QMC Instruments Ltd

Cryogenic Composite Bolometer System Operating Manual

Model QSIB/2

Serial N^{o}'s: System Detector Preamplifier Cryostat

13th April 2005

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Lifting Warning

Take care when moving / lifting the system because it is heavy. You should ensure that provision is made for manipulation of the cryostat.

Using Cryogens

Handling cryogenic liquids can be dangerous. If you are not already familiar with the standard procedures appropriate for the use of liquid nitrogen and liquid helium, please seek advice before proceeding.

Safety Warning

Operating this equipment involves the use of vacuum and cryogenic techniques that are potentially dangerous. Please read this manual carefully – it may help to avoid accidents. The photo below shows a damaged system. We do not want this to happen to you. Please ensure that all personnel involved in the use of the detector system are fully accustomed with the techniques involved.

Introduction

- **The Detector System. Type QSIB/2**

This is a QMC Instruments Ltd. detector system type QSIB/2 which incorporates a composite structure silicon thermal bolometer. The detector is mounted in an optical integrating cavity behind Winston cone optics and low pass blocking filters. These components are mounted in a type TK1813 liquid helium cryostat.

- **The Detector. Type QSIB/X**

The active absorbing area of the detector is 2mm diameter. The Silicon thermistor is approximately cubic with sides of 0.25mm and this is mounted with good thermal contact on a blackened thin diamond substrate to provide enhanced absorption over a wide range of wavelengths through the IR region. The detector is designed for operation around 4.2K.

- **Filter Performance**

Unrivalled cryogenic efficiency is achieved using our unique multimesh filter technology (product code QMMF.) This versatile filter technology has been qualified for space use and was originally developed for astronomical applications where the need exists for high in-band transmission efficiency and good out-of-band rejection in order to generate the right conditions for ultra-sensitive detection.

In this system, low pass filters with transmission edge at $600cm^{-1}$ (18THz) are mounted on the liquid nitrogen radiation shield of the cryostat and on the entrance aperture of the cone optics at 4.2K. These filters offer efficient short wavelength blocking which greatly reduces the radiative heat load incident on the liquid helium cooled stage of the cryostat. Hence we achieve excellent cryogenic efficiency and optimised sensitivity

The filters are mounted using a high thermal conductivity low temperature varnish to ensure that they operate at as low a temperature as possible. The measured transmission spectra of the filters in this system are presented in **Appendix C** of this document.

- **The Preamplifier**

The system incorporates a ULN95 preamplifier. This is mounted to the side of the body of the cryostat to reduce signal interference. The preamplifier is run either from internal rechargeable NiCad batteries or from an external supply. The circuit includes a bias potentiometer and a number of test/monitoring facilities for ease of operation.

QMC Instruments Ltd

Packing List

The following items are included in this shipment. Please check the contents against this list and contact QMC Instruments as soon as possible if you suspect that any items are damaged or missing.

Detector System Type QSIB/2

- Thomas Keating Ltd. cryostat type TK1813 containing:
  - Detector type QSIB/X
  - Cold condensing optics (f/3.5 Winston cone with 15mm diameter entrance aperture)
  - 600cm^{-1} Low pass filters type QMMF mounted on the Winston cone at 4.2K and on the 77K stage aperture with 16mm diameter through aperture

- Cryostat fitted with
  - Transit protection fixtures
  - Safety pressure relief valve
  - Non-return valve
  - 2 off preamplifier mounting screws

- Cryostat central neck safety baffle
- ULN95 preamplifier with power supply lead
- Outer vacuum case base-plate with O-ring
- 77K radiation shield base-plate
- Operating manual
- Liquid nitrogen blow-out tube
- Spares kit which includes:
  - 1 off 10 pin socket and shroud
  - Complete set of O-rings and washers
  - Set of screws
  - 2 off brass disks for the blow-out tube
  - blanking disks and circlips
  - NW16 clamp, O-ring and 16mm KF adaptor nozzle type pipe fitting
  - 4 off support struts
  - M3 and M4 Allen keys

1. Unpacking and Preparing the System for Operation

The system is not supplied in a condition that renders it ready for immediate use. A temporary base-plate has been installed to protect the system from damage during its journey. The following procedure must be carried out to prepare the detector system for operation. To prepare the system for transportation the following procedure should be followed in reverse.

Please note that the photos included are general photos that may not be specific to your particular system.

Initial Inspection

Please inspect the box in which the goods were shipped and the contents for any obvious sign that damage has occurred in transit. If you think that the package has been damaged in some way, please contact us before proceeding further. Remember that your detector system is guaranteed for two years against failure resulting from effects beyond your control, and we will be happy to make any repairs at no cost to you during this time.

Please note that the O-rings, bolts, screws, black base-plate spacers etc, that are required to prepare the system, can be found in the spares kit.

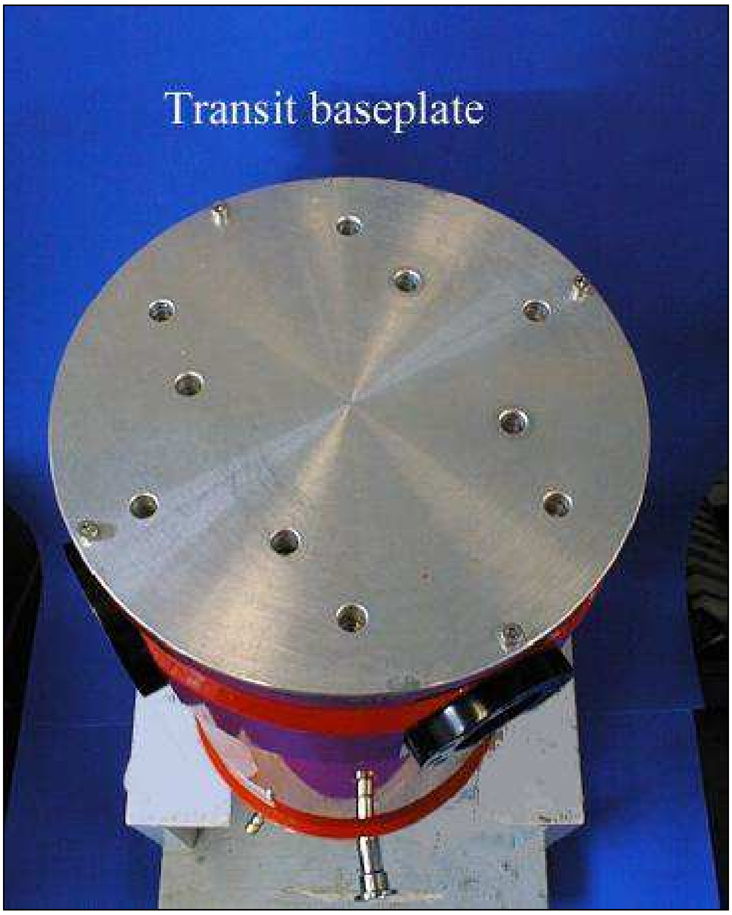


Photo 1.1. Transit base-plate

Removing the transit-plate. Photo 1.1

Invert the cryostat to allow access to the bottom-plate. The weight of the cryostat should not be allowed to rest on any of the top-plate fittings. Rather it should be supported by the top lifting handle. To avoid marking the chrome handle stand the system on something to protect it such as soft tissue / cloth or bubble wrap.

The aluminium transit base-plate should be removed by removing the socket head screws holding it in place and carefully lifting it off of the cryostat.

Detector / optics checks. Photo 1.2

Taking care not to disturb the wires that run along the work surface, remove the four support pillars.

The detector block is bolted onto the cold-plate with the Winston Cone attached to it. There are two filters, one of which can be found mounted onto the end of the Winston Cone and held in place by the filter cap; the other is located in the optical aperture of the liquid nitrogen shield. It is important for good detector performance that the detector / cone assembly is in good thermal contact with the work surface. You should confirm that the detector block is firmly screwed in position and that the filters have not worked loose in transit. It is possible that vacuum grease that is used to ensure good thermal contact of the detector block with the cold-plate, and small flakes of hardened GE varnish, which is a yellow substance used to glue the wires to the cold-plate, may be found in the cryostat. This is quite normal and will not give rise to operating difficulties.

