New Cryostats for Scientific CCD Systems in the VLT Era

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Introduction

Since the installation of the first device on La Silla in 1982, the CCD has become the standard detector in ESO's optical instruments. In order to use a CCD for astronomy, it must be cooled to 140–160 deg K to reduce dark current to a negligible level. For this reason, the CCD detectors are mounted in vacuum dewars with cooling provided by liquid nitrogen (77 deg K). In addition to keeping the CCD cold, the dewar also serves the very important purpose of holding the CCD in a very rigid position, with motion of less than 3 microns as the telescope points to different positions in the sky.

During the past 15 years, ESO has installed 36 different CCDs at the telescopes on La Silla, of which 10 are presently operational. For these CCDs, two generations of CCD dewars have been used. Most of the CCDs are cooled using the well-known HD-2(8) dewar made by InfraRed Laboratory.

CCD technology has developed very rapidly during the last few years so that the size of currently available chips is much larger than the preceding generations and it is not possible to fit the new large devices into the old dewars. Besides having enough room to house the CCD, more cooling "power" is needed for larger CCDs. In a well-constructed dewar, the most important heat load is the thermal radiation of the window. With a larger window, the old HD-2(8) dewar would need refilling twice a day to keep the detector cold.

Figure 1 : Continuous-flow cryostat.

Since ESO has a need for a large number of optical detector systems during the VLT era, now is the opportune time to reconsider the complete re-design of the CCD dewars.

Requirements

A major goal of the VLT plan is the operation of the Paranal facility with the minimum number of staff. Since the filling of dewars with liquid nitrogen can be a labour-intensive process, one goal of a new design must be the maximisation of the nitrogen "hold time". After investigation of the cooling requirements of each instrument, it was clear that a universal system cannot be designed for all instruments. However, we have been able to reduce the complexity by splitting the dewar functionality into two parts:

• a detector head that holds the CCD detectors and associated electronics, such as wiring, analogue filters, preamplifier and temperature sensing and control,

• a cryostat that provides the cooling function.

To our knowledge, the new ESO design is one of the few that distinctly splits the dewar into these two parts. By doing this, we have been able to design a single detector head that can be used for nearly all of the instruments. The interface between the cryostat and the head has been designed such that an exchange of cryostat is a very simple operation which does not require any special adjustment. Apart from the time due to the vacuum and cryogenic operation (warming-up, evacuation, cooling) an exchange of cryostat does not require more than a few minutes.

The major differences in various instruments are related to the cryostat function and we have designed a system optimised for each of the two major categories: static instruments and movable instruments.

Static Instruments – Continuous Flow Cryostat

Some large instruments or instruments fitted with optical fibres are simply resting on the Nasmyth platform and do not move relative to the telescope building. UVES is the first instrument of this type and, being a high-resolution spectrograph, it is very sensitive to any type of disturbance, especially thermal variations. For this reason the complete instrument, including the two detector systems, is surrounded by a thermal enclosure. It would be a major source of

Figure 2 : Bath cryostat, Cassegrain version.

disturbance if it were necessary to open the thermal enclosure to refill the detector cryostats every day. Therefore, for UVES, and other Nasmyth and coudé instruments, we have developed a continuous-flow cryostat. This cryostat is based on a continuous circulation of coolant supplied from a de-localised reserve of liquid nitrogen. This system uses a large tank of liquid nitrogen so that the cooling operates autonomously for relatively long periods between replacement of the nitrogen reservoir. Another advantage of the continuous-flow cryostat is that it only occupies a small volume at the instrument. Figure 1 shows the compactness of the continuous-flow cryostat relative to the detector head.

One prototype cryostat based on this principle has been successfully operating at the CES since March 1995. Based on this experience, we modified the design to make a more compact cryostat which has achieved an especially low rate of nitrogen consumption. Using a 120-litre storage tank, the standard selected for the VLT, the hold time can easily reach 1 month.

