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Performance of the new pyrolytic graphite analyser bank on the IRIS spectrometer at ISIS – preliminary results

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ABSTRACT

The pyrolytic graphite (PG) analyser bank on the IRIS high-resolution inelastic spectrometer at ISIS has been upgraded. While the original design utilised a 6 row by 225-column array of 2mm thick (1 cm^2) graphite crystals cooled to 25K, the new design is comprised of 4212 crystal pieces (1mm thick, 18 rows by 234 columns). In addition, the graphite is now cooled close to liquid helium temperature to further improve the sensitivity of the spectrometer. In this report we compare the performance of the newly upgraded instrument to resolution and intensity measurements collected prior to the modifications.

I. INTRODUCTION

IRIS is a time of flight (t.o.f) inverted-geometry crystal analyser spectrometer designed for high-resolution quasi-elastic and low-energy inelastic spectroscopy [1]. It employs two large analysers (pyrolytic graphite and muscovite mica) oriented close to back-scattering geometry (Fig. 1). Using non-backscattering geometry avoids the loss in intensity caused by a beam modulation chopper when exact back scattering is employed.

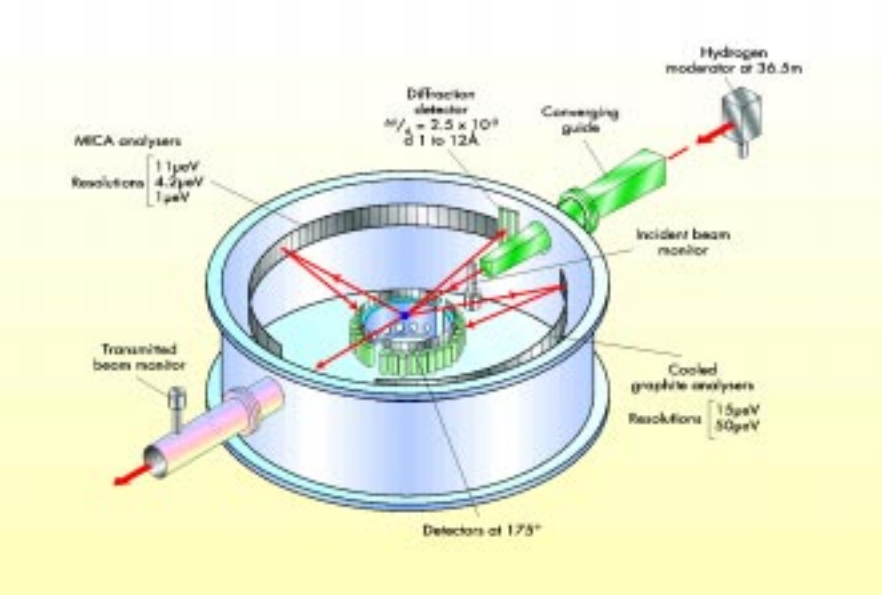

Figure 1 *The IRIS spectrometer at the ISIS Facility, Rutherford Appleton Laboratory, UK*

The pyrolytic graphite (PG) analyser bank on IRIS is set approximately 0.85 meters from the sample position in the horizontal scattering plane and covers scattering angles from 15° to 165°. The analysed beam is back scattered through 175°, slightly below the horizontal scattering plane, and detected using a multidetector composed of 51 scintillator detectors located approximately 0.6 meters from the analyser. Prior to July 2000, the analyser comprised of a 6 row by 225 column array of cooled (25K [2]) pyrolytic graphite crystals (10mm x 10mm x 2 mm thick) with a mosaic spread (η) of 0.8° mounted on a spherically machined aluminium backing plate. However, while the use of pyrolytic graphite affords the possibility of two

analysing reflections, 002 and 004, with analysing energies of 1.82meV and 7.28meV providing resolutions of 15μeV and 50μeV respectively, this original analyser design intercepted only a small percentage (~ 1.5%) [1] of the total scattered beam. In theory, the count rate of the spectrometer could therefore be significantly improved by simply increasing the area of the analyser.