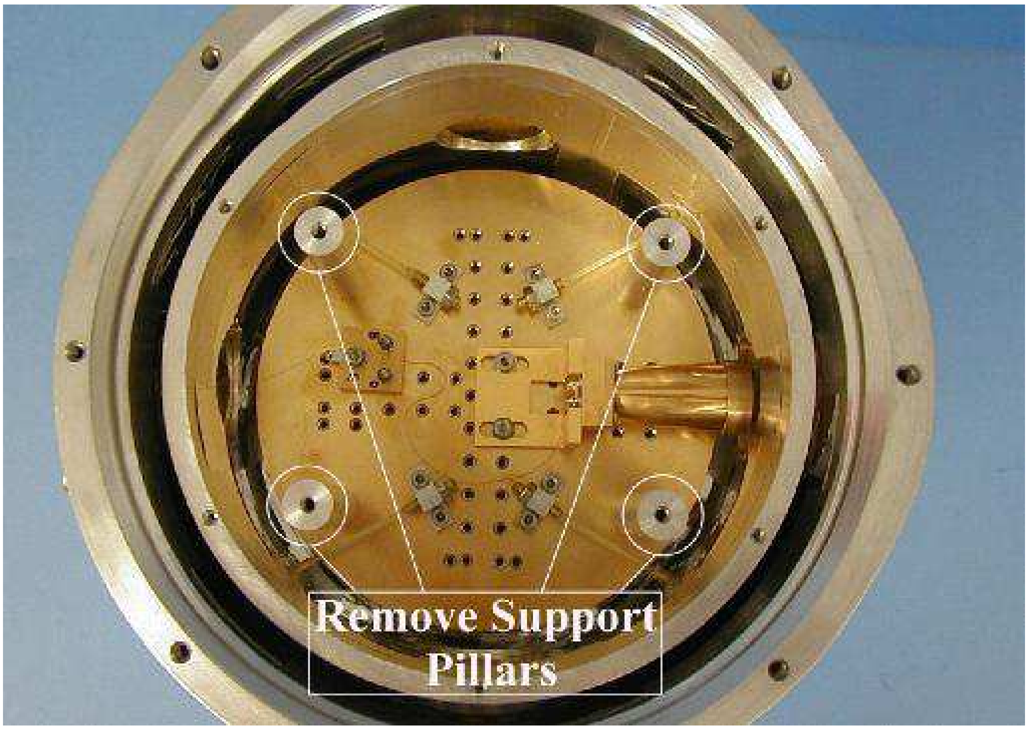


Photo 1.2. The 4 support pillars and the detector / optics

Fitting the cryostat base-plates. Photos 1.3 and 1.4

The TK1813 cryostat has a liquid nitrogen cooled 77K radiation shield base-plate, and a room temperature outer vacuum casing base-plate. The 77K shield is located using the set of M3 screws provided. The black OVC base-plate is located using the M4 socket headed screws provided. It is important to check that the O-ring is in place, that it is clean, well greased and that its seating is free of marks and scratches. The screws locating the OVC base-plate should not be overtightened, as this can distort the O-ring and perhaps cause vacuum leaks. If the screws are equally tightened, it is normal for a small gap to show between the lip of the OVC base-plate and the bottom of the cryostat casing.

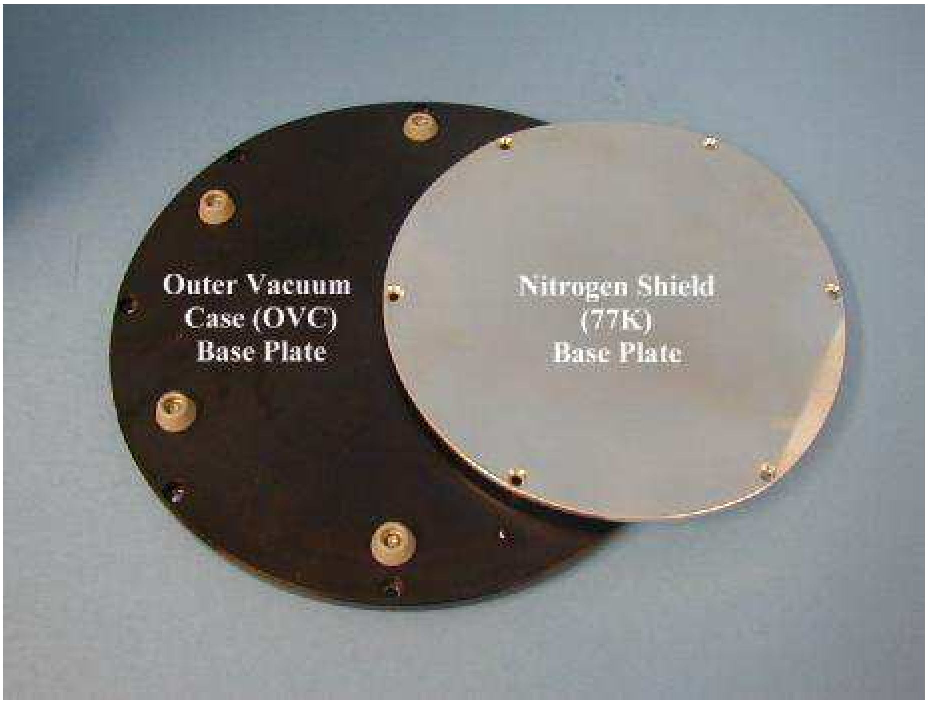


Photo 1.3. Cryostat radiation shield base-plates

Photo 1.4. Liquid N_2 base-plate in position

The preamplifier. Photos 1.5 and 5.1(a, b)

The ULN95 preamplifier is detached from the cryostat during transport. It should be connected to the electrical output port on the side of the cryostat. The preamplifier box locates to the black clamping ring using the two short M6 screws supplied. Appropriate clearance holes are located in the preamplifier casing back panel.

The preamplifier input plug should be connected to the cryostat electrical output socket through the larger hole in the preamplifier casing. The battery stack, which has been disconnected during transit, should be reconnected and recharged prior to operation of the detector

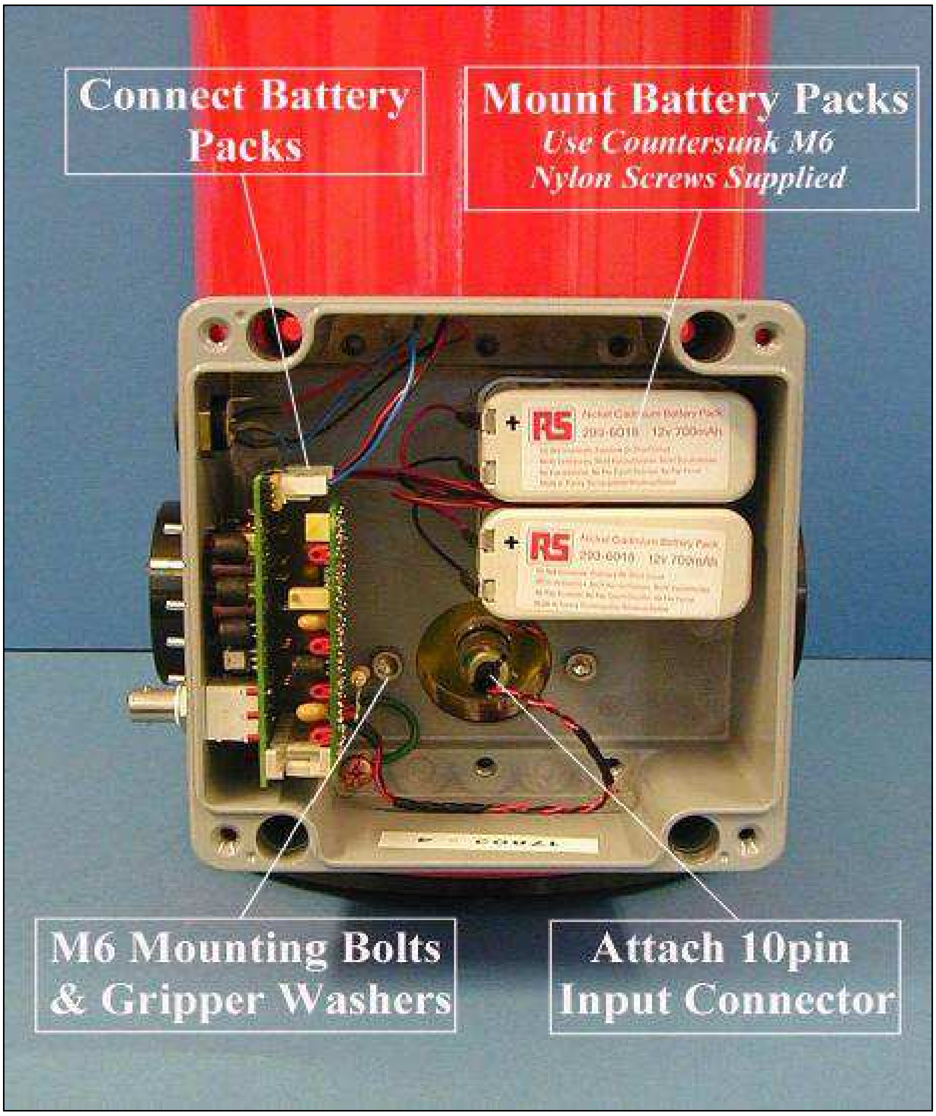


Photo. 1.5. Mounting the preamplifier

2. Evacuating the Cryostat

Please refer to **photo 2.1.** Before cooling the cryostat, the vacuum chamber must be evacuated by connecting a suitable pump to the evacuation port located on the top-plate. The pump should be capable of reducing the pressure in the cryostat to below 10^{-1}mbar. This can with time be achieved using a rotary pump only, but for optimum cryogenic performance of the cryostat it is better to use a diffusion or turbo-molecular pump to reduce the pressure still further.

The pumping system should ideally have a pressure gauge measuring the pressure as close to the cryostat as possible. The spare NW16/KF16 port located on the top-plate of the cryostat can be used to attach a pressure gauge to monitor the pressure in the cryostat directly.

Always check the quality of the pump system and pumping line prior to opening the cryostat valve.

