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ISIS Target Station 2 Reflector Modifications

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Abstract. Following the successful completion of the second target station (TS2) Phase 1 project at ISIS in July 2009, the phase 2 project was initiated. This phase of the project is to deliver 4 new instruments. The design of 2 of these beam lines require modifications to be made to the TS2 reflector; a direct view of the target for ChipIR and widening the view of the coupled moderator's grooved face for the LARMOR instrument. In addition to these changes other beneficial modifications were identified and included in the new design. The modified reflector will be installation in the ISIS' long operational shutdown in 2014. This paper will provide greater detail of the changes made and report on the progress of the installation and commissioning.

1. Introduction

1.1. Background

1.1.1. *Target Station 2*. Operation since 2009, Target station 2 (TS2) typically takes a 40mA proton beam (800Mev) at a repetition rate of 10 Hz. The new target station produces extremely bright beams of low-energy neutrons enabling the ISIS science programme to expand in the key research areas of soft matter, advanced materials and bio-science.

1.1.2. *Target Station 2 Reflector*. TS2 represents a step forward in technology when compared to target station 1 (TS1) which first took beam in December 1984. One such area of advance was the design of the reflector. In TS1, the reflector is made up of beryllium rods (coated with 'Berylcoat D') housed in external stainless steel vessels that form the various parts of the full assembly. For TS2, the reflector is made from solid beryllium blocks plated in Nickel. This significantly increased the volume fraction of beryllium surrounding the target.

Another key change was the reduction in power deposited on the target and in the reflector (approximately 4kW), which meant the TS2 reflector could be cooled using light water flowing through water-cooling pads attached to the extremities of the reflector, as shown in Figure 1.

More fundamentally, operational experience from TS1 led to the reflector design incorporating a system that allowed much greater access to the target and moderators for maintenance and exchange, vastly reducing the time need to perform these operations. Figure 1 also demonstrates this 'splitting' ability.

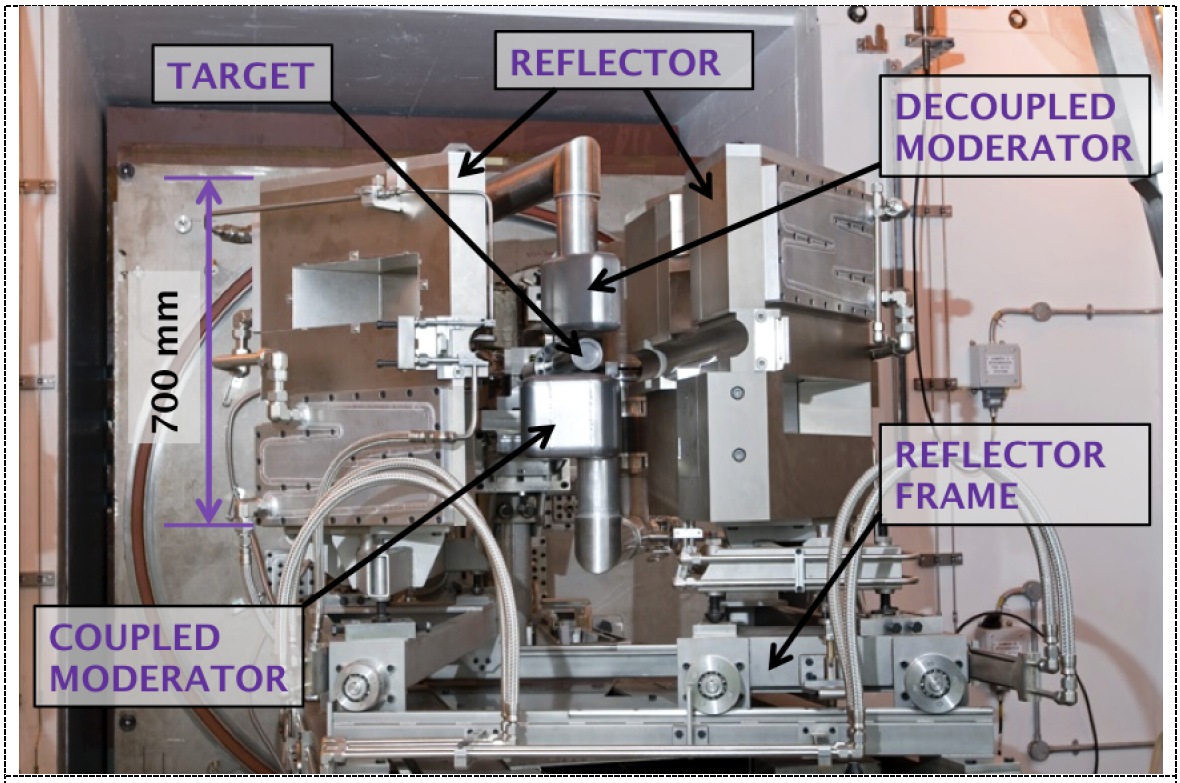

Figure 1. Labelled TS2 reflector in its 'split' state exposing the target and moderator positions

