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# The ISIS Second Target Station Reflectometers

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ABSTRACT

This paper describes some of the engineering and construction of the three reflectometer instruments that were recently completed on the second target station at the ISIS facility of the Rutherford Appleton Laboratory, UK. Below is a description of the 3 instruments: Offspec, Inter and Polref.

Offspec is an advanced reflectometer using neutron wavelengths of 1Å - 14Å that gives access to nanometre length scales both parallel and perpendicular to interfaces. It uses large, rotating DC magnets and RF spin-flippers to perform spin-echo measurements that allow the neutron path through the instrument to be encoded very precisely.

Inter is a high-flux neutron reflectometer using neutron wavelengths of 0.5Å - 22Å designed for the study of chemical interfaces. It builds upon the success of the Surf instrument at ISIS and provides a unique facility for the study of a range of air/liquid, liquid/liquid, air/solid, and liquid/solid interfaces.

Polref is a polarised neutron reflectometer using neutron wavelengths of 0.5Å - 15Å designed for the study of the magnetic ordering in and between the layers and surfaces of thin film materials. Through precise control of the neutron spin, unique information on the size and direction of the magnetism as a function of depth can be obtained, allowing complicated structures to be studied layer by layer.

This paper gives an overview of the reflectometers, particularly the engineering problems encountered and overcome during the design of the Double bounce Polarisers and Moveable Optical Benches used on Polref and Offspec.

## 1. Introduction

Recently ISIS has expanded the capacity by building a new second target station. Seven instruments currently populate this target station. The three reflectometers are situated on the east side of the hall and sit in their own 300mm deep pit. The pit is needed as these reflectometers all view the lower moderator with their neutron beams traveling downwards at an angle of 2.3˚ to the horizontal.

Fig 1. The ISIS Second Target Station.

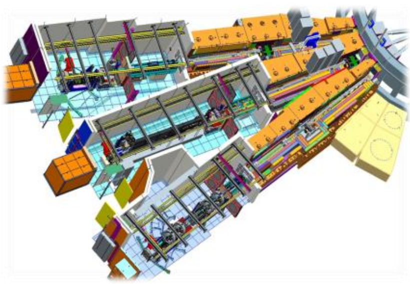


Fig 2. The three Reflectometers.

## 2. Polref

Polref is a polarised neutron reflectometer designed for the study of the magnetic ordering in and between the layers and surfaces of thin film materials.

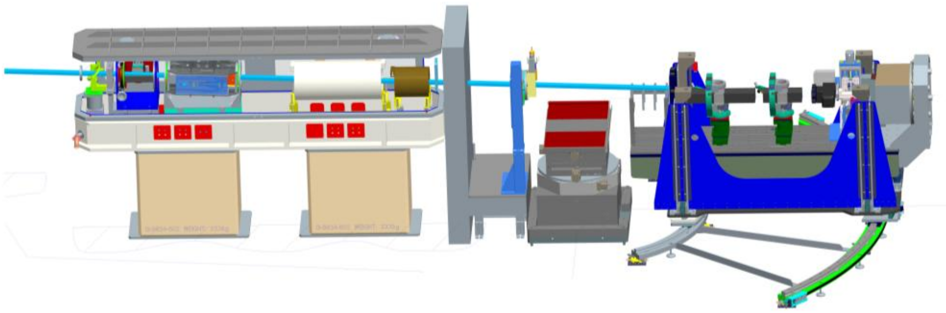


Fig 3. The Polref Internal Instrument Components.

### Science

It is now routinely possible to grow artificial structures comprising many layers of different atoms (multilayers) with almost atomic-plane precision and distinct physical properties. The revolutionary development has been the exploitation of the magnetism of electrons (called spin) rather than the charge.
Through precise control of the neutron spin, unique information on the size and direction of the magnetism as a function of depth can be obtained, allowing very complicated structures to be studied layer by layer.

### Example applications

- Spintronics.
- Magnetic nanostructures.
- Complex biological layered structures.
- Fundamental magnetism and superconductivity.

### Techniques

- Reflectometry.
- Polarised neutron reflectometry.
- Neutron depolarisation.
- Magnetic layer contrast variation.

