dans l'Hémisphère Austral
Europäische Organisation für astronomische Forschung in der südlichen Hemisphäre

Optical Detector Lab

The potential of CryoTiger Cryostats (upgrades) for ESO's Observatories

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CHANGE RECORD

ISSUE	DATE	SECTION/PARA. AFFECTED	REASON/INITIATION DOCUMENTS/REMARKS
0.1	16.5.2003		Draft
0.2	20.5.2003		New pictures, minor changes
1.0	25.6.2003		Comments from DBA, JLL and MDO

The actual version of this document can be found in colour under
http://www.eso.org/projects/odt/contamination/Cryotiger_potential.pdf

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APPLICABLE DOCUMENTS

[1] VLT Electronic Design Specification VLT-SPE-ESO-10000-0015
[2] Electromagnetic Compatibility and Power Quality Specifications Part 1 VLT-SPE-ESO-10000-0002.
[3] Electromagnetic Compatibility and Power Quality Specifications Part 2 VLT-SPE-ESO-10000-0003.
[4] VLT Environmental Specification VLT-SPE-ESO-10000-0004.

REFERENCE DOCUMENTS

[5] Phillip MacQueen: CryoTiger, Communcation to CCD-world on December 5, 2001
[6] Les Saddlemyer: CryoTiger, Communication to CCD-world on December 4, 2001
[7] IGC Polycold Systems Inc., DATA sheet of CryoTiger, www.polycold.com and Safety documents at www.igc.com/polycold/images/pdf_images/MSDSforPTgases.pdf
[8] David Hula and Bernd Kasparick: Private communication at the Semicon fair in Munich, 4,2002
[9] Jerry Cabak: CryoTiger at Keck telescope, Communication to CCD-world at May 15, 2002
[10] Bacon et al.: Proposal for VLT 2nd generation instrument, 2002
[11] Deires, S.: CryoTiger Cryostats for cooling of scientific CCDs, VLT-TRE-INS-13620-2862 and under http://www.eso.org/projects/odt/contamination/Cryotiger.pdf

ABBREVIATIONS USED AND GLOSSARY

CCD Charged coupled device (imager for optical wavelengths)
CC CryoTiger cryostat
CFC Continuous flow cryostat
CryoTiger Modified closed cycle cooler from Polycold Inc. without moving parts in the cold end (head)
ODT Optical Detector Team

1 Scope:

This document gives an overview about a thermo-electrical cooling system for optical CCDs. It also explains how nitrogen cooled cryostats for optical CCDs could be replaced by a electrical cooling system.
Based on the commercially available CryoTiger the ODT Garching developed this cooling system, which has been made (cold-finger) compatible with the current standard CCD detector heads.
This document does **not** intent to declare obsolete the existing nitrogen based cryostats. But in principle, a current nitrogen based cryostat (bath cryostat and continuous flow cryostat) could be replaced with this thermo-electrical based CryoTiger cooling system in order to avoid the safety hazards and costs of liquid nitrogen and to save man-power for delivery and re-filling. Costs, constraints and advantages of this operation are discussed in the following..

2 Introduction:

A suitability discussion: *CryoTiger Cryostats for cooling of scientific CCDs* is given in [11].
See also http://www.eso.org/projects/odt/contamination/Cryotiger.pdf.
From this document only some basic points are repeated here.

The so-called CryoTiger is a thermo-electrical closed cycle cooler without moving parts inside the cold head from Polycold Inc., USA. This system is optimized for reaching temperatures of the same range as liquid nitrogen. Several observatories around the world have been using this system at their telescopes for some years [5] [6] [9]. ODT Garching developed an adapter, which contains the CryoTiger cold head and fits the current standard CCD head without the need of modifying it. This system has been under successful test at the ODT test-bench for 6 months. For a 2 by 1 2kx4k mosaic temperatures down to -150 degrees centigrade at the CCD surface can be attained by merely switching on electrical power.

This paper first discusses the requirements of a cooling system for optical CCD detectors. From this the pro's and con's are derived. Then, the components of the CryoTiger and the ODT's cryostat construction are given. After this, a possible configuration with all components at the telescope is discussed. The total price including shipment to Santiago (Chile) is given from an actual offer and the last chapter is a possible time schedule for an upgrade with this proposed CryoTiger cooling system at the observatory site in Chile.

3 Requirements of Cryostats foreseen for cooling of Optical CCDs:

CRYOSTAT TYPE	**CRYOTIGER based cryostat**	**LN2 based cryostat**
REQUIREMENTS		
Little manpower needed	6-month mainten. For daily operation no manpower needed	Daily LN2 filling with bath cryostat. Weekly exchange of large LN2 vessel with continuous flow cryostat (CFC)
Acquisition/manufacturing costs (in kEUR) low Low maintenance costs (in kEUR/10years)	Cost of CCD head: 4 Cost of cryostat: 13 Cost of w-cooler: 5 Cost of electricity: 5 Cost of manpower: 5 Cost (travel and installation): 5 Sum(10years): 37	Cost of CCD head: 4 Cost of cryostat: 10 - 13 Cost of liquid nitrogen and supplies: 10 - 20 Cost of manpower: 55 - 100 Cost (installation): 5 Sum(10years) approx: 84(CFC) –141(bath cryostat)
Lifetime more than 10 years	10 years or more	15 years or more
Long autonomy	Half a year	48 hours with bath cryostat 330 h with continuous flow cryostat
Safe operation	See safety sheet [7] (inflammable high pressurized gas)	Liquid nitrogen hazard for people Leak danger with spilling LN2
EMC part 1 & 2 According to Doc.No.: VLT-SPE-ESO-10000-0002 VLT-SPE-ESO-10000-0003	Cold end does not require electricity; Compressor is CE, UL and S293A Approved	CFC Controller induces minor noise at FIERA – to be checked maybe grounding scheme can be improved
VLT environmental specifications VLT-SPE-ESO-10000-0004 : -10 until +30 centigrade	For compressor OK according to Ferrotec	OK
No vibration at telescope	Very low vibration at cold end because of no moving parts (Existing closed cycle coolers with moving parts in the head give more vibration depending on instrument mass and are used e.g. at ISAAC)	OK
No heat dissipation into telescope hall	Compressor dissipates 510 W and water cooled version is needed	CFC Controller dissipates heat of approx. 50 W
		Table is continued on next page