II. MODIFICATIONS

By considering the geometric and physical constraints (shielding etc.) of the instrument, it has been possible to achieve a three fold increase in the area of the graphite analyser. Such an increase equates to a new analyser array comprised of 4212 crystals ($1cm^2$, 1mm thick, 18 rows by 234 columns). However, while an increase in area should produce a corresponding increase in neutrons incident upon the detector, it is important to ensure that vertical extension of the analyser array out of the horizontal scattering plane does not degrade the current instrument resolution. As operation of the original set up of the spectrometer demonstrated, a limited vertical extension of the analyser out of the horizontal scattering plane can be achieved without considerable effect upon instrument resolution. However, potentially problematic optical aberration effects worsen as this extension is increased further. Non-backscattering geometries suffer this drawback whereas backscattering geometries do not.

To limit the effect of optical aberration, the cross sectional profile of the new '18 row' analyser array was optimised using Monte Carlo (MC) methods [4]. In brief, the cross section profile of the original IRIS analyser was determined by considering the hybridisation of two geometrical options to i) set the analyser crystals in a near back-scattering geometry which achieves good resolution whilst obviating the need for a beam modulation chopper to increase intensity and ii) to limit optical aberration. This process hybridised the Rowland circle (constant analysed wavelength, λ_a) with an elliptical line giving a constant secondary flight path (L_2). However, our MC calculations in fact show that for an analyser 18 crystal pieces high (i.e. 18cm high) the cross section profile simply favours the geometry of an ellipse with the focal point at the detector [4].

In addition, provision has been made to cool the graphite crystals on the new analyser from the originally achieved 25K to close to liquid helium temperature. Cooling the graphite to 4.2K further reduces background contributions arising from Thermal Diffuse Scattering (TDS) thus improving the sensitivity of the spectrometer [2]. To achieve this lower temperature it has been necessary address the method by which the graphite crystals are cooled. Full details of the revised cooling circuit will be presented elsewhere. However, in brief, while the original design utilised a Closed Cycle Refrigerator (CCR), liquid helium temperature is now achieved by employing the continuous flow technique, similar to that used by some cryostats.

III. RESULTS

Performance of the new IRIS pyrolytic graphite analyser was ascertained by comparing instrument resolution measurements collected before and after the analyser upgrade, the results being depicted in Figures 1-4 and tabulated in Table 1. These findings were also likened to the predicted performance of the complete upgraded IRIS spectrometer obtained from the aforementioned Monte Carlo simulations [4]. In addition, photographs depicting the installation of the new analyser bank are presented in Appendix 1.

In brief, the spectra presented in this report were generated by collating the data collected in each of the 51 pyrolytic graphite bank detectors, each detector having been first corrected for efficiency. The resolution measurements themselves were collected using a cylindrical vanadium standard with the spectrometer configured to use either the 002 or 004 analysing reflection afforded by pyrolytic graphite. From here on in, these two analysing reflections will be referred to as PG002 and PG004 respectively. In addition, vanadium spectra were also obtained with, and without, the IRIS radial collimator in position between the sample and PG analyser bank.

Despite the marked increase in vertical extension of the new analyser out of the horizontal scattering plane, no appreciable degradation of the original spectrometer's resolution is observed. For PG002, comparison of resolution

measurements collected before and after the analyser upgrade highlights a 2.5μeV increase in the breadth of the elastic line at full width half maximum (fwhm); i.e. from an originally achieved 15μeV to 17.5μeV. Similarly, for PG004, an increase in fwhm of 5μeV (from 50μeV to 55μeV) is observed.