Fig 4. T.Charlton, N.Webb & R.Coleman inside the Polref Blockhouse

### Technical

Polref has a flexible, three-directional polarisation control, allowing access to all elements of the polarisation matrix over a wavelength range from 1-15 Å. Accurate three-dimensional control of applied magnetic fields at the sample position are achieved with a 5 Tesla magnet, and in-situ magneto-optic Kerr microscopy will give complementary information on the magnetic configuration.

## 3. Inter

Inter is a high-intensity chemical interfaces reflectometer offering a unique facility for the study of a range of air/liquid, liquid/liquid, air/solid, and liquid/solid interfaces.

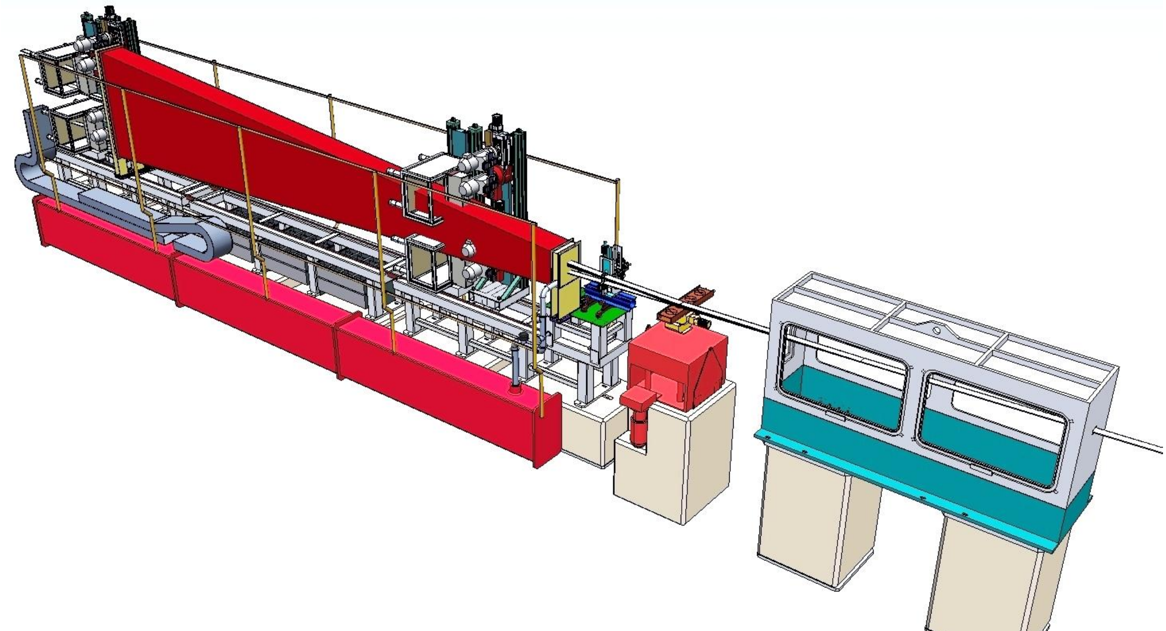


Fig 5. The Inter Internal Instrument Components

### Science

In neutron reflectivity experiments, a narrow beam of neutrons is bounced off a surface. Like beams of light bouncing off a mirror, neutron beams bounce off surfaces at the same angle as they arrive, and are collected by neutron detectors. Inter enables the use of smaller samples and expands the time scales that are observable for dynamic studies, encouraging the investigation of systems more closely aligned with those found in nature and industry.

### Example applications

• Gene delivery: Finding ways to get medicines to where they are needed in the body.
• Atmospheric chemistry: Pollutants and cloud formation.
• Ionic Liquids: ‘Green’ solvents for industry.

### Techniques

• Reflectometry.

### Technical

Inter represents the next generation of neutron reflectometers, allowing for higher resolution and enhanced measurement speed.
A spacious sample position allows for complex sample environment equipment to be positioned.

Fig 6. Various different sample position setups on the Inter beamline.