	CRYOTIGER based cryostat	**LN2 based cryostat**
REQUIREMENTS cont.		
System usable at a) Coudé Focus b) Nasmyth Focus c) Cassegrain Focus	 OK with long gas pipes as reported from other observatories with long gas pipes up to 50 meters, to be investigated	 OK Bath Cryostat OK CFC only with special de-rotator Only bath cryostat
Temperature provided to CCD head at cold-finger <= 100 Kelvin	95 Kelvin with Pt14 gas	approx. 80 Kelvin
Cooling power > 5 Watts for a mosaic of 2 x 2kx4k CCDs	6-10 Watts	6 Watts with 48h hold-time (bath) >=6Watts with CFC
No contamination induced by cooler	OK	OK
Cool down time less than 12 hours	OK	OK with standard CCD head
Weight of cooler in cryostat backpart should be small	Less than 6 kg	Bath cryostat: 25 kg CFC: 10 kg
Remotely controllable	Yes	Bath cryostat: Not currently (exception: OmegaCAM) CFC: Yes
Vacuum volume of cooling system should be small	approx. 3 liter	approx. 5-10 liter
Possibility to operate one cooling system with more than one cooling head e.g.: MUSE	Yes with less cooling power per head, 2 heads are maximum	Bath cryostat: No CFC: Yes (VIMOS)
Insensitivity to power failure	System warming up during power off	Bath: Yes CFC: Yes (with by-pass valve)

This table refers to a standard type CCD cryostat with a maximum of a 2 x 1 CCD mosaic of two 2048x4096 pixel Marconi or MIT/Lincoln Lab CCDs, like currently used e.g. at FORS2 and EMMIred.

From this results the following conclusion: The current cryostats are in the long view more expensive because the needed liquid nitrogen filling makes them more man power intensive.

4 Technical description and components of a CryoTiger Cryostat

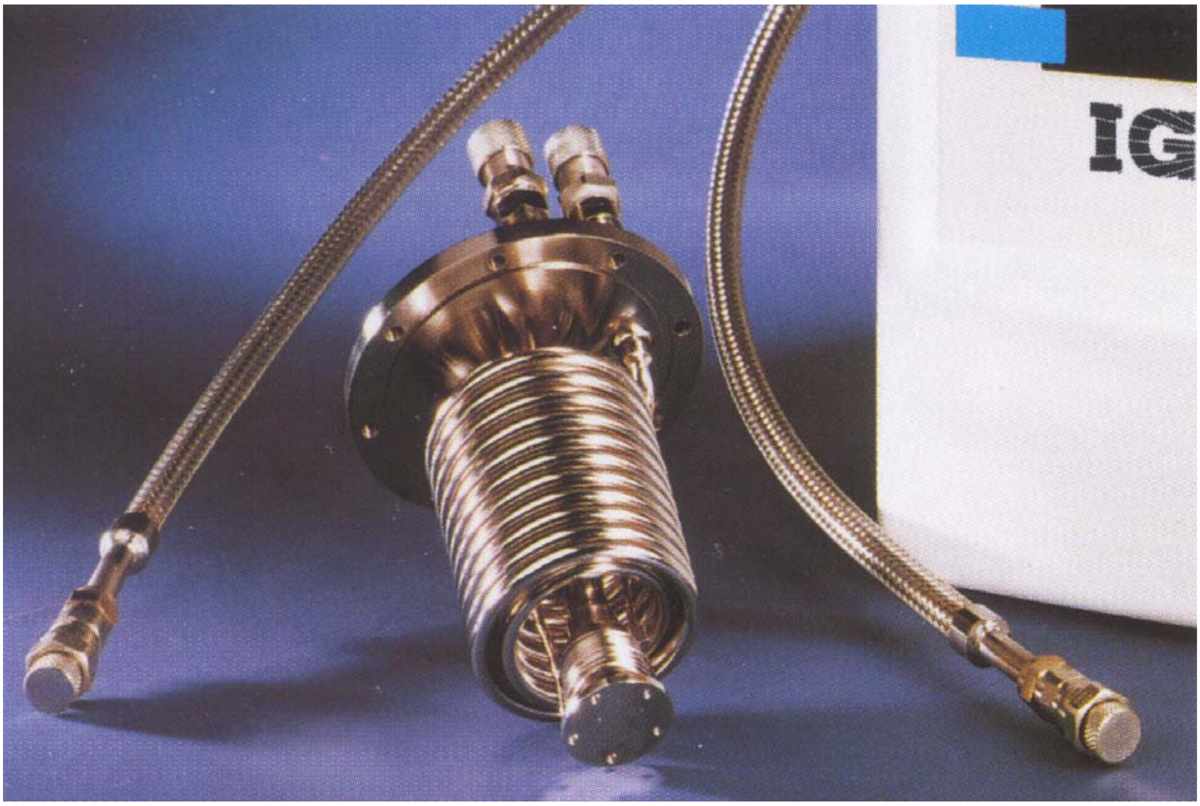


Figure 1: CryoTiger cooling head (Cold End) and two flexible gas lines (for gas in/out)

The CryoTiger system consists of a head or "Cold End" which is 145mm long with a diameter of 73 mm, which has to be placed inside a vacuum chamber, the so-called CryoTiger Cryostat (CC). The overall dimensions are 230 mm of length and 110 mm diameter. Its weight is 1.7 kg. The total weight of the CryoTiger Cryostat is less than 4 Kg.
From the two available main options the "Standard Cold End" is sufficient for present standard cryostat requirements. With this we reach down to -150 degree centigrade at the CCD surface. The present standard ESO CCD cryostats deliver a cooling power consumption of approx. 6 Watts as considered with a 2 x 1 mosaic of CCDs of two 2048x4096 pixel Marconi CCDs. With the CryoTiger option this power consumption will be a bit less, because there is no liquid nitrogen vessel in the cryostat and no filling line, which have losses, that are included in the above given cooling power.
Therefore it is estimated, that a CryoTiger cooling power of 5-7 Watts should be sufficient for a temperature of approx. 95 Kelvin (-178 degree centigrade) at the top of the cooling head. The CCD surface in the CCD head is approx. 30-40 degrees warmer.