The vacuum valve should be opened very slowly when the pressure in the cryostat is at or close to atmospheric. This prevents rapid pressure changes that risk damage to the delicate components inside the cryostat.

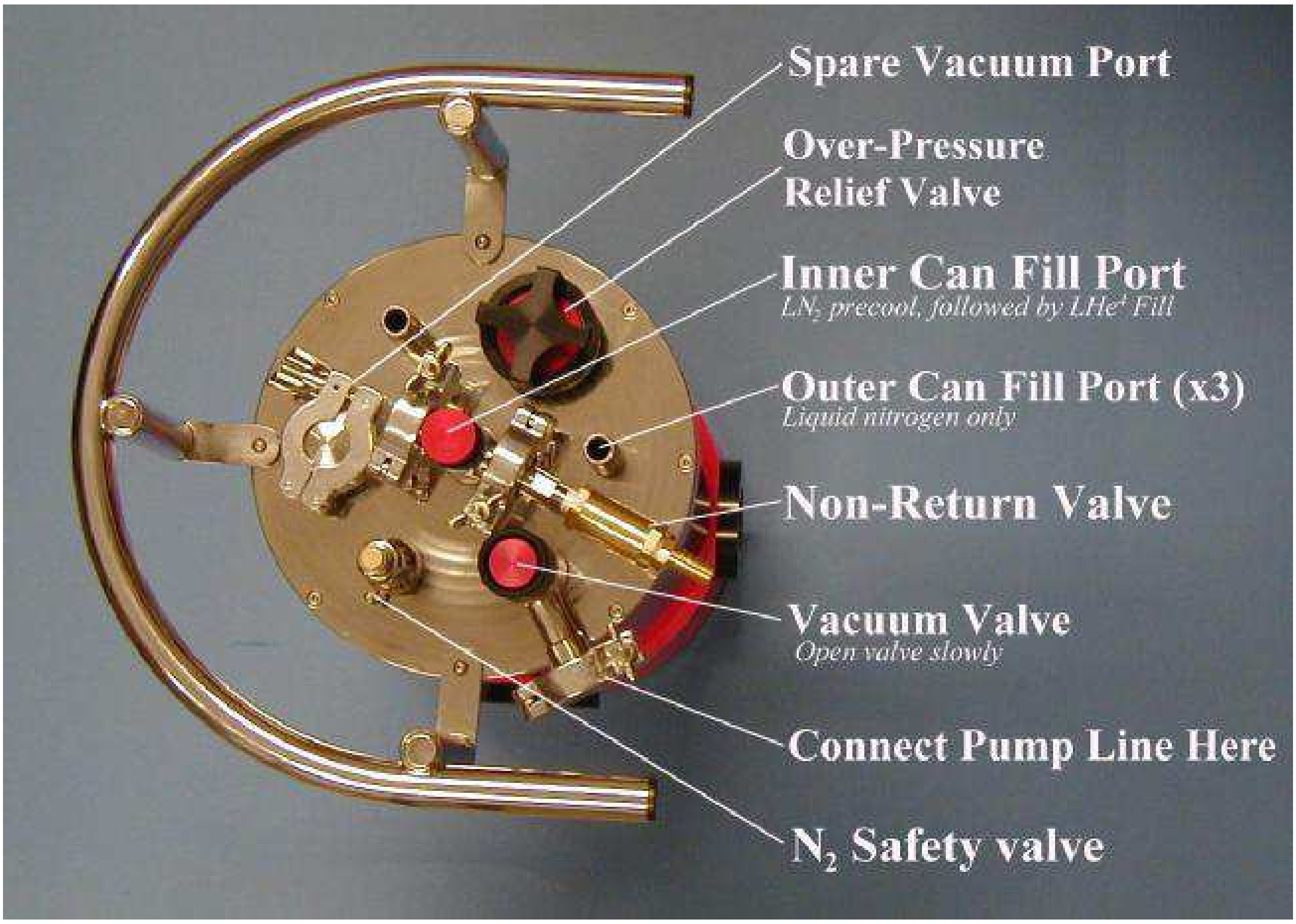


Photo 2.1. Cryostat top-plate fittings

3. Liquid Nitrogen (LN_2) Pre-cool

IMPORTANT: Refer to the warning at the front of the manual before proceeding with cryogenic cooling of this system.

Vacuum pumping prior to cooling

The pressure in the cryostat should drop rapidly when filling with LN_2 because some of the gas, mainly oxygen, begins to cryopump (condense onto the cold surfaces). The system can remain attached to the pump during the pre-cool period if the pump you are using is an oil diffusion or turbomolecular type pump with a base pressure lower than 10^{-6}mbar. If you are only using a rotary pump, then the pressure in the cryostat will be lower during the pre-cool period than the pump is capable of generating, and the pump must therefore be detached immediately prior to cooling.

LN_2 pre-cool

When a satisfactory pressure has been reached in the cryostat vacuum chamber, it is necessary to pre-cool the cryostat with LN_2 before cooling with liquid helium (LHe). This will reduce the amount of LHe used.

Fill both LN_2 and LHe reservoirs with LN_2 using the appropriate ports, **photo 2.1**. LN_2 need only be poured in through one of the three LN_2 ports. The neck baffle assembly should be unscrewed and removed from the central LHe port to enable the LN_2 cryogen to be poured into the LHe reservoir.

For preference, transfer the LN_2 directly from a pressurized LN_2 storage dewar which should take around 15 minutes to complete. You may have to pour the LN_2 using a bucket and a funnel, as shown in **photo 3.1**, which may take in excess of an hour to complete. In this case, the funnel must be attached to a pipe which extends down into the neck and well into the reservoir itself. For a TK1813 a length of at least 200mm is needed. The pipe diameter should be about 6mm (1/4 inch) to allow both reasonable throughput and space outside of the pipe for boiling N_2 gas to escape.

When both reservoirs are full of LN_2, ensure that the safety valves are all in place

The top-plate fittings are shown in **photo 2.1**. The helium reservoir access port should always be fitted with the non-return valve to stop the condensation of moisture within the neck. This moisture could freeze and block the neck of the cryostat which in turn could lead to failure and damage.

The cryostat neck baffle is shown in **photo 3.2**. The baffle incorporates an overpressure release valve. Should an ice blockage form in the central neck of the cryostat, gas will be unable to escape through the non-return valve. Such an event will cause the overpressure relief valve, located at the top of the baffle, to open thereby releasing pressure from the inner reservoir.

Time to cool the system to LN_2 temperature (77K)

The length of pre-cool period will determine the initial efficiency of use of LHe. For a TK1813 we recommend a minimum pre-cool of four hours, but it is often convenient to leave a cryostat overnight if, for example, it has been attached to a pump throughout the day. Larger cryostats (TK1840, TK1865 and TK1875) require a longer minimum pre-cool period because the additional gas cooled radiation shield is only weakly linked to the other temperature stages and therefore cools slowly. For these larger cryostats, a twelve hour minimum pre-cool period is recommended.

Photo 3.1. Using a funnel to fill the cryostat with LN_2

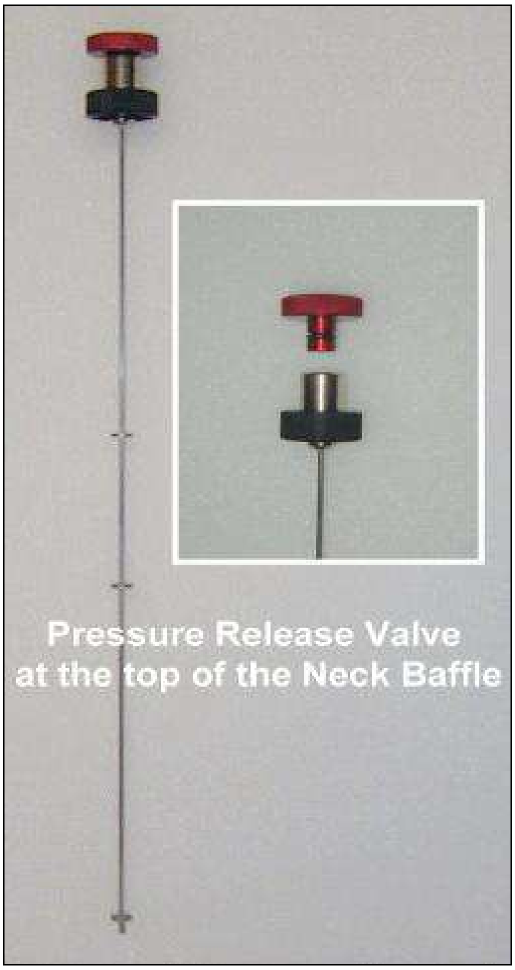


Photo 3.2. Cryostat neck baffle

Removing the LN_2 from the central reservoir

When the pre-cool period is complete the LN_2 in the He reservoir should be removed. This is best done using a supply of compressed dry N_2 gas and the blow out tube supplied. The O-ring and tightening ring around the central reservoir access port should be arranged on the blow out tube as shown in **photo 3.3**. The non-return valve should be replaced with the adaptor nozzle. The LN_2 can now be removed from the central reservoir by applying a small overpressure within the reservoir as shown in **photo 3.4.** The LN_2 is directed into a safe container, and can be used to replenish the outer reservoir.