## 4. Offspec

Offspec is an advanced reflectometer giving access to nanometre length scales parallel and perpendicular to interfaces. It uses the technique of neutron spin-echo to encode the path that neutrons take through the instrument.

### Science

Measurements of specular reflectivity give information about structure perpendicular to a surface interface, but an increasing number of important science and technology issues in the study of thin films, multilayers and interfaces concern structure in the plane of the interface.

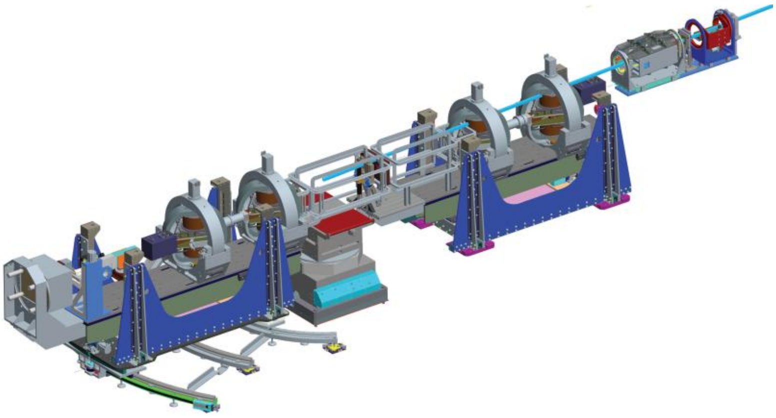


Fig 7. The Offspec internal blockhouse components

### Example applications

• Polymer films: The behaviour and performance of new polymer display screen technologies are strongly influenced by the structure of interfaces between different polymers.

• Complex detergents mixtures: Mixtures of detergents and polymers form complex structures at interfaces which can influence efficiency.

• Data storage: New types of data storage media with higher capacities rely on the interaction of nanometer length scale islands of material deposited on surfaces.

Fig 8. N.Webb, R.Dalgliesh & R.Coleman inside the Offspec instrument.

### Techniques

• Reflectometry.
• Spin-Echo SANS.

### Technical

Offspec can perform a variety of different measurements:
1. Neutron Reflection (NR).
2. Polarised neutron reflection with polarisation analysis (PNR).
3. Spin-Echo Resolved Grazing Incidence Scattering (SERGIS).
4. Spin-Echo Small Angle Neutron Scattering (SESANS).
5. High angular resolution neutron reflection.
6. Neutron Reflection from macroscopically curved surfaces.
7. Quasi-Elastic Neutron Spin-Echo (Over a very limited dynamic range.