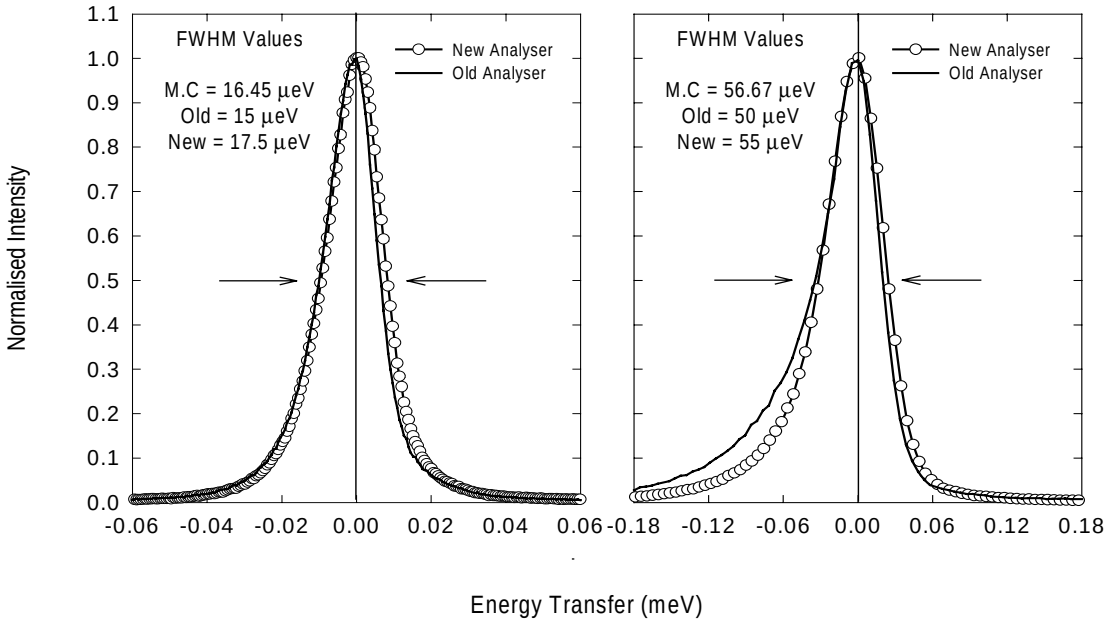

Figure 2 *Normalised intensity vs. energy transfer for PG002 and PG004 respectively*

As Table 1 illustrates, these results are in good agreement with those fwhm values predicted from our Monte Carlo simulations of the complete upgraded IRIS spectrometer [4].

	Monte Carlo Prediction [4]	Original PG Analyser (25K)	Upgraded PG Analyser (4.2K)
FWHM of Elastic Line			
PG002	16.45 (34) μeV	15 μeV	17.5 μeV
PG004	56.67 (23) μeV	50 μeV	55 μeV
Increase in no. of detected neutrons			
With Radial Collimator (PG002)	-	× 1.0	× 2.2
With Radial Collimator (PG004)	-	× 1.0	× 2.3
Without Radial Collimator	× 3.0	× 1.0	× 3.0
Signal to Noise Ratio	-	1350:1 at 25K	3250:1 at 4.2K

Table 1 *Performance of the new pyrolytic graphite analyser on the IRIS spectrometer at ISIS*

Figure 2 highlights the increase in number of detected neutrons. With the instruments radial collimator in position, as is the situation during a typical neutron scattering experiment on IRIS, a 2.2 / 2.3 increase in detected flux is observed.