Ensure that all of the LN_2 is removed

All LN_2 must be removed from the central reservoir before the LHe transfer is started. Any LN_2 remaining in the central reservoir will be frozen by the He, and the ice forms an effective insulating layer which will prevent the detector reaching its intended operating temperature. A large amount of expensive LHe will also be wasted in creating a small amount of nitrogen ice!

At this stage therefore, the supply of dry nitrogen gas can be continued until the stream of ejected LN_2 ceases. Ensure that the blow out tube does not block, and that it is properly located and reaches the bottom of the He reservoir. In the case of an InSb detector, the detector impedance should be monitored to check that the temperature is above 77K (the composite Silicon thermistor exhibits no change in impedance above 10K.)

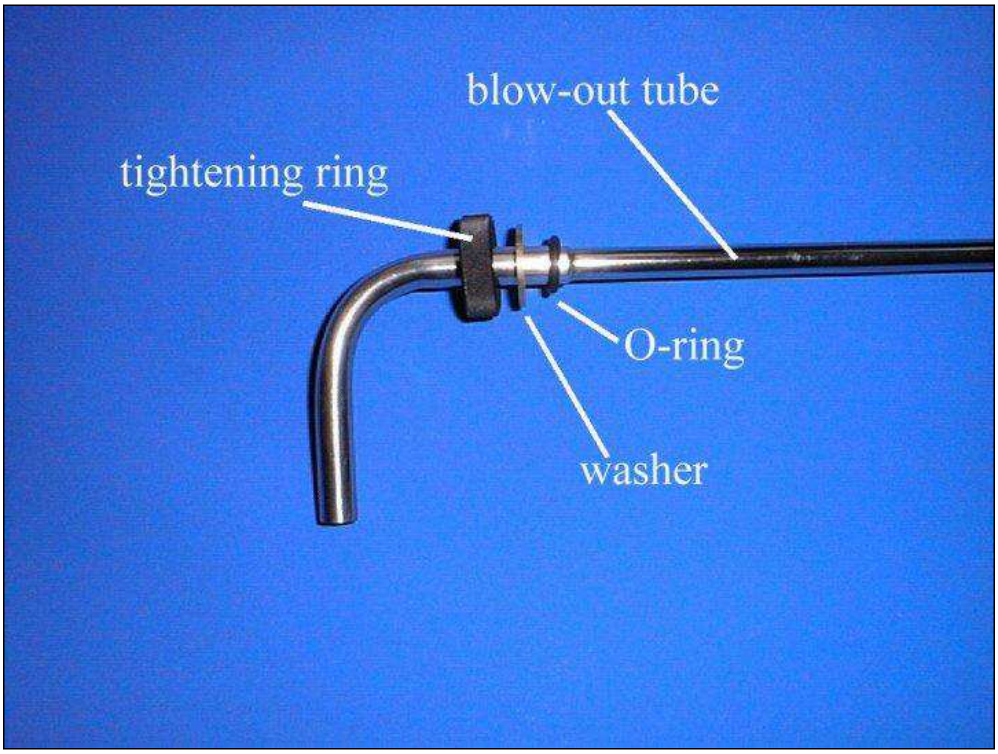


Photo 3.3. The blow out tube

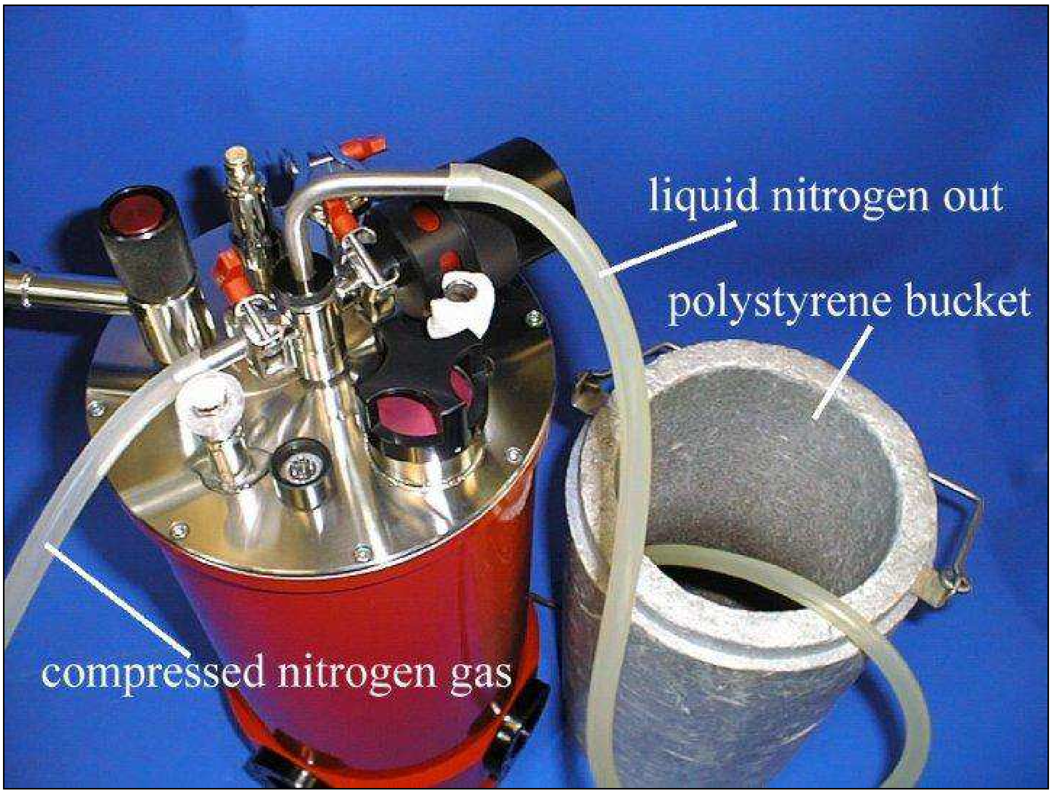


Photo 3.4. Arrangement to blow the LN_2 out of the LHe reservoir

4. Liquid Helium (LHe) Transfer

When the pre-cool Liquid nitrogen (LN_2) has been removed the cryostat can be filled with LHe. The blow-out tube should be removed from the central neck and the cryostat should be arranged such that the transfer tube reaches the bottom of the cryostat and the storage dewar simultaneously.

It is wasteful to transfer LHe too quickly. A rubber bladder can be used to control the pressure driving the transfer, and the rate of filling can be judged from the size of the plume of exhaust He gas rising from the cryostat.

The LHe transfer tube

It is important that the LHe transfer tube used is designed to suit both the detector cryostat and the LHe storage dewar. The delivery end of the transfer tube should have a fully evacuated section with diameter approximately 6mm (¼ inch) and length at least 200mm. It should therefore permit LHe to be delivered efficiently into the central reservoir while at the same time leave space for spent He gas to escape without a build-up of pressure within the cryostat.

QMC Instruments Ltd. can arrange to supply a suitable LHe transfer tube for your cryostat. We offer a rigid transfer tube with a reach of 800mm, product code QTT/R, and a flexible transfer tube with a reach of 1000mm, product code QTT/F. Please contact us, or your supplier, if you have any questions regarding the suitability of your equipment.

Photo 4.1 depicts a LHe transfer in progress. **Photo 4.2** shows a typical boil-off plume in the phase when the cryostat is cooling between 77K and 4.2K. **Photo 4.3** indicates the larger, cloudier and more erratic plume, which results when the LHe reservoir is full. At this stage the transfer should be terminated. It should take about 30 to 40 minutes for a TK1813 cryostat to cool down from 77K to 4.2K and to fill with LHe; and consume about 4L of LHe.

He gas recovery

Here in Cardiff we have no facilities for recovering spent He gas, hence all the LHe transfers undertaken in our laboratories are "open" in the manner shown in the photos. However some installations offer recovery facilities whereby a He return line is attached to the exhaust port of the cryostat. Use the black anodized aluminium tightening ring and O-ring from the central neck fitting to make a seal around the LHe transfer tube. Under such circumstances, a coarse flowmeter could be inserted in the return line to indicate flow rate from the transfer. Usually a steady flow-rate is indicated during the cool and fill phases of the transfer. When the reservoir is full however, the flow rate becomes erratic, and the transfer should be terminated.

When the transfer is complete the transfer tube should be removed carefully but swiftly and the safety valves fitted without delay. This kind of detector exhibits a rapid increase in resistance as it approaches LHe temperature and this can be used as a guide to the progress of the final stages of the transfer. The detector resistance can be measured using a multimeter across pins D and E of the preamplifier input connector as shown in **Photo. 4.4.**

Photo 4.1. LHe transfer

Photo 4.2. He gas exhaust during fill

Photo 4.3. Helium plume when complete

Notes on keeping the cryostat cold

It is important to keep all the neck fittings and safety valves in place whenever the cryostat is cold. If these are removed for LHe transfer, they should be removed only at the last moment when all other preparations have been made. They should be replaced as soon as the transfer tube is removed.