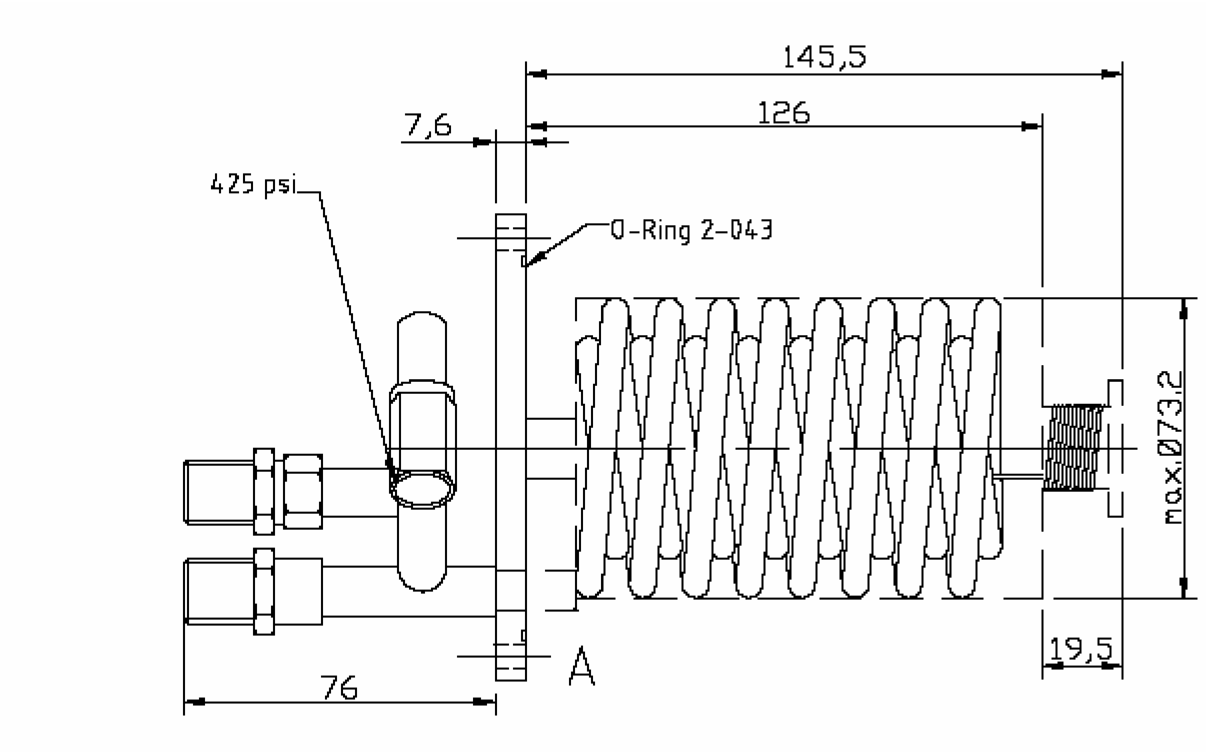


Figure 2: Dimensions of the Standard Cold End (seen from the side)

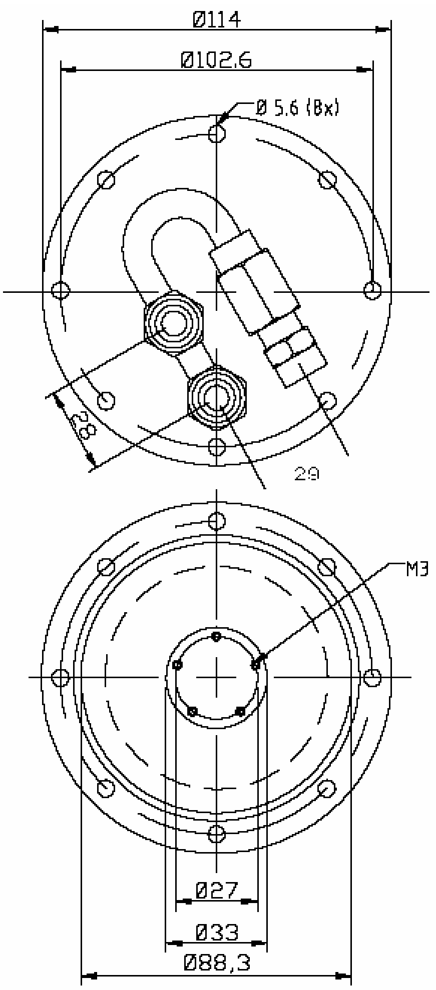


Figure 3: Dimensions as seen from behind and from the front

The cooling power and temperature range of a CryoTiger is selectable as an option when ordered (by the type of gas used), but can also be changed later with a refilling of another gas type. We selected Pt-14 (see Figure 4)
The principle of a CryoTiger is that of a closed cycle cooler. But there are no moving parts at the cold head, thus minimizing the vibrations induced on the instrument. The cold-head itself is nickel plated for the use in a high vacuum chamber.
A special gas mixture is pressed through (with a pressure of 14-19 bar) up to 60 meters long gas lines and expands near the top of the cold head. This happens inside its system of gas channels in order to cool down only the top of the cold head, which has a diameter of 33.2 mm and a thickness of 3 mm. The gas expansion is provoked by a remote compressor (see Figure 6) connected to the other end of the gas lines. Weak vibrations can be transmitted by this pulsed expansion and also from the compressor via the pipes (see Figure 7 for vibration spectrum at the Cold End measured from Polycold).

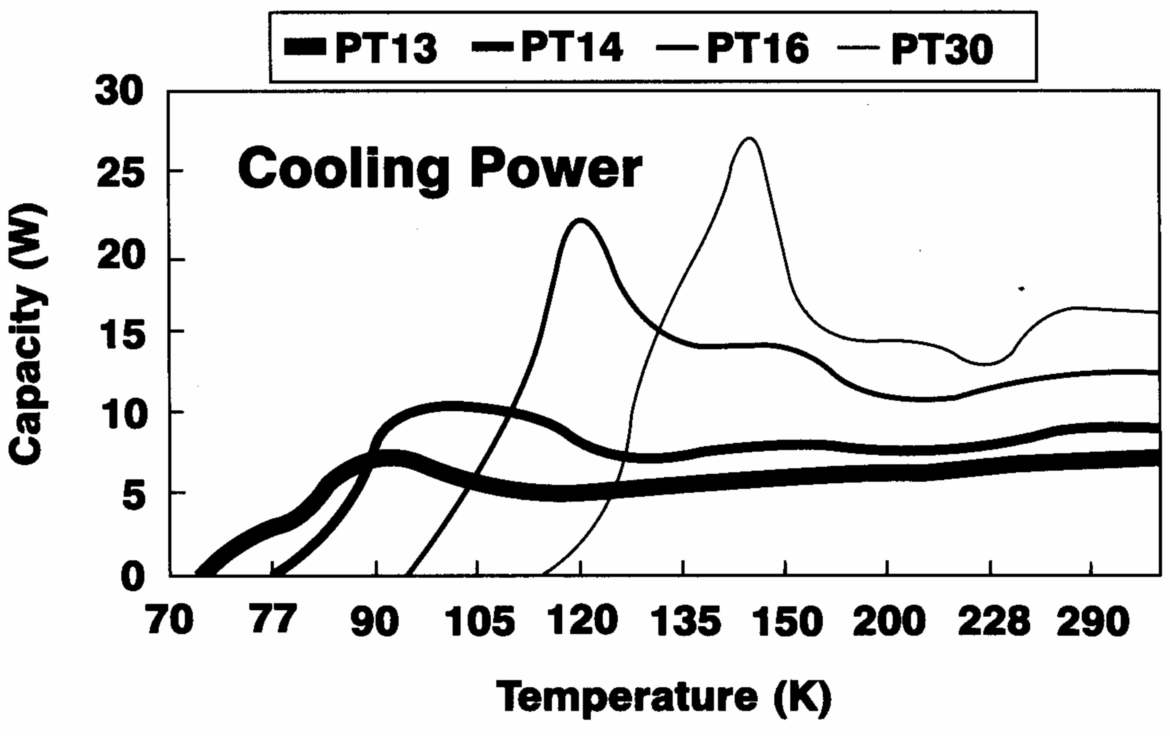


Figure 4: Cooling power of CryoTiger at the cold head achieved with different gas brands