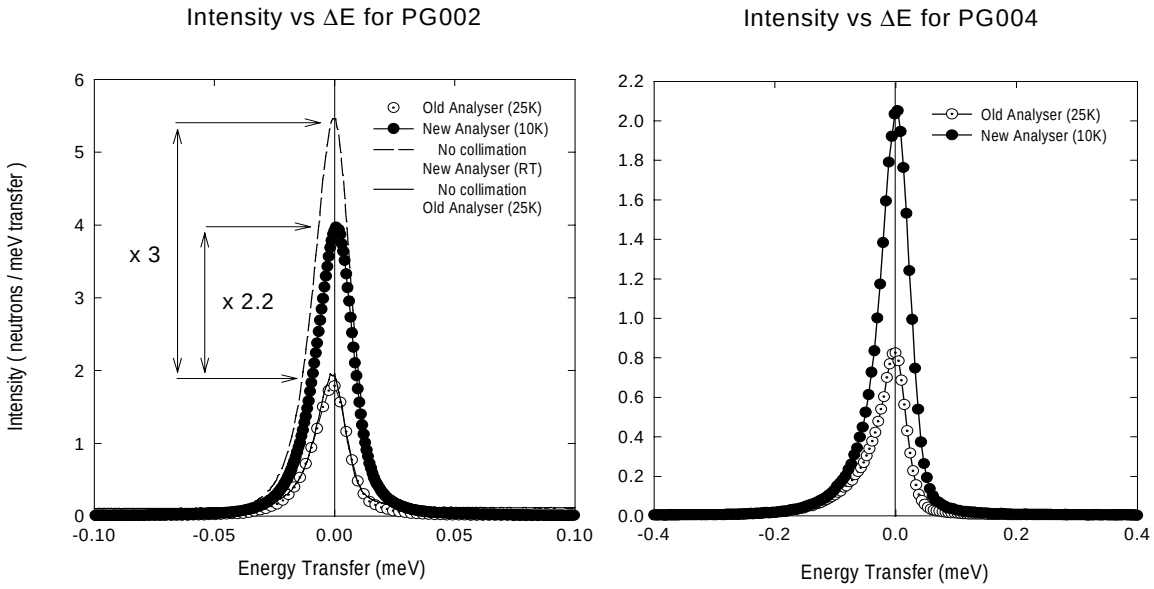

Figure 3 *Increase in number of detected neutrons for both PG002 and PG004*

However, by simply removing collimation, the predicted 3-fold increase [4] in neutron count rate is obtained. Collimation on IRIS is imperative since it alleviates potentially problematic background features (Bragg reflections etc). However, subsequent ray diagram projections of the complete upgraded instrument using Computer Aided Design (C.A.D) packages suggest that the loss in detected flux is due to the current collimator assembly inhibiting those neutrons scattered toward the top and bottom two rows of the new analyser array. Despite this, a factor of 2.3 increase in detected flux is clearly a marked improvement over the design of original graphite analyser bank.

Finally, cooling the graphite crystals from the previously achieved 25 Kelvin to close to liquid helium temperature is seen to significantly improve the sensitivity of the spectrometer, as illustrated in figure 4(a) and 4(b). While the original IRIS

analyser, cooled to 25K, exhibited a signal to noise ratio (SNR) of 1350:1, the new design far surpasses this, achieving a SNR of greater than 3000:1 by 4.2K.