The cryostat can be kept continuously cold by repeatedly replenishing the cryogens. Hold times for both the LHe in the central reservoir and LN_2 in the outer reservoir are shown in **Table 1 in Section 6.**

Note that the LN_2 in the outer reservoir will require topping up more often than the LHe, and that the first fill LHe hold-time may be shorter. This is because the initial LHe boil off rate may be high if significant further cooling takes place when the transfer is complete.

When transferring LHe into a cryostat that already contains LHe, the transfer tube should be fully cooled before it is inserted into the cryostat neck. This prevents the warm transfer tube and warm He gas from boiling away excessive amounts of the LHe already in the cryostat. In this case the transfer tube is inserted into the storage dewar and the pressure control bladder inflated slightly to pass gas through the tube to cool it. When the transfer tube has cooled, thick milky helium gas emerges from the delivery end, **photo 4.5**, and the transfer tube can then be manoeuvred carefully to the cryostat and lowered into the central neck. The refill can then proceed in the way described above.

The detector system is ready for operation as soon as the LHe fill is complete

The performance may improve very slightly during the first hour or so after the first fill He transfer while the detector and filters cool to their final operating temperature. Remember that the resistance of the detector is a function of current once it is at operating temperature. Nonetheless you may still measure the detector resistance to check that the temperature is correct and stable.

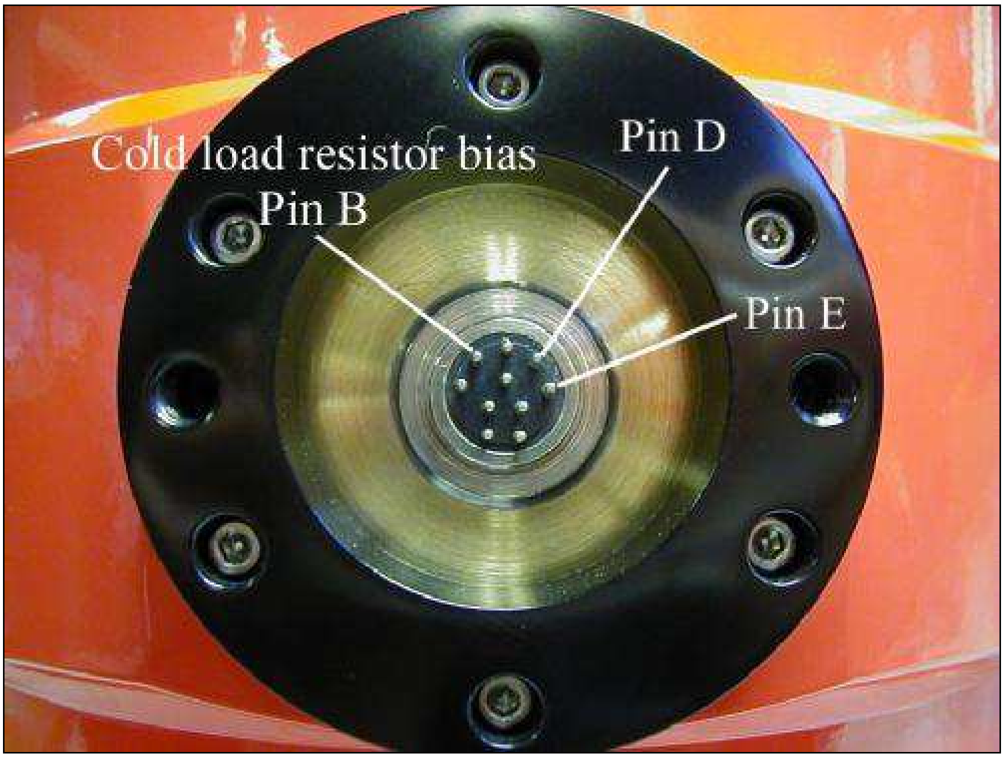


Photo 4.4. Electrical port pin assignments

DE Detector Resistance BD Bias Resistance BE Detector Resistance + Bias Resistance

Photo 4.5. LHe emerging from a cold tube

5. The ULN95 Preamplifier

Background

The ULN95 (Ultra Low Noise) preamplifier is a voltage mode low noise preamplifier designed for use with cooled detectors. It can be powered either from internal rechargeable batteries or from an external ±15V DC supply. Switchable gain options, a potentiometer bias supply control and full detector status monitoring are provided. Output is 50Ω bnc as standard, and the circuit is housed in an RF shielded enclosure designed to mount directly to the detector cryostat to reduce interference and provide a common ground.

The input impedance is high, so the preamplifier can be used with a range of cooled detectors, including InSb hot electron bolometers (types QFI/X, QFI/XB and QFI/XBI) and composite Silicon and Germanium bolometers (types QSIB/X and QGEB/X).

The technical specification of the ULN95 is given in **Table 5.1** below.

Output Impedance	50Ω bnc	**Bias Supply**	0-9V multi-turn potentiometer
Input Impedance	>10GΩ	**Voltage Gain**	x100, x1000 switchable
Bandwidth (-3dB)	0.5Hz to 1MHz	**Output Noise** (Input Shorted)	≅ 1nV $Hz^{-1/2}$ rms >1kHz ≅ 3nV $Hz^{-1/2}$ rms at 10Hz

Table 5.1. ULN95 Technical specification

Mounting the preamplifier

The batteries in the preamplifier have been disconnected during transit. Open the front of the ULN95 by unbolting the 4 bolts that hold the lid in place. The battery pack should be fixed in position as shown in **Photo 5.1a,** using the 4 plastic fixing screws.

The battery connecting lead, **Photo 5.1b,** which can only be fitted one way, should be connected to the 4 pin connector at the top of the left hand circuit board as viewed with the battery pack uppermost in the box. . The preamplifier should be mounted onto the black anodised vacuum window surrounding the 10 pin electrical feedthrough which is located on the side of the cryostat. The two mounting bolts can be found screwed into this. Once mounted, the preamplifier 10 pin electrical input lead should be connected to the cryostat 10 pin electrical feedthrough through the hole in the lower section of the preamplifier housing, **Photo 5.1a.**

Powering the preamplifier

The ULN95 can be operated from the internal batteries or from an external power supply. External power is supplied via the 4 pin socket located at the top of the preamplifier control panel. The 3 isolated pins are used while the earth tag is not used. A twin channel power supply (PS), an example of which is pictured in **Photo 5.2**, will be needed to run the preamplifier from external power. A power lead is supplied for this purpose. The internal NiCad batteries, which may not necessarily be charged before despatch, are recharged from the external PS via the same socket. Please note that the NiCad rechargeable batteries will not be able to be recharged and used indefinitely. Through normal and proper use they will need replacing after about 200 charge/discharge cycles.

