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# DESIGN & DEVELOPMENT OF AN INNOVATIVE 6 AXIS SAMPLE MANIPULATOR

M Purling †, Diamond Light Source Ltd., Oxfordshire, UK


## *Abstract*

The accurate positioning & alignment of sample specimens within the experimental test chamber on a beam line is always a challenge. The ability to move in any direction and angle to very precise increments with repeatable positioning is crucial for being able to focus on the exact part of the sample required in the correct orientation. This is more complex when the sample is required to work within the Ultra High Vacuum environment and cooled to cryogenic temperatures of below 20k. Initially in conjunction with St Andrews University, Diamond Light Source Ltd. have developed their own manipulator for this purpose, it has six degrees of freedom for alignment of the sample and easy remote sample plate loading via a transfer arm system. (Fig.1 & Table 1)
This paper describes the developments made from initial design to working manipulators with increased functionality for bespoke requirements on four different beam lines within Diamond.


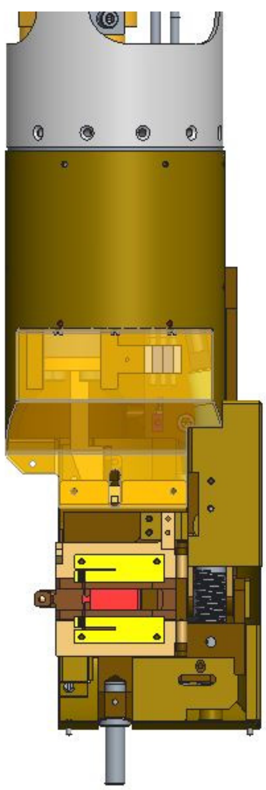

Figure 1: Manipulator Lower Half.

† martin.purling@diamond.ac.uk

Table 1: Manipulator Motion Specification

| Axis | Range | Resolution | Repeatability |
|---|---|---|---|
| x | +/-12mm | 0.5 micron [1] | 1 micron [1] |
| y | +/- 12mm | 0.5 micron [1] | 1 micron [1] |
| z | 100mm | 1 micron [1] | 1 micron [1] |
| Polar | 360° | 100 nrad [2] | 10 µrad [2] |
| Azimuth | +/- 90° | 0.01° | +/- 0.05° |
| Tilt | -10/+45° | 0.1° | +/- 0.05° |

## DRAIN CURRENT MEASUREMENT

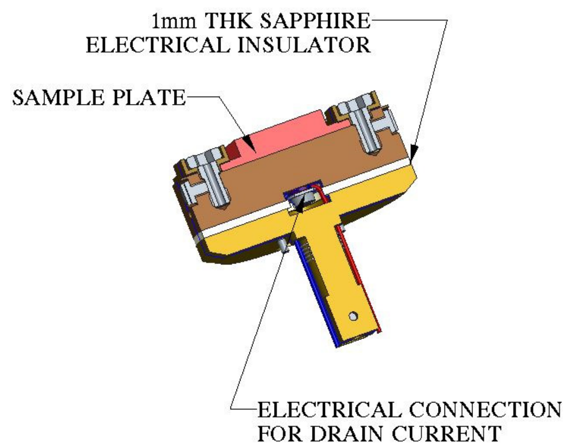


Figure 2: Section Showing Drain Current Connection.

Certain types of experiments, Photo Emission Spectroscopy and Absorption Spectroscopy use & measure the drain current flowing to the sample. It is important that the sample remains at a neutral potential but electrons are allowed to flow to the sample replacing ones emitted during the experiment. A new azimuth drive (Fig. 2) was designed to enable this to be done. A top and bottom made from copper, for good thermal conduction that are separated with a 1mm thick piece of sapphire which kept the top & the sample electrically isolated from earth. A wire is connected to the underside of the top and this is used for the drain current is measurement.
Sapphire was used as it has the properties of an excellent electrical insulator, 1 X $10^{14}$ Ωcm [3], with good thermal conductivity.

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## FULL 180° GRAZING ANGLE

The original manipulator had restricted angle access to the sample surface, this would inhibit using the manipulator for some experiments where the photons at the sample surface edges are of interest. For this type of experiment the full 180° grazing angle is required. The angle limitation was caused by the tilt bearing position physically blocking the x-ray beam. To improve this the sample was raised by 6 mm so that it was above the tilt axis (Fig. 3), this allowed the beam to have unimpeded access to the sample surface with a full 180° grazing angle. There was a compromise where the sample surface no longer rotated centrally around the polar axis.

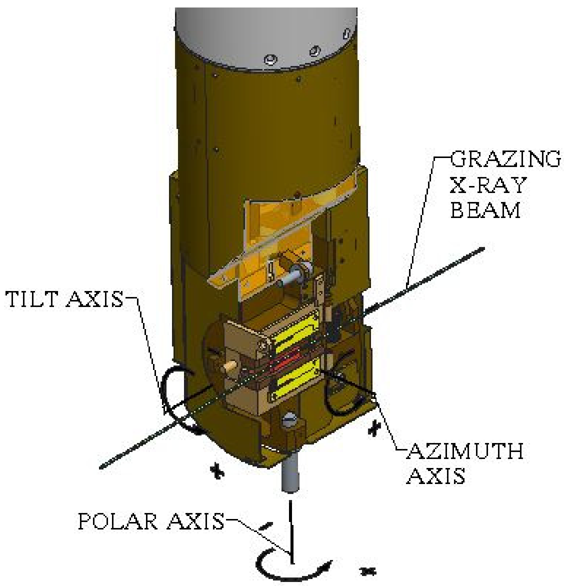


Figure 3: Diagram Showing Manipulator Axis and Grazing X-ray beam.