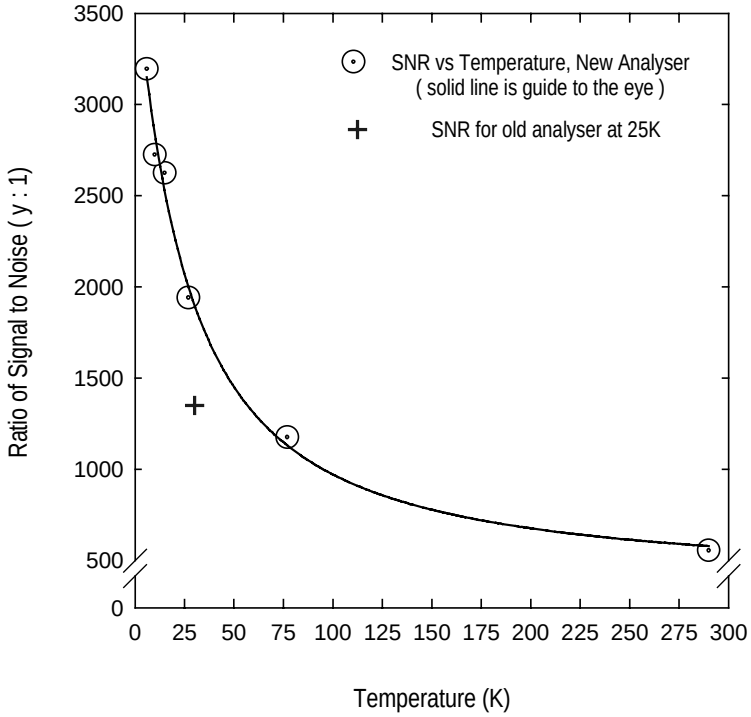

Figure 4(a) *Signal to Noise ratio (SNR) as a function of analyser temperature. The solid line is a guide to the eye*

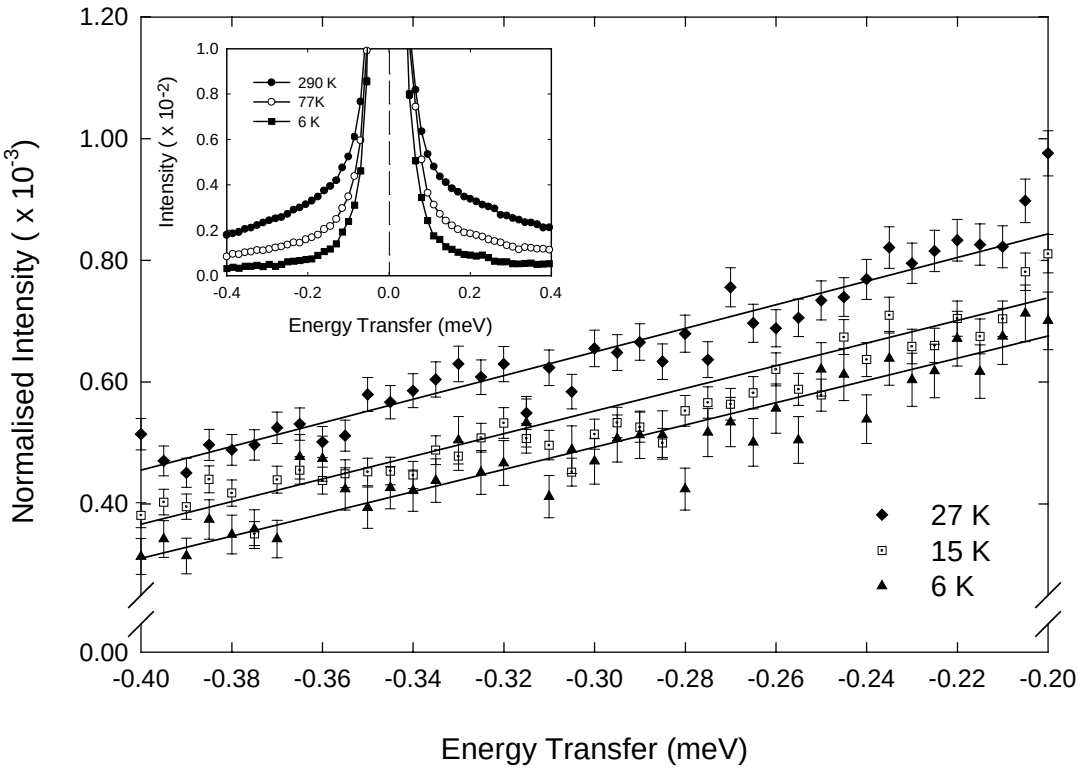

Figure 4(b) *The variation of background level as a function of analyser temperature. The solid lines are a guide to the eye*

IV. DISCUSSION

The performance of the new pyrolytic graphite analyser bank on the IRIS spectrometer at ISIS has been compared to resolution and intensity measurements collected prior to the instrument upgrade. The results show a marked improvement in the performance of the IRIS spectrometer. In addition, the results are in good agreement with predictions made for the performance of the complete upgraded instrument spectrometer using Monte Carlo simulations [4].