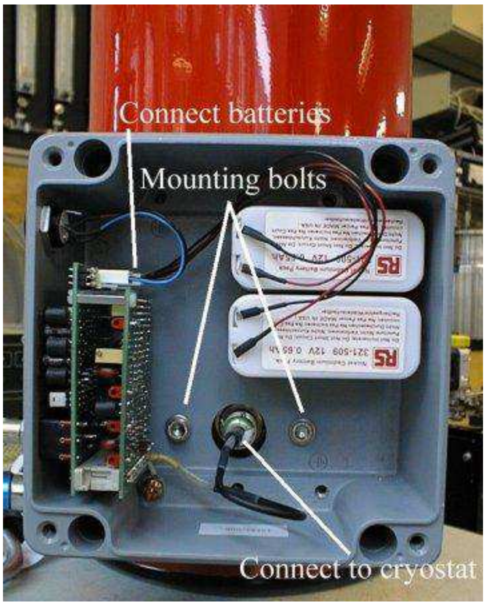


Photo 5.1a. Mounting the preamplifier

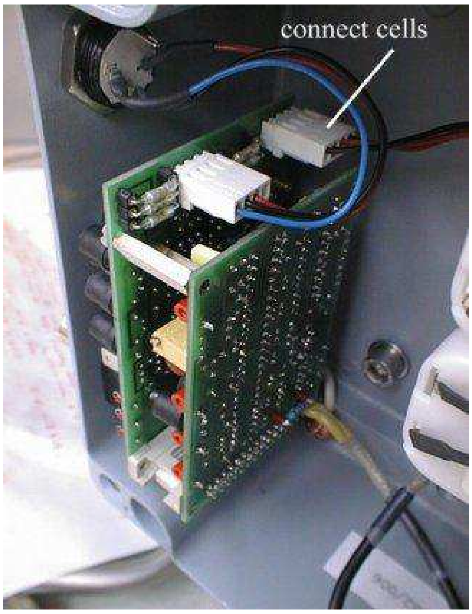


Photo 5.1b. Connecting the batteries

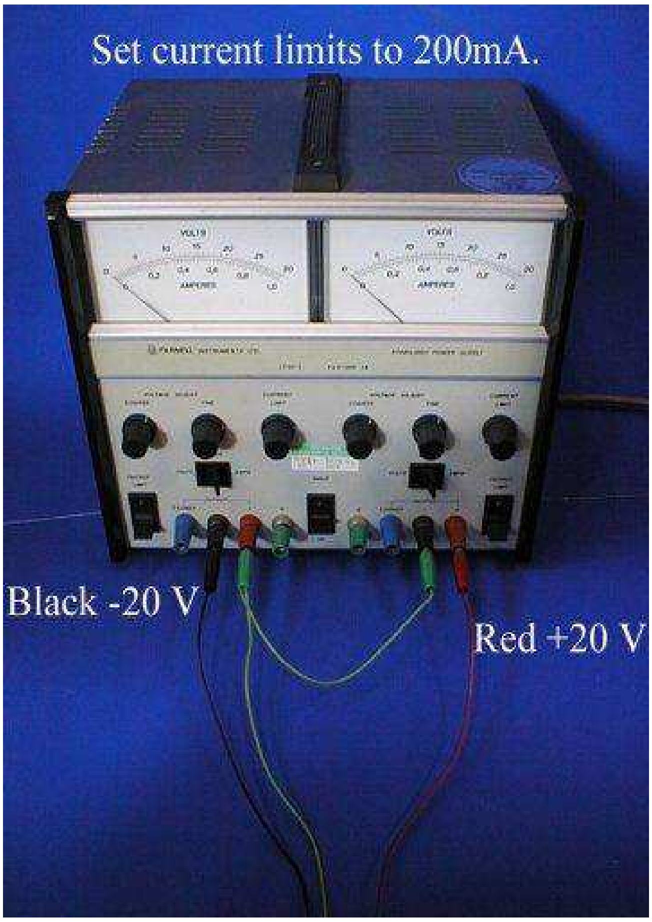


Photo 5.2. Power supply connections

Using an external PS

Photo 2 shows a typical twin channel PS, which can supply 30V dc. To connect this supply to the preamplifier, the red banana plug is connected to the positive red terminal of the depicted right hand PS (call the positive PS) and the black banana plug connected to the negative black terminal of the depicted left hand PS (call the negative PS). By connecting the negative socket of the positive supply to the positive socket of the negative supply with the green lead, the PS's are connected in series. When powering the preamplifier, make sure that the voltage output is at zero before switching on, then increase the voltage gradually on both PS's simultaneously to 15V.

If the PS has a current limiting facility, this should be set to 200mA. The current supplied to the power socket is limited internally but occasionally transients can blow the 500mA protection fuses.

The initial settings for the preamplifier are as follows:

RECHARGE **OFF**; POWER **EXT**; GAIN **x100**; INPUT **SHORTED**; BIAS **OFF**

1. Connect the preamplifier **OUTPUT** to your signal measuring device – signal analyser, CRO, voltmeter
2. Ensure that the PS output voltage is at 0V
3. Connect the power lead to the **RECHARGE SOCKET**
4. Increase the voltage to 15V as described above. **DO NOT EXCEED 15V**. The **PREAMP ON** light should illuminate
5. Set the INPUT switch to the **OPEN** position
6. Set the BIAS switch to the **ON** position
7. Select the desired GAIN

At this stage, you can "Say Hello" to your detector. A hand waved rapidly in front of the detector window should generate a readily visible response on the scope.

Photo 5.3. View of the switchboard and amplifier circuit board identifying the voltage test points and multi turn potentiometer

Using the battery supply

The initial settings for the preamplifier are as follows:

RECHARGE **OFF**; POWER **EXT**; GAIN **x100**; INPUT **SHORTED**; BIAS **OFF**

1. Connect the preamplifier **OUTPUT** to your signal measuring device – signal analyser, CRO, voltmeter
2. Set the POWER switch to **BATT**. The **PREAMP ON** light should illuminate
3. Set the INPUT switch to the **OPEN** position
4. Set the BIAS switch to the **ON** position
5. Select the desired GAIN

Fully charged batteries will be able to operate the preamplifier for at least 12 hours. However, this does depend to an extent on the level of output used. The power drain on the batteries is higher if the signal level is large.

Recharging the batteries

The initial settings for the preamplifier are as follows:

RECHARGE **OFF**; POWER **EXT**; GAIN **x100**; INPUT **SHORTED**; BIAS **OFF**

1. Ensure that the PS output voltage is at 0V
2. Connect the power lead to the **RECHARGE SOCKET**
3. Set the RECHARGE switch to **ON**
4. Increase the voltage to 15V as described above. The **PREAMP ON** light should illuminate.
5. If the **RECHARGE ON** light does not illuminate when recharging, **without exceeding 20V**, increase the voltage gradually above 15V until the **RECHARGE ON** light illuminates

The batteries will then be recharged. It is not possible to overcharge the cells. The batteries will be fully charged when the recharge light goes out, which should take no more than eight hours.

Altering the detector bias

The detector requires a d.c. bias current I_B which is supplied by the preamplifier. I_B is set to the optimum value during testing at the QMC Instruments; hence it should not normally be necessary to alter the bias conditions of the detector. However, I_B will have to be optimsed if the temperature of operation is altered, for example by pumping and cooling the helium bath to 1.5K.

The bias voltage V_B supplied to the bias load resistor can be measured using the test points within the preamplifier box. On the board closest to the battery pack there are 4 test points and a variable resistor which are assigned, **photo 5.3**, as follows:

TP1 Zero volt test point
TP2 V_B test point
TP3 I_B test point (1mV/µA)
TP4 Detector voltage test point, V_{Det}
VR1 V_B adjust

To measure V_B connect a voltmeter across TP1 and TP2. To set V_B adjust the multi-turn potentiometer VR1. V_B will have been set during QMC Instruments tests but can be altered using the potentiometer VR1 and measured between TP1 and TP2. To measure I_B connect a voltmeter across TP1 and TP3 and convert the measured voltage in mV to I_B/µA using the conversion factor 1mV/µA. V_{Det} is measured by connecting a voltmeter across TP1 and TP4. The operating resistance of the detector can then be calculated from $R_{Op} = V_{Det}/I_B$. Occasional monitoring of this voltage will confirm that the detector temperature and the bias current are correct and stable.

Figs. 5.2(a, b) give typical input shorted noise of the ULN95 amplifier at a gain of x100

Troubleshooting

If after recharging the battery packs performance starts to fall it is likely that the NiCad rechargeable battery packs will need replacing. It is normal for NiCad rechargeable batteries to need replacing periodically when they no longer hold charge. Replacement battery packs can be obtained from RS.

If problems are suspected with the ULN95 preamplifier there are some basic checks that can be carried out. Disconnect the ULN95 from the external supply, open it by undoing the four bolts and check the following:

- Check the five 500mA fuses to make sure that they have not blown, **photo 5.4**
- The switchboard should be firmly attached to the RF shielded case
- The switchboard and amplifier board should be firmly attached to one another
- The 10 pin plug should be firmly attached to the cryostat 10 pin electrical feed through
- Confirm that the battery packs are firmly attached in position to the RF shielded casing, and that they are connected to the switchboard
- Confirm that there are no obvious problems with the switchboards and amplifier board. The boards can be detached and removed them from the case for inspection. Check for any lose components, or blackened areas.

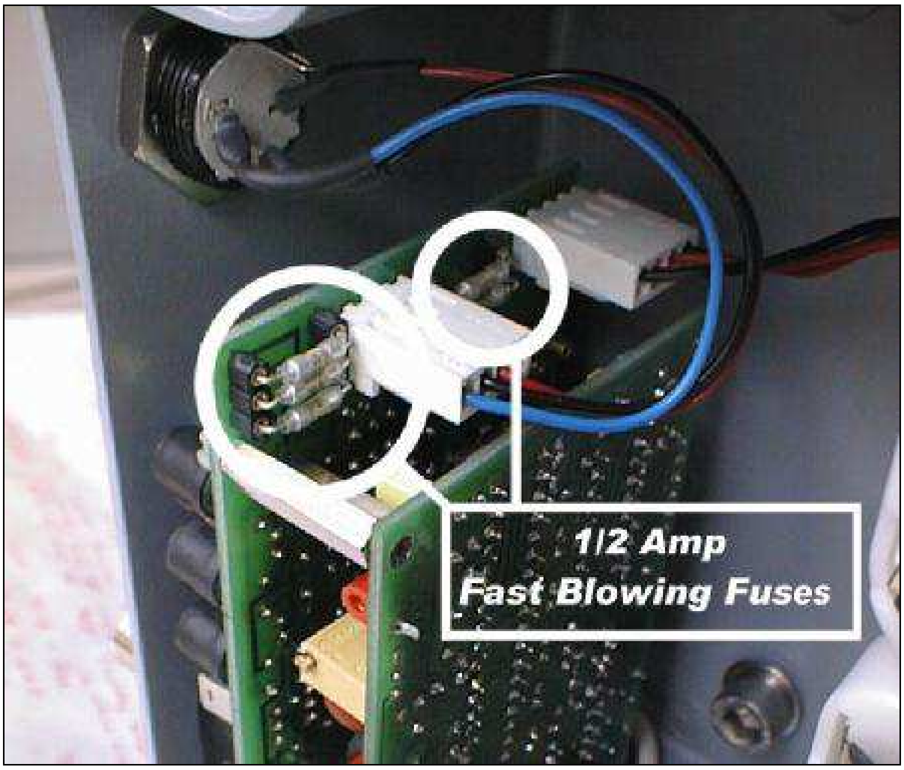
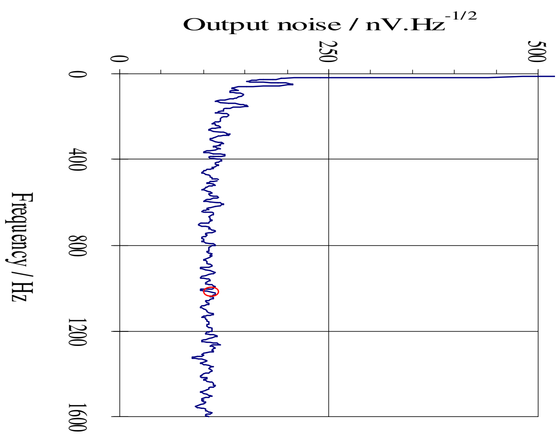
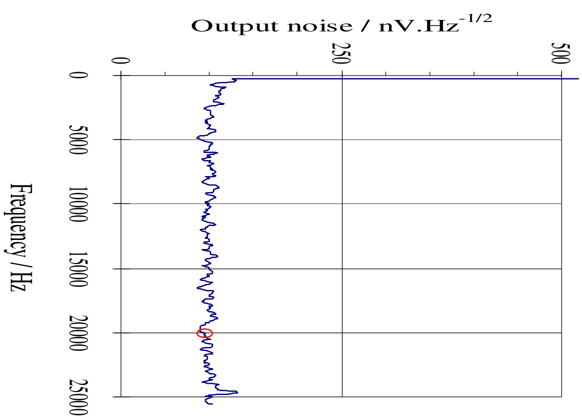