## 5. Offspec Instrument Internal Optical Components

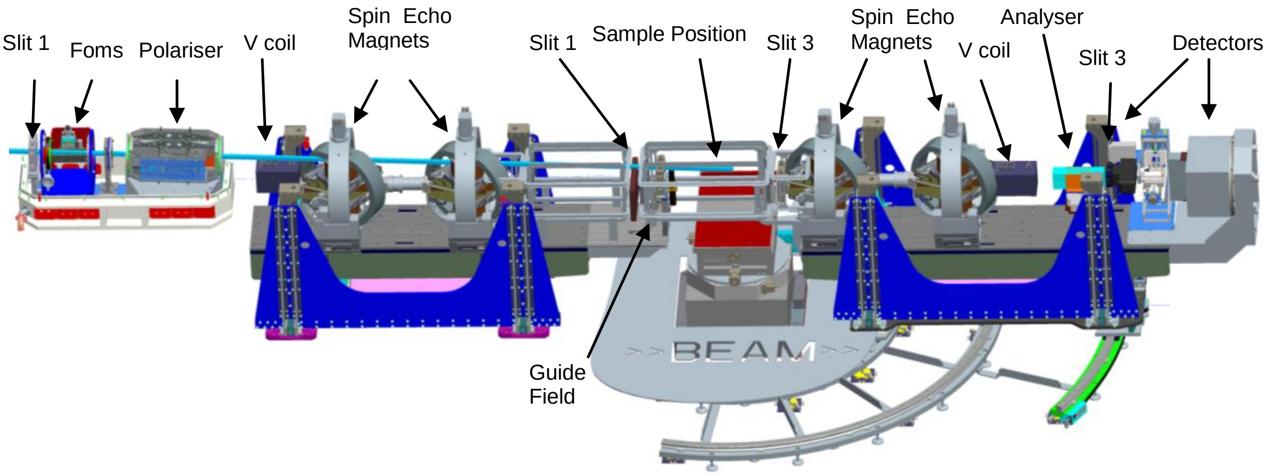



Fig 9. Offspec Blockhouse Internal Optical Components

Figure 9 shows the layout of the Offspec instrument components. The slit packages upstream of the sample collimate the beam into a ribbon often 1x30mm in size while the downstream slits provide background suppression. The frame overlap mirrors (FOMS) suppress long wavelength contamination of the detected signal and also double as the first stage of a compound polariser with the double bounce polariser. The two V-coils, "spin-echo magnets", field stepper and guide fields provide a well defined magnetic field environment within which the neutron spin is controlled. By careful tuning, the precessions neutrons makes around the applied field can be measured in order to determine minute angular changes resulting from scattering in a sample. The technique allows a divergent, high flux, ribbon beam to be used to measure small angles instead of the tradition method of a highly collimated beam with a prohibitively small flux.

The components along the Offspec beamline can be configured in various different angular arrangements.

The polariser consists of 2 mirrors. By adjusting the angle of these mirrors it is possible to adjust the angle of the incident beam on to the sample. This angle normally varies between -5.7 deg to +2.3 deg.

The pre-sample bench is then moved into position to match the angle of the incident beam.

The sample position orientates the sample into the correct position using its 6 axis of motion.

The post-sample bench containing the detector is moved into position to collect the data from the sample.

The post-sample bench has angular adjustment in both the vertical and horizontal plane.

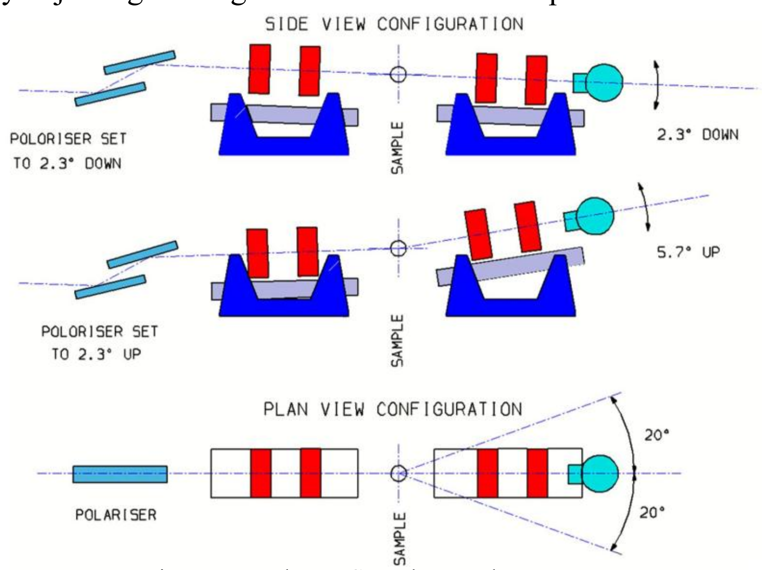



Fig 10. Various Pre and Post Sample Bench set ups.

## 6. The Offspec Optical Benches

The pre and post sample optical benches control the angle of the beam onto the sample and also the angle that the detector reads information from the sample. The benches are designed to carry heavy loads including 2 x 500kg Spin echo magnets. The benches move into different configurations with a positional accuracy with in 0.1mm. It is important that the benches have a low magnetic signature so that they do not influence the spin echo component situated on top of them. This was achieved by constructing them mainly out of aluminium. Both benches rotate about a central sample position. Three axes on motion are needed to manoeuvre the benches to the various angles necessary for the experimental set ups.