ODTs CryoTiger (Construction see Figure 9) cryostat can replace the current cryostat tank (CFC or Bath Cryostat) leaving the CCD head unmodified. From Figure 4 it can be seen, that the gas brand PT14 is the most suitable, because this gives a similar performance as liquid nitrogen. It gives a cooling power of more than 6 Watts at 90 K.

Figure 5: Flexible stainless steel gas lines from 1.5 to 50 meters length are available

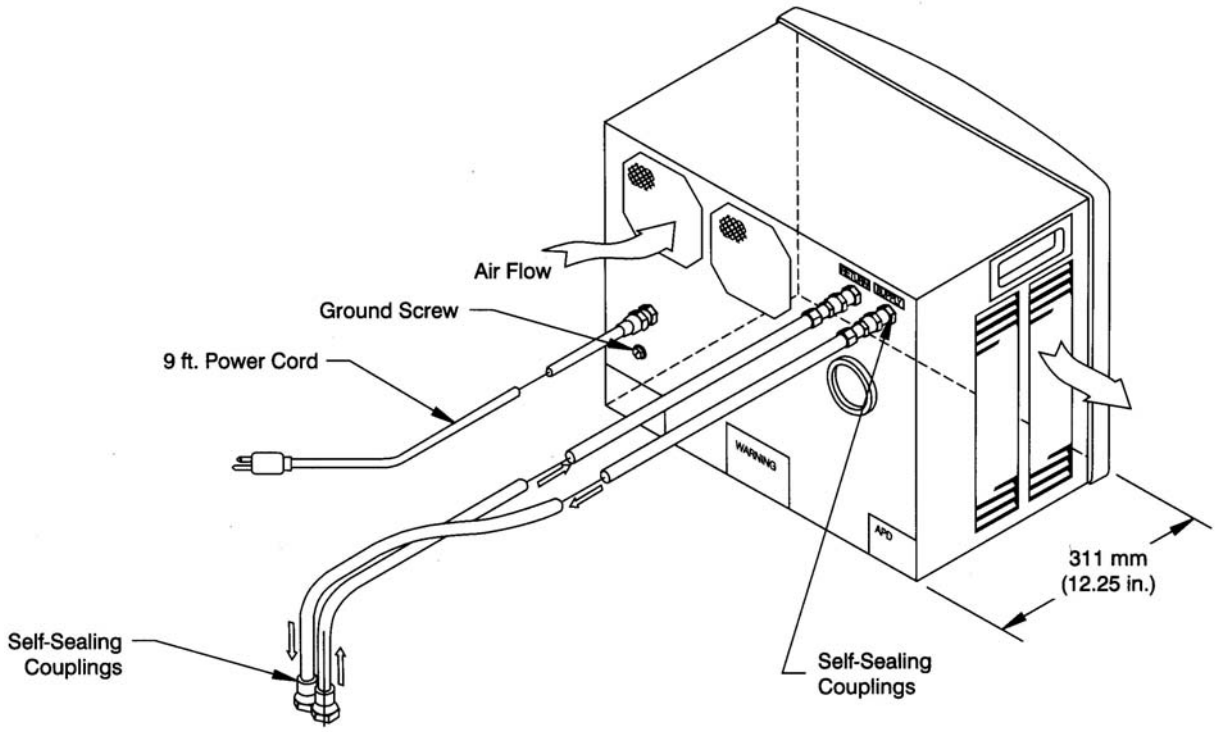
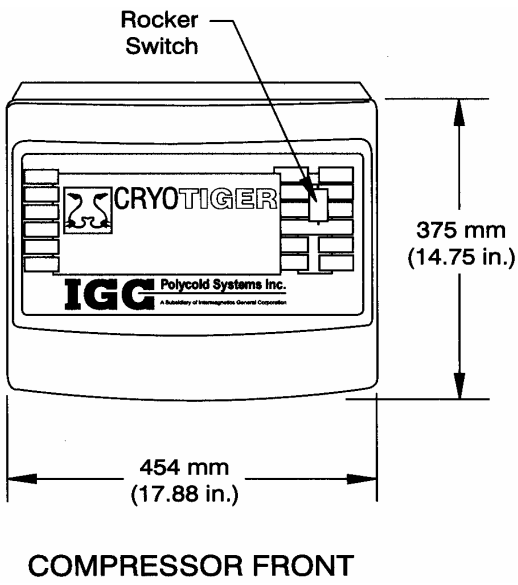


Figure 6: Compressor of CryoTiger

The gas line (Figure 5) connects the Cold End with a compressor, which is advertised as very robust and durable, because it consists of standard household refrigerator compressor parts. It is operated with 220 V/ 50 Hz. Its power consumption is 520 Watts. Now it is air-cooled, but a water-cooled version is under development and should be available this year. The noise of this air-cooled compressor is given with 56 dBA. Its weight is 32.2 kg. All gas couplings are self-sealing, but they should not be connected and disconnected too often. There are reports [5] [6], that if the couplings are reconnected in a humid environment, after some months a freezing in the head can happen. This would have the consequence, that there is no cooling anymore. We prevent this with a filter dryer, which is included into the proposed set-up. In case of a freezing the system has to be warmed up to +6 degree centigrade twice in order to get rid of the ice. It is recommended to do this anyway as a regular maintenance approx. every 6 months.