Photo 5.4. View of the switchboard and amplifier board, showing the location of the 500mA fuses





Typical preamplifier input shorted noise spectra. Amplifier gain = x100

Fig. 5.2a. Noise at 1kHz = 1.02nV.Hz$^{-1/2}$ **Fig. 5.2b.** Noise at 20kHz = 0.99nV.Hz$^{-1/2}$

6. System Calibration and Test Results

The detector is calibrated at a signal wavelength of 1.1mm (275GHz). A blackbody source is used to provide a broad band signal, which is then passed through a 1.1mm band-pass filter. This provides a measured amount of incident power on the cryostat window. A lock-in amplifier and / or signal analyser are used to measure the detector output signal. The optical parameters that define the performance of the detector are defined below and the arrangement for the optical tests is shown in **Fig. 6.1**.

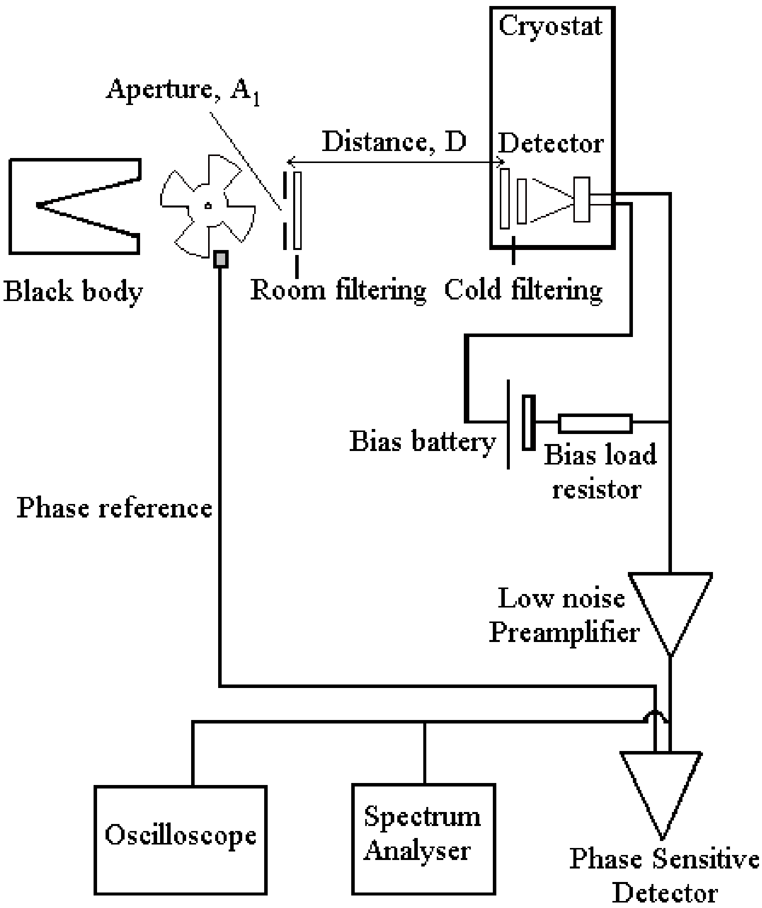


Fig. 6.1. The optical test arrangement

The system optical responsivity, $R_{optical}$, is defined as:

$$R_{optical} = V_{out} / P_{\det}$$

where V_{out} is the voltage response at the input of the amplifier (i.e. assuming a preamplifier gain of 1) and P_{det} is the power incident on the window of the cryostat within the field of view determined by the cold optics.

The incident power, P_{det}, is calculated using

$$P_{\det} = \frac{A_1 A_2}{D^2} \frac{2k\beta\Delta T}{3c^2} \left(\nu_2^3 - \nu_1^3 \right)$$

where

- A_1 and A_2 are the aperture areas of the black body source and the receiving optics respectively
- D is the distance between these points
- $k = 1.38\text{x}10^{-23}\text{JK}^{-1}$ is Boltzmann's constant
- β is an attenuation factor, which accounts for the room temperature filter transmission losses and the square wave modulation
- ΔT = 500K is the temperature difference between the black body source temperature, T_s = 800K, and ambient temperature, T_b = 300K
- $c = 3\text{x}10^8\text{ms}^{-1}$ is the vacuum speed of light
- ν_2 and ν_1 define the upper and lower frequency of the filter passband

For apertures with diameters of 5mm at a distance 100mm apart, and a value of β = 0.252 for a 1.1mm filter, the incident power is $1\text{x}10^{-10}$W.

The rms. noise voltage N_m, generated by the detector system is measured in a 1Hz bandwidth at a spot frequency of 1kHz using a signal analyser. This is also referred to the input of the amplifier.

The sensitivity of the system is represented by the system optical Noise Equivalent Power (NEP_{opt}). It is this parameter which predicts the signal/noise ratio that will be produced when a certain known signal flux density is incident at the cryostat window within the field of view. NEP_{opt} represents the power incident that will produce a voltage response equal to the noise voltage i.e. a signal to noise ratio of 1.

The System Optical N.E.P. is defined as follows:

$$NEP = N_m / R_{optical}$$

System Cryogenic Performance

The liquid nitrogen (LN_2) and liquid helium (LHe) hold-times of the system are measured in QMC Instruments Ltd. tests and tabulated below.

The LHe boil-off is measured over a few days to allow the internal components and radiation shields within the cryostat to reach thermal equilibrium. When equilibrium is reached the base boil-off is measured and used to determine the LHe hold-time of the cryostat. The hold-time indicated below is the subsequent fill hold-time. Note that a first fill will not last for as long due to the high initial boil-off when the cryostat is cooling from LN_2 temperatures.

In order to achieve these figures it is important that the operating instructions laid out in this manual are followed, and that care is taken to ensure that the cryostat is completely full before the LHe transfer is terminated.

The system test log sheet is given in **Appendix B.** This shows exactly what steps were taken to run the system and the elapsed time between each action.

LHe capacity / litres	1.79
LN_2 capacity / litres	1.75
Base He boil-off / litres of gas per min at STP	0.30
LHe Hold-Time / hours	75 ± 5
LN_2 Hold-Time / hours	25 ± 5

Table 6.1. System cryogenic performance of the TK1813 cryostat

Detector Test Results

T/K	R_{DE}/kΩ	R_{BD}/MΩ
300K	0.07†	10.0†
77K	0.07†	10.0†
4.2K	1700†	10.1†

Table 6.2. Measured values of:

- resistance R_{DE}/kΩ across the detector only (pins D-E)
- resistance R_{BD}/MΩ across the bias resistor only (pins B-D)

as a function of temperature T/K as the detector is cooled

† Measured resistance non-rectifying

NOTE: The values tabulated in **Table 6.2** are only intended as a guide. They are dependent on the actual temperature of the detector element and the Ohmmeter's measuring current at 4.2K.

LN_2 shield aperture	16 mm diameter
Winston cone field of view	f/3.5 @ 15 mm diameter
300K Window	2mm thick HDPE
77K Filter	600cm^{-1} Low pass QMMF*
4.2K Filter	600cm^{-1} Low pass QMMF*

Table 6.3. Optical aperture sizes and filter details

*Refer to **Appendix C** for the transmission profile

Bias Resistance / MΩ	10.1
Bias voltage, V_B/V ‡	10
Detector voltage, V_{Det}/V ‡	1.200
Detector operating resistance R_{Op}/MΩ	1.50
Speed of response	300
System optical responsivity at 80Hz / kV W^{-1}	15.0
System noise / nV.Hz$^{-1/2}$ at 80Hz	32
System optical NEP / pW.Hz$^{-1/2}$ at 80Hz	2.0

Table 6.4. Detector test results

‡ Refer to 5. The ULN95 Preamplifier, Altering the detector bias for a description of the preamplifier test points settings used to take these measurements

The system output noise spectrum is given in **Fig 6.1**. This was measured using a gain of 100 on the ULN95 preamplifier.