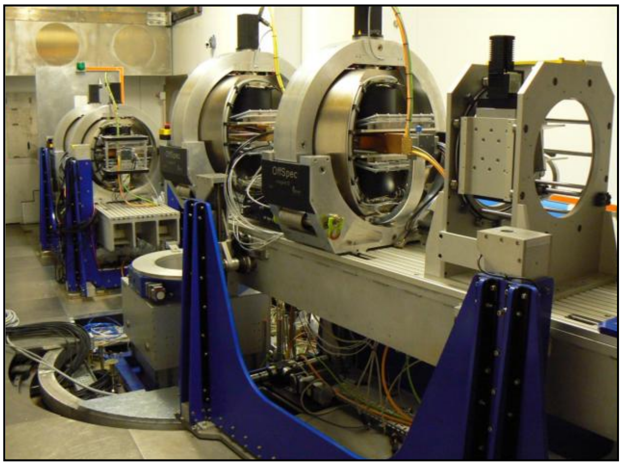
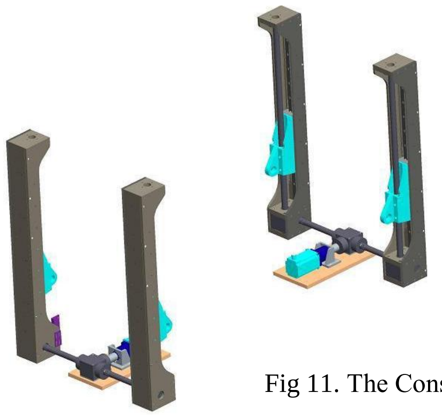


Fig 10. The Optical Benches inside the Offspec Instrument.



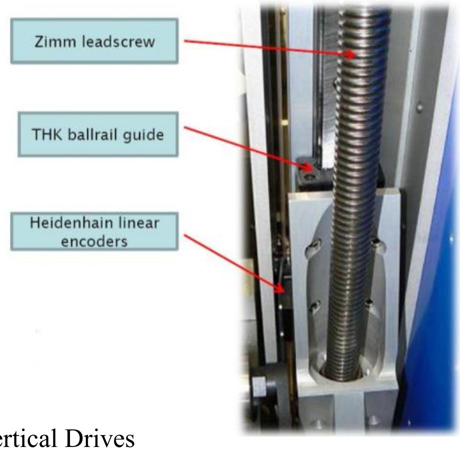



Fig 11. The Construction of the Vertical Drives

The benches have a height stage mounted in each corner these are grouped into pairs at either end. (See fig 11) These stages consist of two leadscrews attached to one stepper drive via a bevel gearbox. The motion is guided on precision ball guides and encoded via linear encoders giving positional accuracy within 0.1mm and incremental movements of 0.01mm. Leadscrews were chosen over ballscrews for this motion as they are do not down drive meaning that if ever there was a sudden loss of the power the bench top would not fall to the floor damaging personnel or equipment.

The bench tops move in an arc about the sample position to stay within the correct distance away from the sample it was necessary to add a horizontal movement onto the benches, this was done using a pair of ballscrews attached to a stepper a drive, again encoded using a linear encoder.

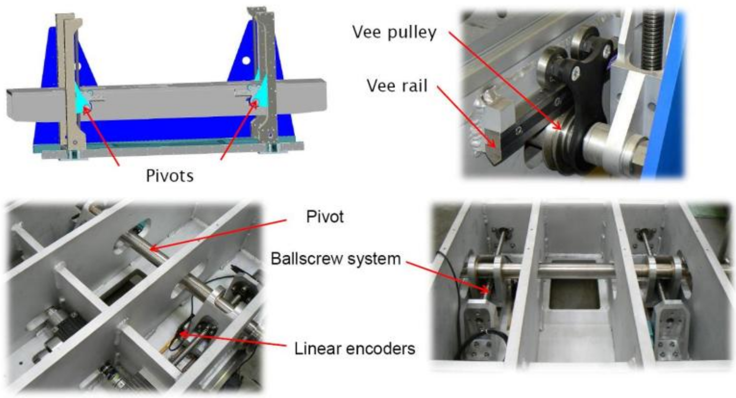



Fig 12. The Construction of the Horizontal Drives.