Use of the new PG analyser bank results in a factor of 2.2 (PG002) / 2.3 (PG004) increase in detected flux over that obtained using the original analyser array. While this is deemed a notable improvement, the results do suggest that the detected flux on IRIS can be improved further still by simply considering improved collimator geometry. In addition, cooling the graphite crystals close to liquid helium temperature significantly improves the sensitivity of the IRIS spectrometer, a SNR greater than 3000:1 being achieved at 4.2K. Both these improvements will greatly aid and enhance the study of low energy excitations on IRIS. Finally, and of greater importance, no appreciable degradation of the original spectrometer's resolution is observed when using the newly installed analyser bank.

Future effort on IRIS is focussed toward fully exploiting the increase in surface area of the new pyrolytic analyser array by considering improved collimator and detector geometry.

V. REFERENCES

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3) S.I.Campbell, Ph.D Thesis, University of Salford, 1998

4) *The optimisation of analyser geometry for a near backscattering spectrometer – IRIS on the ISIS pulsed source,* M.T.F.Telling and S. I. Campbell, Technical report RAL-TR-1999-044 (*http//www-dienst.rl.ac.uk/library/1999/tr/raltr-1999044.pdf)*

VI. APPENDIX – INSTALLATION PHOTOGRAPHS

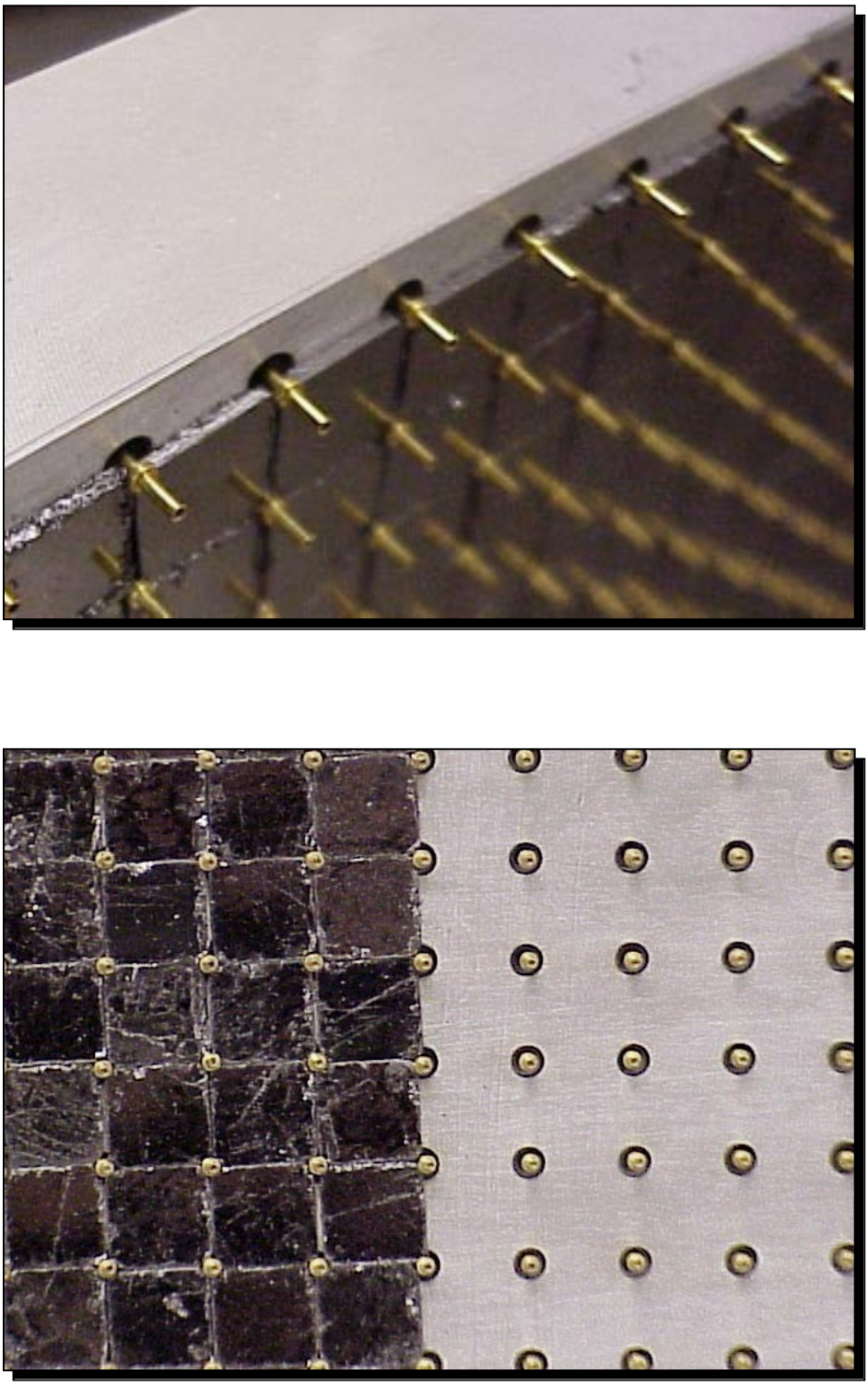

Figure 5 *The method of 'pinning' the pyrolytic graphite crystals to the cadmium sheet lining the face of the aluminium backing plate*

Figure 6 *The graphite analyser bank being lowered into position. The entire analyser assembly, including the mounted graphite crystals, is surrounded by a nitrogen shield and fronted by an aluminium window.*

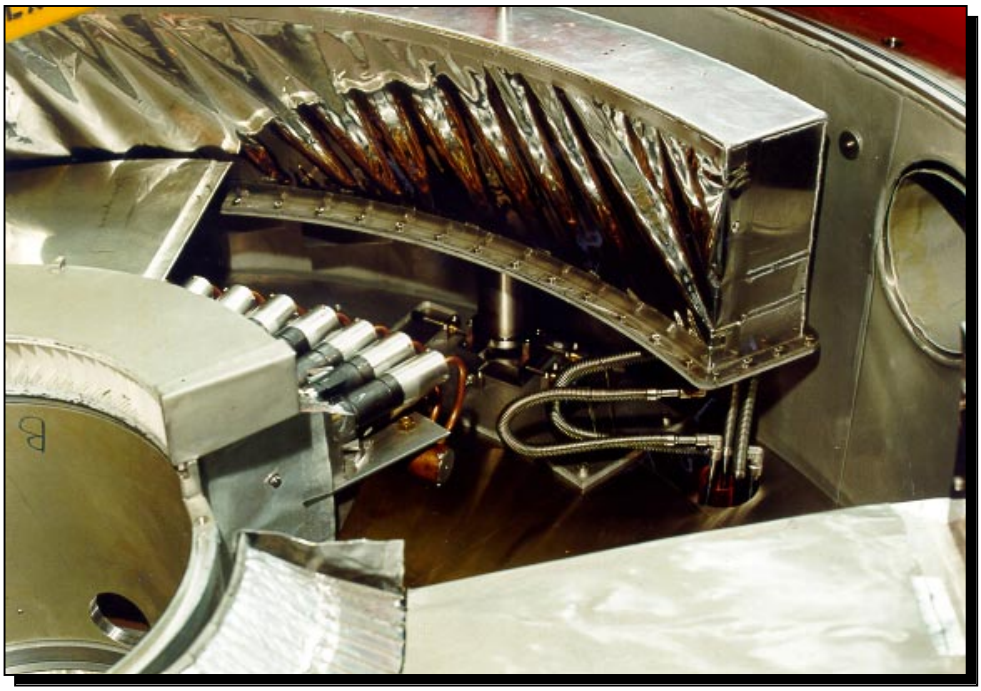

Figure 7 *The pyrolytic graphite analyser bank in the IRIS instrument tank. Connections to the nitrogen and helium cooling circuits are visible.*