## THERMAL SHIELD IMPROVEMENTS

To achieve lower sample temperatures the cold end of the manipulator is enclosed within an assembly of thin copper sheets to make a thermal shield. Access for insertion and removal of the sample plate is done via a door; it can be opened and closed with a modified wobble stick within the vacuum chamber. Incorporated in the door there is provision to insert plates with different size slots to accommodate different sample sizes (Fig. 4). These plates are to ensure that the minimum amount of the sample surface/plate is exposed the internal temperature of the experimental vessel. The slots are required to allow for grazing angle experiments.

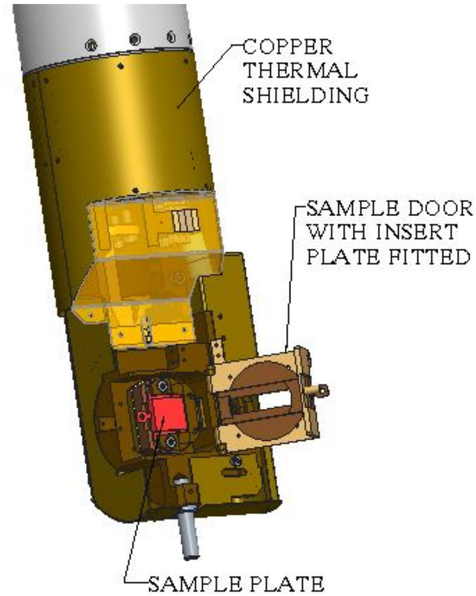


Figure 4: Thermal Shielding with Sample Door Open.

## HEATING AND COOLING

To be able to heat and cool the sample plate would make the manipulator much more versatile. The target max higher temperature is 600k while the target min lower temperature is between 20k and 10k. A more complex Azimuth drive assembly is in development consisting of a tungsten filament inside a faraday cup for heating. This is thermally isolated from the copper using a ceramic outer cover (Fig. 5). The cooling is still done using a helium cryostat and the copper braid from the original design.

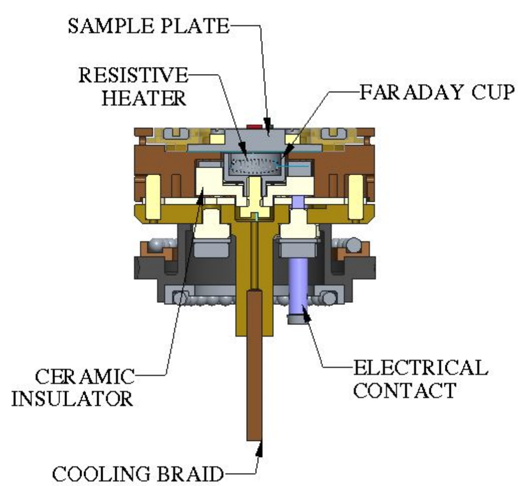


Figure 5: Thermocouple Position on Sample Plate.

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## ACCURATE SAMPLE TEMPERATURE MEASUREMENT

The original manipulator had the thermocouple for measuring sample temperature mounted on the stem of the azimuth drive; directly connected to the cold thermal braid. This could give an unrealistic sample temperature. The first change was to move the thermocouple to the top plate. Ideally attaching the thermocouple directly on the sample plate (Fig. 6) would give the most accurate reading. A new design is being developed to incorporate this with two contacts making the electrical connection to the azimuth drive assembly.

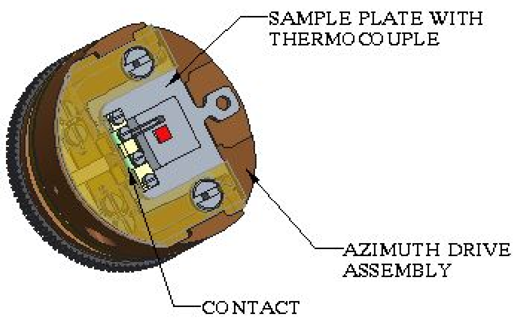


Figure 6: Thermocouple Position on Sample Plate.

## FUTURE DEVELOPMENTS

As more experience is gained using the manipulator, it can be seen that there are ways that it could be developed further. Among these are:

- Increased Azimuth rotational range, full 360° (+/- 180°) without effecting the cooling time.
- Tilt bearing redesign so that the sample azimuth axis and tilt axis are aligned without restricting the grazing angle.
- Reduction in component parts to reduce complexity and make easier to assemble.
- Wider sample temperature range (lower & higher limits)
- Easier sample plate clamping.
- Gold plating of the thermal shielding to help reduce the sample temperature and improve emissivity.

## REFERENCES

[1] Vacgen, http://www.vacgen.com

[2] Huber, http://www.xhuber.com

[3] Goodfellow, http://www.goodfellow.com