## 7. The Offspec & Polref Double Bounce Polariser

The polariser sits in the front of the beamline. It consists of two 500mm long super mirrors mounted opposite each other. Each mirror must is able to move independently in the vertical plane by 60mm and to an accuracy of less than 0.01mm. The mirror must also rotate through +- 5 degrees to an accuracy of less than 0.001 degrees. The whole assembly is also able to rotate through 180 deg around the beam axis. The mirrors must be kept in a constant 400 gauss magnetic field by permanent magnets. The whole assembly was constructed from materials with a low magnetic signature.

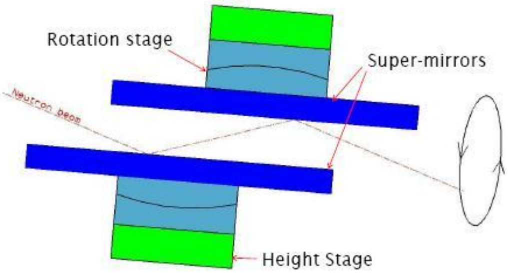



Fig 13. Polariser Schematic.

For the rotation stage an off the shelf item made by Huber was used. It was not possible to purchase such an item for the height stage.
There are many accurate height stages available but none had the required travel necessary within the very compact size envelope required.

A height stage was designed using a very simple but effective concept of horizontally driving a 15° wedge under an opposing 15° wedge. This turned a large horizontal motion of around 200mm into an accurate vertical motion of 60mm. Using THK high precision linear guides to constrain the motion and a precision ballscrew and stepper motor drive we achieved incremental movements of less than 0.002mm. The stage uses high precision linear encoders to feedback its position.
Two of these stages were mounted opposing each other to achieve the double bounce configuration.

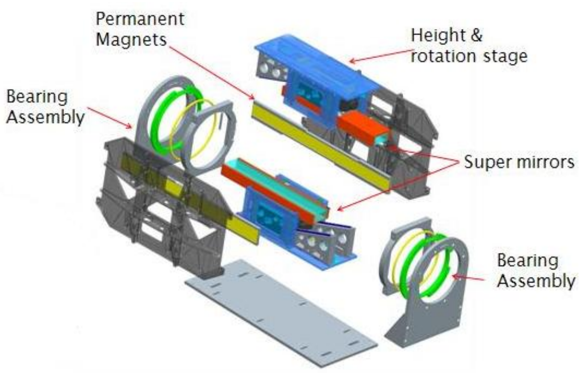



Fig 14. Polariser exploded view

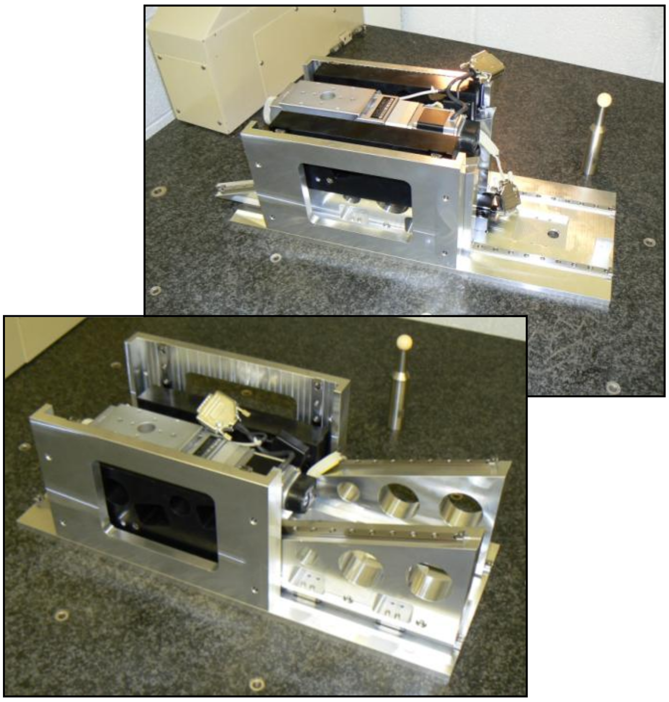


Fig 15. Polariser Height and Rotation Stage.

## . Acknowledgements

The reflectometer had a large group of scientists, engineers and technicians involved in the design, construction and commissioning.