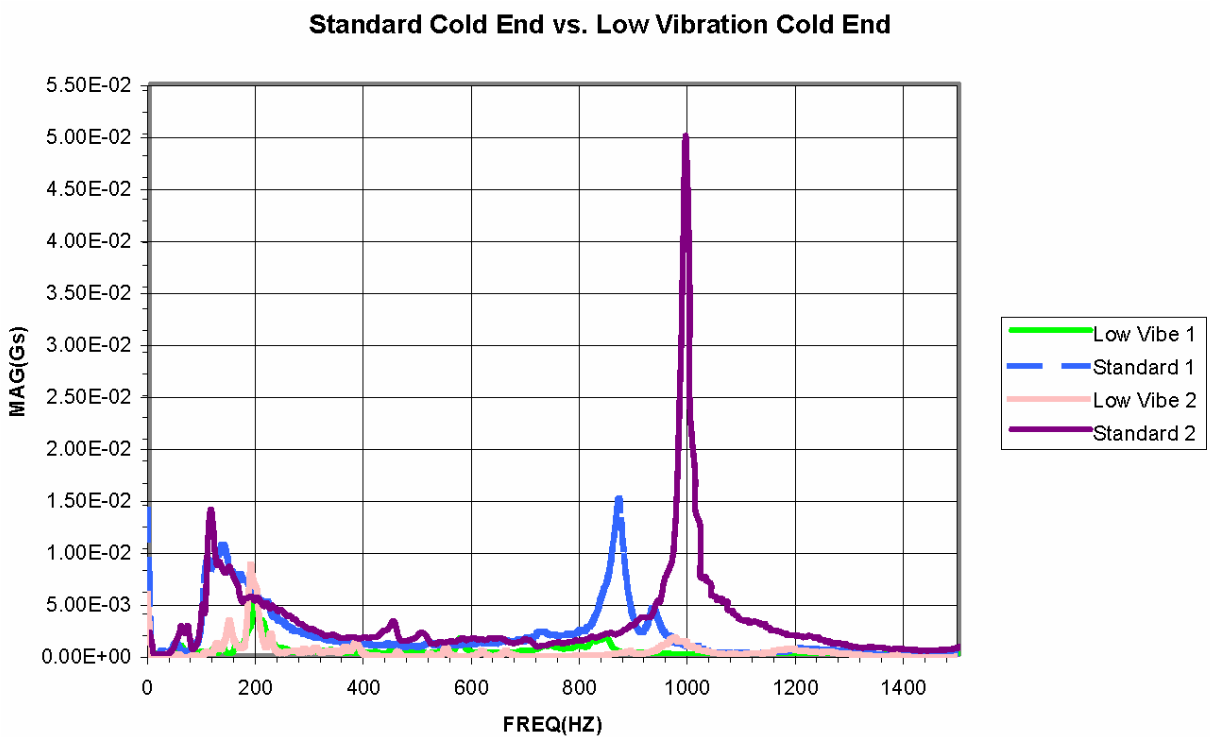


Figure 7: Vibration spectrum measured at the Cold End (G = earth acceleration, Standard 1 & 2 is used) (A vibration spectrum of the compressor could be measured on request by the Integration lab)

5 Experience with CryoTiger cooler at ODT test-bench in Garching

From our half year test of the CryoTiger cryostat in our test-bench we got very good experiences:

Since December 2002 we are using the CryoTiger cryostat there under highest thermal and mechanical stress possible.

We mounted and dismounted the CCD head many times and always reached the same minimum temperature again. Also the numerous thermal cycles during standard CCD testing (approx. 20 cycles) represent a high stress, which later will not happen at the telescope.

First we did not reach a temperature of -120 degree Celsius at the CCD surface, but after some optimization of the pressure on the cold-finger we are now reaching down to -150 degree centigrade at the CCD surface.
See Figure 8 for the cool-down curve with FIERA connected, which adds an additional thermal load. We need approx. 7 hours to reach a CCD surface temperature of -120 degree centigrade.

Figure 8: Cool-down curve of CryoTiger Cryostat with FIERA connected to CCDs

Because of all these positive experiences we can recommend this device for the observatory site. The best place for a CryoTiger cryostat would be a fixed focus, like a Coudé focus or a Nasmyth focus with a de-rotator, because of the gas pipes to the CryoTiger compressor. In principle, preferably a current CFC cryostat could be exchanged with a CryoTiger cryostat. But also at Cassegrain foci it can be installed, if a cable wrap rotator is built-up for the long gas lines.

6 Possible configuration at the telescope

The dimensions of a CryoTiger cryostat are smaller than the dimensions of a CFC or bath cryostat.

- Diameter without CCD head: 150 mm
- Length without CCD head without gas connectors: 158 mm
- Overall length with CCD head without gas connectors: 280 mm
- Total overall length: 360 mm

The CryoTiger compressor can be placed via its gas pipes up to 50 meters away from the cryostat. These gas pipes are quite stiff, but there are reports from observatories [5] [6], that the CryoTiger was even used at a Cassegrain focus with 50 meter long gas pipes to its compressor. These gas pipes can be bended with a radius down to approx. 20 cm. The tough torsion of these pipes is not a problem, because they can be mounted at the cold-head in any angular position. Vibrations problems are not expected from the CryoTiger, because there are no moving parts inside the cold-head. The heat from the compressor (approx. 500 W) could be removed by a special water cooled box or by the water cooled compressor version, which is promised by Polycold for the end of 2003.

Possible upgrade of existing cryostats with CryoTiger coolers:

Instrument	Focus type	Current cryostat type	Feasibility of upgrade to CryoTiger cryostat	Ranking (1 very suitable 6 impossible)
PARANAL				
FORS-1	Cassegrain	Bath cryostat	intensive discussion needed	4
FORS-2	Cassegrain	Bath cryostat	intensive discussion needed	4
UVES-blue	Nasmyth	CFC	straight forward	2
UVES-red	Nasmyth	CFC	straight forward	2
VIMOS-1	Nasmyth	CFC	intensive discussion needed	5
VIMOS-2	Nasmyth	CFC	intensive discussion needed	5
VIMOS-3	Nasmyth	CFC	intensive discussion needed	5
VIMOS-4	Nasmyth	CFC	intensive discussion needed	5
NAOS	Nasmyth	CFC	discussion needed	4
FLAMES	Nasmyth	CFC	straight forward	1
LA SILLA				
CES	Coudé	CFC	straight forward	1
EFOSC2	Cassegrain	Bath cryostat	intensive discussion needed	4
EMMIblue	Nasmyth	Bath cryostat	discussion needed	3
EMMIred	Nasmyth	Bath cryostat	discussion needed	3
FEROS	Special*)	CFC	straight forward	1
HARPS	Cassegrain	Special CFC	nearly impossible	5
SUSI-2	Nasmyth	Bath cryostat	discussion needed	3
WFI	Cassegrain	Special bath cryostat	impossible	6

*) FEROS is fiber-fed, stored in an air-conditioned room and not attached to the telescope

More specific advice can be requested by e-mail to sdeiries@eso.org.