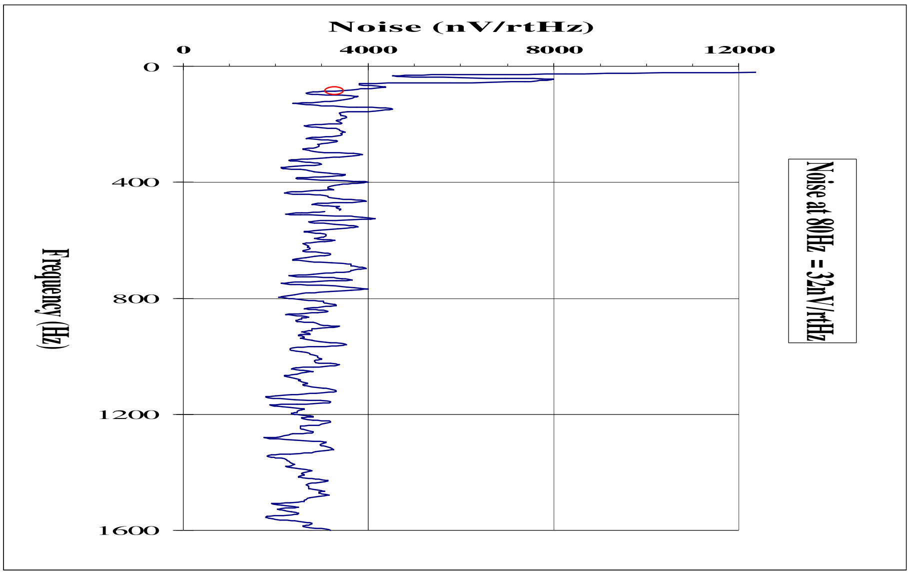


Fig. 6.1. System output noise spectrum (<1.6 kHz). x100 gain

Appendix A. Theory of Operation of the Composite Silicon Bolometer

The detector mounted in this system is a composite silicon bolometer designed for operation at 4.2K. The active element is mounted on an absorber which is suspended in an integrating cavity behind the condensing optic. The substrate is coated to give an impedance matched approximately to that of free space in order to optimise absorptivity over a large range of wavelengths. The substrate warms as radiation is absorbed. The detector element is in good thermal contact with the substrate, and therefore warms with it. It is the change in electrical impedance as the element changes temperature that generates a detection signal.

The substrate is suspended within the integrating cavity by very fine support fibres. The wires connecting the bolometer element to its mount are thin and as short as possible in order to reduce the thermal capacitance (and therefore time constant) of the detector to give a reasonable speed of detection.

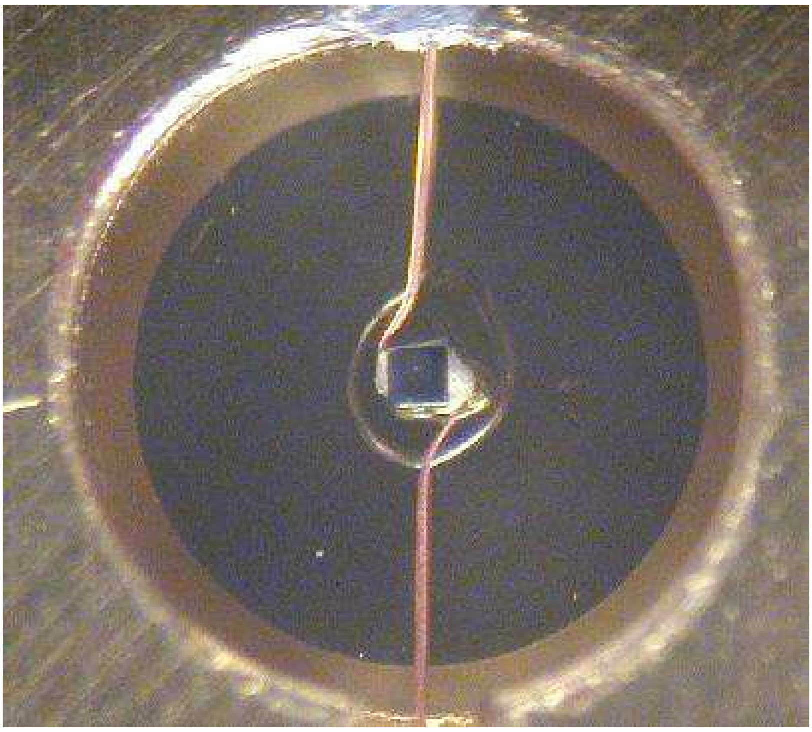


Photo A.1. Composite Si bolometer detector suspended from its support wires

Based on the V-I characteristic measured at 4.2K, we define the detector Electrical Responsivity, measured in Volts per Watt (VW^{-1}) as:

$$Resp_{elec} = -\left(\frac{I_0}{2}\right)\left(\frac{Z_0 - R_0}{R_0}\right)$$

where the detector impedance $R_0 = V_0 / I_0$

- V_0 is the voltage across detector at operating point
- I_0 is the bias current at operating point

- Z_0 is the slope of V-I at the operating point

The electrical responsivity represents the volts per watt response of the detector under ideal conditions in which all incident photons are absorbed. This is an idealised maximum and does not represent the true sensitivity of the actual detector.

Total intrinsic detector noise is dominated by Johnson noise V_J and phonon noise V_{Ph}:

$$V_J = \sqrt{4kT_{det}R_0 f}$$

$$V_{Ph} = \sqrt{4kT_{det}G}$$

$$V_T{}^2 = (V_{Ph}{}^2 + V_J{}^2)$$

where

- $k = 1.38 \times 10^{-23} JK^{-1}$ is Boltzmann's constant
- T_{det} is the detector temperature
- f is the measurement bandwidth
- G is the detector thermal conductance (WK^{-1})

For an optimised bolometer the total intrinsic noise voltage is twice the phonon contribution:

$$V_T{}^2 = 1.5V_J{}^2$$

hence

$$V_T = 1.2V_J$$

In practice the measured detector noise will be greater than the above. The limiting NEP, which represents the ideal NEP of the detector, corresponding to ideal photon absorption in conjunction with ideal noise performance, is defined thus:

$$NEP_{\lim} = V_T / Resp_{elec}$$

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Appendix B. System Test Log Sheet

QMC Project Ref: Product Code:

Date	Time	Action	Comment

Appendix C. Filter Transmission

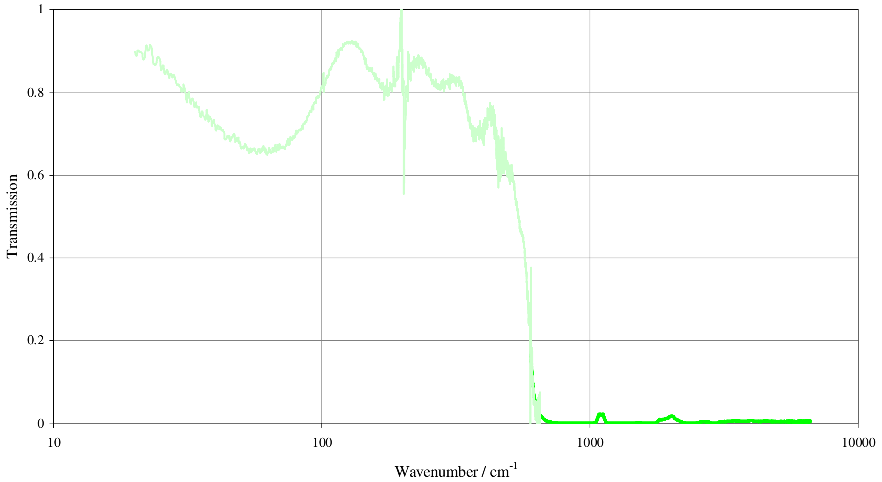

Fig C.1. Transmission spectrum for the type QMMF 600cm^{-1} low pass filter

QMC Instruments Ltd

Contract details and guarantee

This equipment is guaranteed for a period of two years from the date of delivery against failure caused by defective materials or workmanship. Defective parts will be repaired or replaced on return to the final supplier at no cost, provided that failure is not due to misuse or mishandling after delivery. QMC Instruments Limited will assume no liability for loss of life or damage to property arising from the use or misuse of its products.

Purchase Order N^{o}
Purchase Order Date
QMCIL Reference
System Serial N^{o}

On receipt of your shipment

Please check that your equipment has arrived safely. Please advise QMC Instruments if you suspect any damage has been incurred during transport and delivery or if any of the items are missing.

This operating manual contains instructions for operation of the preamplifier, together with QMC Instruments Ltd. test performance data, against which our guarantee is given as stated above. The user is advised to read this document carefully prior to operation of the detector system and is reminded that our guarantee will be invalidated if the equipment is damaged through misuse.

Signed.. Date..
Richard Roberts
(pp Ken Wood - Director, QMC Instruments Ltd.)

QMC Instruments technical staff will be happy to advise you if you have any questions or difficulties. The contact details are:

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