Movable Instruments – Bath Cryostat

These instruments are directly bolted onto the telescope adapter-rotator and thus move with the telescope. For these instruments, the nitrogen must be stored in a cryostat tank that is attached directly to the detector head. This type is called a "bath cryostat", since the coolant is stored in a local tank (i.e. "bath") of liquid nitrogen. The design goals for the bath cryostat include: (a) hold time of at least 2 days, and (b) an interface similar to the old HD-2(8) dewar which offers the possibility of upgrades of systems in operation on La Silla.

Many users of bath cryostat dewars are aware of the constraint that only 50% of the tank can be filled, otherwise the liquid nitrogen can be dumped out of the tank when the telescope is moved. A tank only half full will provide only half of the hold time of a full tank. A major new feature of the new ESO bath cryostat design is a special anti-overflow device that allows 90% filling of the nitrogen tank, independent of the angular position of the cryostat. This can be achieved if the motion of the cryostat axis is limited to half a sphere (relative to the gravity vector), which is true for the two instrument adapters of the VLT (azimuth-elevation telescope mount).

The design of the bath cryostat was a compromise between the total container mass and the mass of the liquid nitrogen in the tank. Our goal was to maximise the amount of liquid nitrogen in the tank while keeping the outside of the cryostat the same size as the older HD-2(8) design. The new cryostat can be filled to 6 litres, three times the 2 litre capacity of the HD-2(8) design (50% fill).

Two different bath cryostats are needed to accommodate the different motions at the Nasmyth and Cassegrain foci. Figures 2 and 3 respectively show the Cassegrain and the Nasmyth versions of the bath cryostat with the detector head integrated.

Five bath cryostats have been fabricated, assembled and tested. The tests of the cryostat for the first instrument to be equipped with this new system (FORS) have proven that we meet the requirements. Hold time of more than 48 hours has been achieved for a complete system with CCD and temperature control. An agreement based on a technology transfer has been signed with the French company SNLS which is prepared to commercialise this cryostat design.

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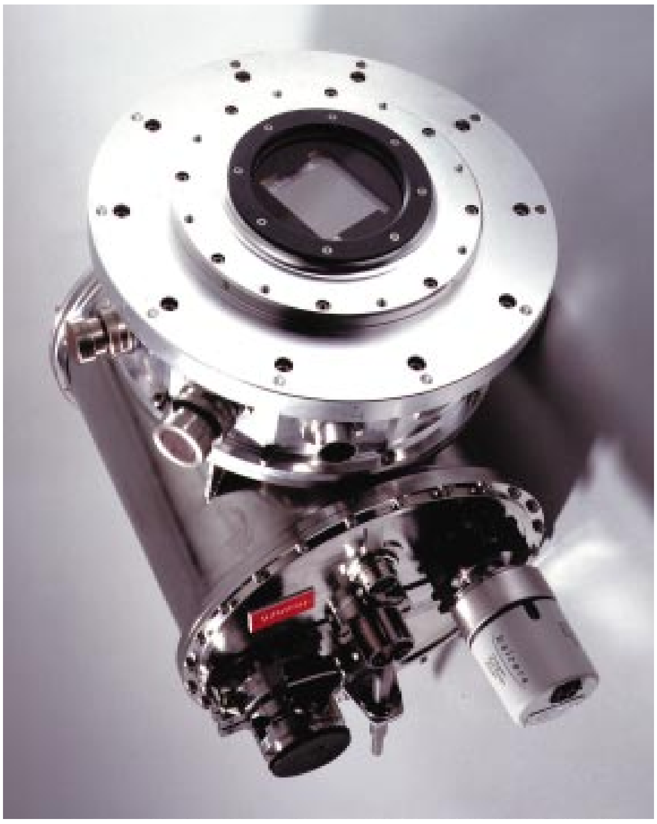

Figure 3 : Bath cryostat, Nasmyth version.