7 Price of the CryoTiger cooling head delivered to Santiago

Item	Decription	Quantity	Price
1	Cold-head, compressor (220V/50Hz air-cooled), electrical insulators, filter-dryer, 90 deg Adapter, Line to line connector	1 set	8105 US $
2	Gas lines (1.2 m – 50 m (flexible, rigid))	1 set	680 – 4000 US $
3	Air freight	1 set	400 US $
4	L/C fee	1 pc	365 US $

Delivery time: 6 weeks from order, a water-cooled compressor will cost approx. 3000 US$ extra

See page 14 for the actual price list (valid for May 2003 and in US $) especially for the prices of the flexible and rigid (copper) gas-lines (lengths in feet) in order to calculate customized gas-line lengths.

In case of interest, ESO Chile would order directly the parts from Polycold Inc, USA.

Then, a person from ODT Garching would go to the observatory site with the corresponding cryostat housing parts doing the final assembly of the CryoTiger, the adaptation to the instrument and the cool-down and acceptance tests for this commissioning/upgrade.

The duration of these actions can be found in Chapter 8. The total downtime of the instrument will be 9 days or less in case of an upgrade (see Table above).

Price List

IGC Polycold Systems Inc.
A Subsidiary of Intermagnetics General Corporation

CryoTiger

June 2000

Product Description	Polycold Part #	Qty 1-10	Qty 11-20	Qty 21-40
Compressor (White Panel and Bezel)	T1102-01-000-XX	4250	3890	3560
Compressor (Plain White Panel and Bezel)	T1102-03-000-XX	4250	3890	3560
Cold end mylar wrap	T2114-00-XX	2390	2190	1980
Cold end nickel plated	T2114-01-XX	2565	2365	2138
Cold end high performance mylar wrap	T2111-00-XX	3160	2950	2670
Cold end high performance nickel plated	T2111-01-XX	3320	3135	2830
Super Flex Gas Lines **				
Gas lines (2) 5'	T3102-005-0-275-XX	680	620	560
Gas lines (2) 10'	T3102-010-0-275-XX	720	650	590
Gas lines (2) 15'	T3102-015-0-275-XX	750	725	700
Gas lines (2) 25'	T3102-025-0-275-XX	980	890	800
Gas lines (2) 35'	T3102-035-0-275-XX	1275	1195	1050
Gas lines (2) 50'	T3102-050-0-200-XX	1350	1230	1160
Copper Gas Lines **				
Gas lines (2) 1'	T3103-001-0-275-XX	560	520	460
Gas lines (2) 2'	T3103-002-0-275-XX	560	520	460
Gas lines (2) 3'	T3103-003-0-275-XX	560	520	460
Gas lines (2) 4'	T3103-004-0-275-XX	560	520	460
Gas lines (2) 5'	T3103-005-0-275-XX	560	520	460
Gas lines (2) 7'	T3103-007-0-275-XX	675	650	625
Gas lines (2) 10'	T3103-010-0-275-XX	695	650	625
Gas lines (2) 15'	T3103-015-0-275-XX	725	675	650
Gas lines (2) 20'	T3103-020-0-275-XX	730	690	630
Gas lines (2) 33'	T3103-033-0-250-XX	880	825	760
Gas lines (2) 40'	T3103-040-0-250-XX	1040	990	895
Gas lines (2) 50'	T3103-050-0-225-XX	1080	1030	935
Gas lines (2) 60'	T3103-060-0-225-XX	1190	1135	1045
Gas lines (2) 80'	T3103-080-0-210-XX	1520	1420	1310

NOTES
XX part number field is for refrigerant type: PT-13,14,16, or 30
**Change the middle number from "0" to "1"of the part number to get 90 elbow on one end - same price
Special length gas line quoted on request by factory, lead time and prices will vary.

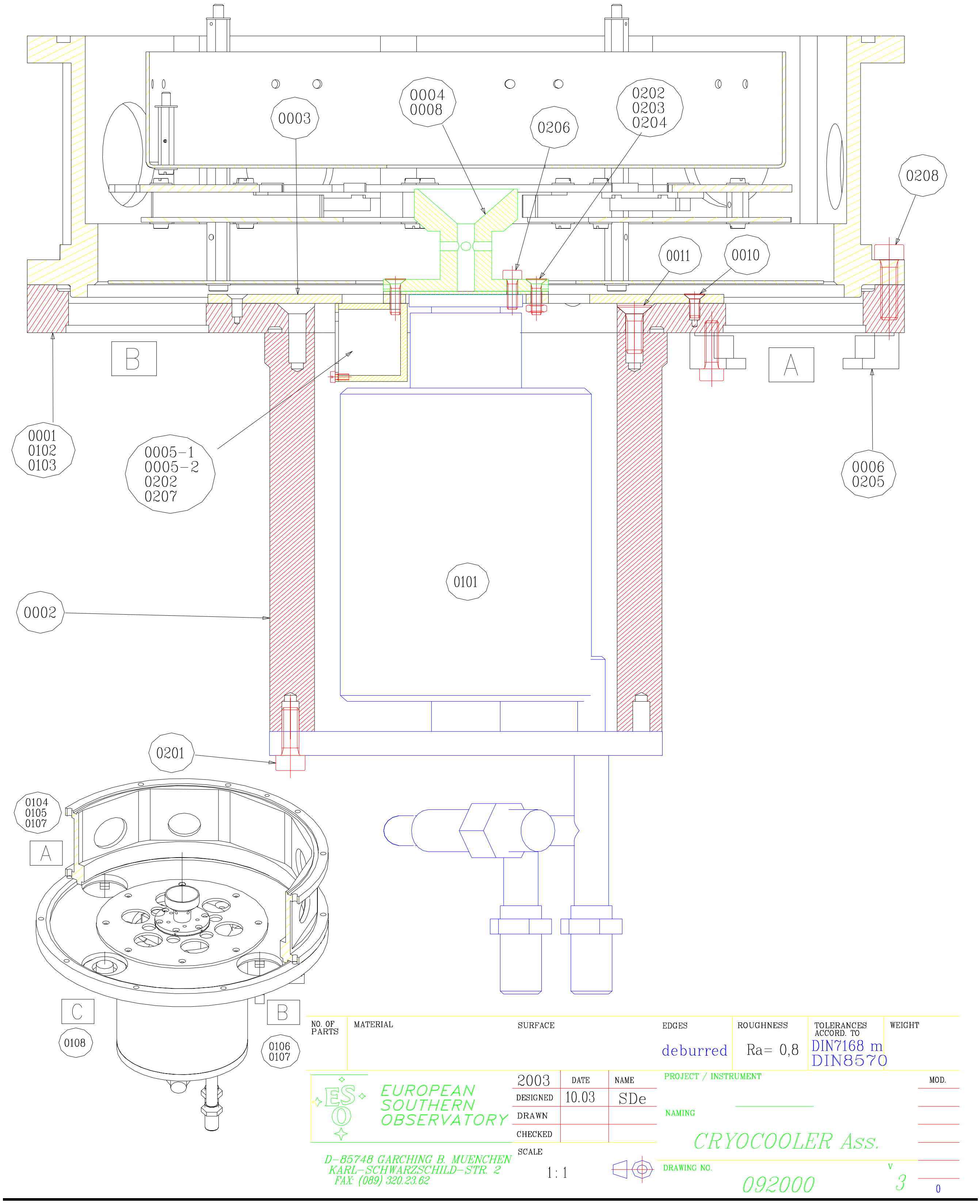


Figure 9: Final Drawing of complete CryoTiger Cryostat (CC)

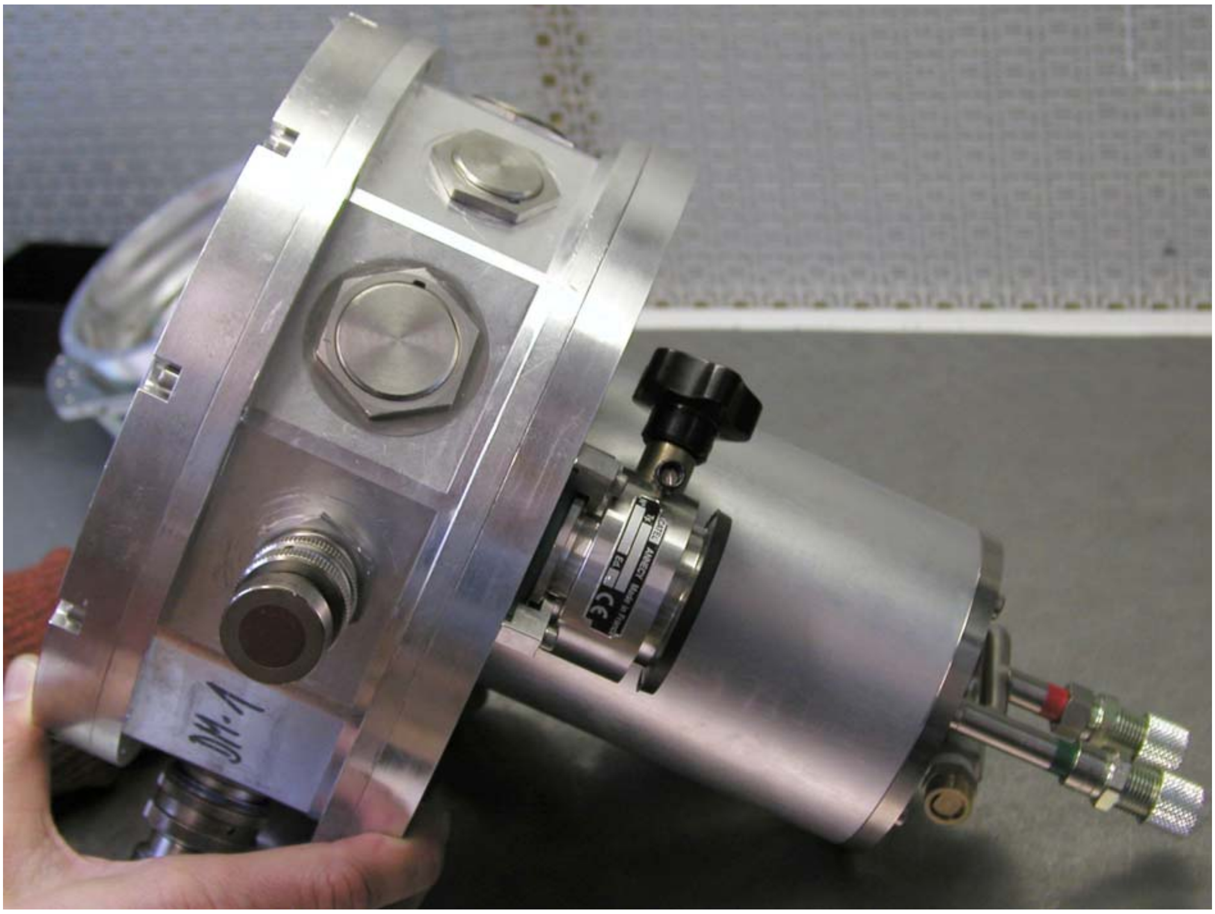


Figure 10: Side view of fully assembled CryoTiger Cryostat (CC) with CCD head mounted

8 Possible schedule for an on-site cooling system upgrade

The successful CryoTiger tests at ODT Garching and the positive reports from different observatories around the world encourage to give the following upgrade-plan for a possible cryostat change at the telescopes in La Silla and Paranal. This could be especially an option for current cryostats, which cause problems or should be operated in the future with less man-power investment.
In the following a possible schedule is given for such a possible upgrade:

***Time 0:* Decision is taken at the Observatory site for an upgrade with a CryoTiger cryostat**
***Next days:* Planning which configuration at the instrument is best and which parts would be needed (maybe a cable wrap rotator is needed for the long gas line)**
***Next days:* The CryoTiger and its components are ordered from Polycold Inc. directly from USA**

Approx. three months later: **A person from Garching is bringing the missing cryostat parts and does the integration of the CryoTiger cryostat and its installation at the instrument according to the following schedule:**

Schedule of installation of a CryoTiger cryostat at the observatory site:
Day 1 and 2: Unpacking of CryoTiger delivery and all other parts and warming up and dismounting of the current cryostat from the instrument to be upgraded **Day 3 and 4: Assembly of CryoTiger cryostat and adaptation to the current CCD head** **Day 5 and 6: Vacuum and cool-down tests**
Day 7-8: Installation at the telescope, changes in the cryostat controller
Day 9: Final test, acceptance

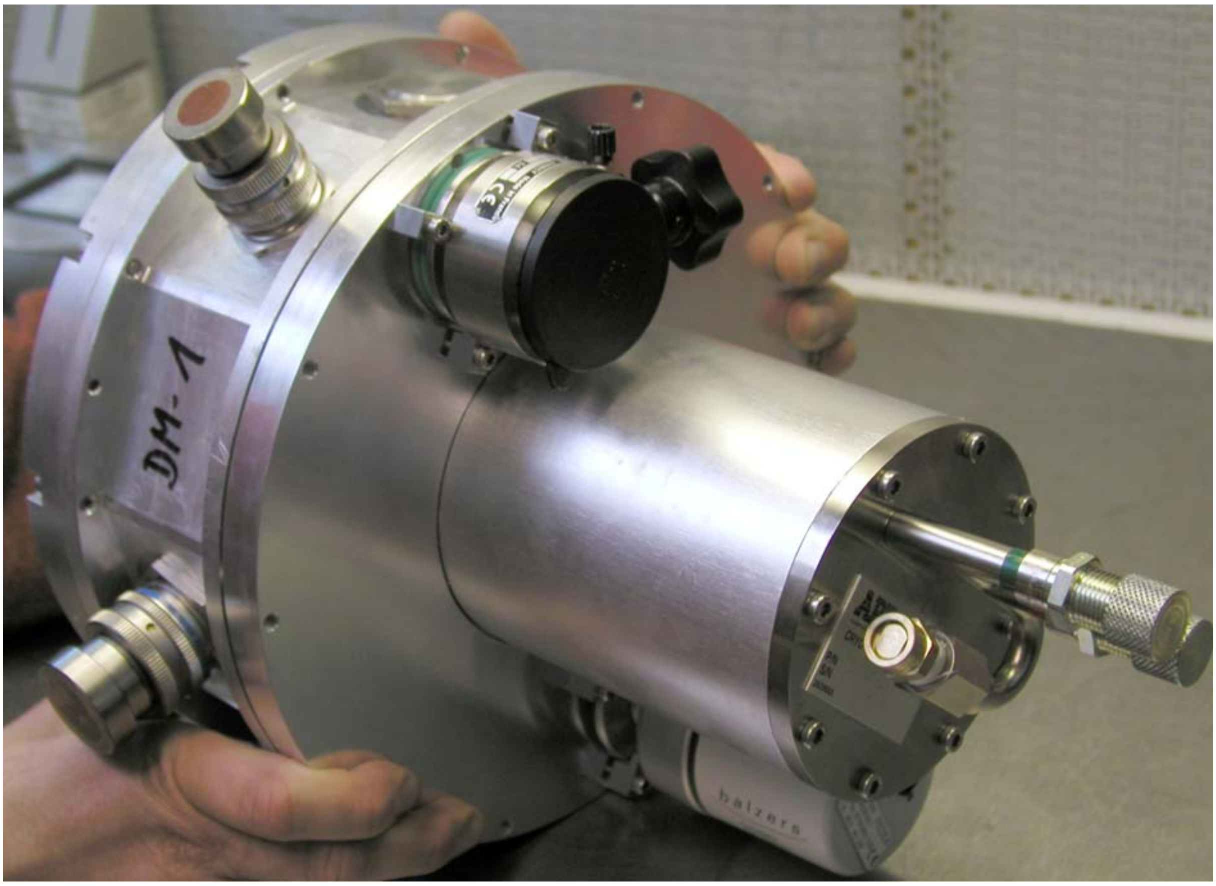


Figure 11: Rear view of fully assembled CryoTiger cryostat(note the positions of vacuum valve and gauge)

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- ___ M Kraus
- ___ R Conzelmann
- ___ G Hess
- ___ G Huster
- ___ F Koch
- ___ H Kotzlowski
- ___ M Quattri
- ___ J Quentin
- ___ M Schneermann
- ___ B Sokar

Optical Sys (5
- ___ L Noethe
- ___ E Brunetto
- ___ B Buzzoni
- ___ B Delabre
- ___ P Dierickx
- ___ F Franza
- ___ Ph Gitton
- ___ F Gonté

Product Assur. (5)
- ___ C Egedal

Software (24)
- ___ K Wirenstrand
- ___ E Allaert
- ___ L Andolfato
- ___ P Biereichel
- ___ G Chiozzi
- ___ M Comin
- ___ L Condorelli
- ___ P Duhoux
- ___ R Frahm
- ___ R Georgieva
- ___ B Gilli
- ___ B Gustafsson
- ___ A Huxley
- ___ B Jeram
- ___ R Karban
- ___ A Longinotti
- ___ M Nylund
- ___ C Ounnas
- ___ M Pasquato
- ___ W Pirani
- ___ D Popovic
- ___ E Pozna
- ___ M Schilling
- ___ P Sivera
- ___ H Sommer

TEL DIV (17
- ___ F Paresce
- ___ D Bonaccini
- ___ W Hackenberg

Interferometry
- ___ A Glindemann
- ___ R Conan
- ___ F Delplancke
- ___ F Derie
- ___ E Di Folco
- ___ B Koehler
- ___ S Leveque
- ___ S Menardi
- ___ T Phan Duc
- ___ F Puech
- ___ A Richichi
- ___ K Scales
- ___ A Wallander
- ___ R Wilhelm

ADMIN (19)
- ___ I Corbett

CP (23)
- ___ R Fischer
- ___ J Strasser
- ___ G Wieland

FIN (22)
- ___ P Fischer

ODG (20
- ___ C Cesarsky
- ___ M Basbilir

SCIENCE (13
- ___ B Leibundgut

VLT PRG SC (4)
- ___ A Renzini
- ___ M Sarazin

PARANAL
- ___ R Gilmozzi
- × J Spyromilio

VLTI Commis.
- ___ P Kervella
- ___ S Morel
- ___ M Schoeller
- ___ M Wittkowski

Engineering
- ___ R Tamai

Electronics
- ___ T Erm
- ___ P Gutierrez
- ___ J Haddad
- ___ G Harding
- ___ G Hüdepohl
- ___ H Nievas
- ___ J Osorio

Instrumentation
- ___ G Gillet
- ___ P Barriga
- ___ R Castillo
- × N Haddad
- × P Mardones
- ___ M Riquelme
- × P Robert

Mechanics
- ___ E Bugueno
- ___ G Ehrenfeld
- ___ V Heinz
- ___ P Ibanez
- ___ M Tapia

Optics
- ___ P Giordano
- ___ S Guisard
- ___ C Lobos

Software
- ___ R Amestica
- ___ A Aguayo
- ___ J Argomedo
- ___ P Baksai
- ___ J Brancacho
- ___ B Bauvir
- ___ N Housen
- ___ M Kiekebusch
- ___ I Munoz
- ___ S Sandrock
- ___ R Schmutzer
- ___ S Skole

Logistics&Facilities
- ___ F Ruseler
- ___ R Bascuñan
- ___ J Costa
- ___ T Höög
- ___ F Luco
- ___ H Nuñez

Science Ops
- × G Mathys
- ___ M Acevedo
- ___ B Camucet
- ___ C Ceron
- ___ M Chadid
- × J-G Cuby
- ___ N Hurtado
- ___ D Hutsemekers
- ___ A Kaufer
- ___ C Lidman
- ___ A Lopez
- ___ G Marconi
- ___ C McKinstry
- ___ J Navarette
- ___ J Parra
- ___ A Pino
- ___ T Szeifert

LA SILLA
- × J Melnick
- ___ L Aguila
- × G Andreoni
- ___ P Francois
- ___ F Gutierrez
- × O Hainaut
- ___ G Ihle
- ___ L Nyman
- ___ M Sterzik
- × U Weilenmann

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- ___ D Hofstadt

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