1.1.3. *Target Station 2 Instruments*. There are seven neutron instruments (see Figure 2) that are currently operational and producing research papers. In 2011, funding was made available to build four new instruments together with the necessary advanced changes to the target reflector system. These four phase II instruments (also shown in Figure 2) are currently in various stages of construction and commissioning. The instruments are:

- Chipir - A strategic facility for the aerospace and computing industries for fast neutron testing of electronics

- Zoom - Small-angle scattering instrument with polarisation for advanced materials, magnetism, environmental science, pharmacy and healthcare

- Larmor - Advanced techniques instrument for polymer science, bio-materials and food science

- Imat - Neutron imaging and materials testing for power generation, civil engineering, transportation and aerospace

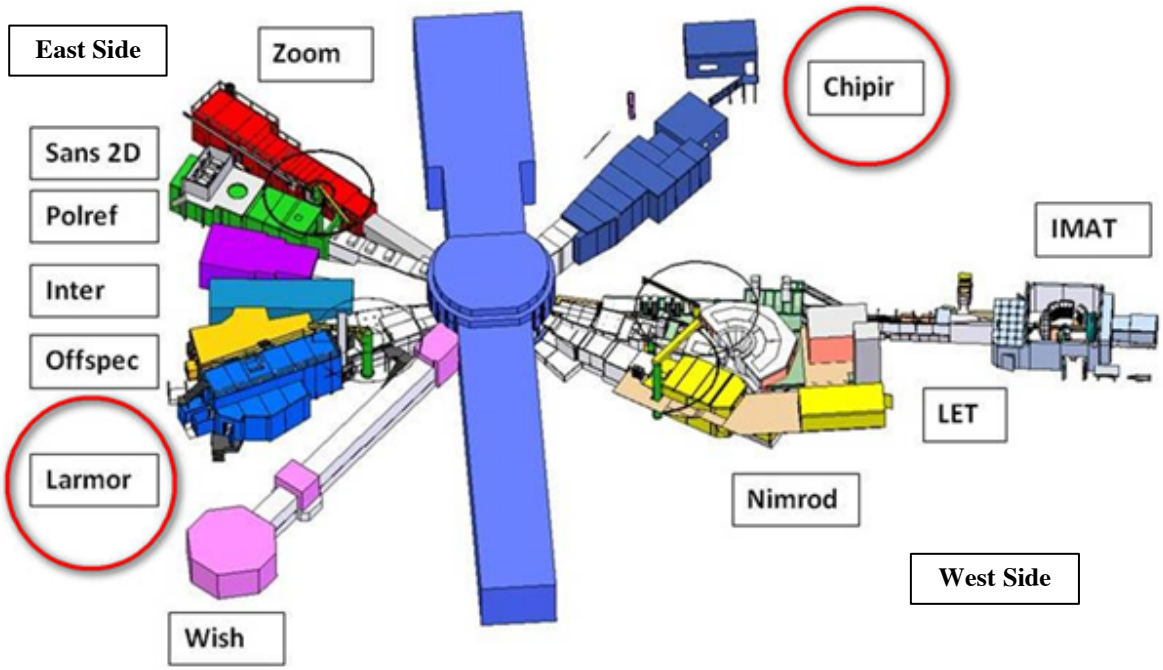

Figure 2. A schematic layout of Target Station 2 (TS2) showing the instrument suite including the phase 2 instruments and highlighting the Larmor and ChipIR beam lines.

2. Motivations to Change

2.1 Introduction

As with any project of this nature that proposes significant and costly changes, and which involves the disposal of activated components, there needs to be strong justification for doing it. The motivations for the changes made as part of RAMP2 (2nd reflector and moderator project) are broadly split into 3 sub categories, each dealt with individually below. Although the operational improvements and provision for future moderator development are worthy reasons to change, it is acknowledge that on their own they would have been insufficient to justify the cost outlay and risk to operations of the facility. It required the 2 phase II instruments in order to make the whole package of changes a viable project. Once the decision was made to change then it was prudent to try and make the other changes at the same time.

2.2 Phase II Instruments

In order to perform to their design specifications, two of the phase II instruments, Larmor and ChipIR, proposed changes to the reflector assembly. The changes required for Larmor were a consequence of the selected beam line position; the instrument selected the E6 port, which was designed to allow a view of either the upper or lower moderators. This meant that the flight line groove cut in the reflector for viewing the moderator would have to be widened. ChipIR being a unique instrument on ISIS required a completely different spectrum of neutrons in order to achieve its science and this required the instrument to have a view of target, so that it may extract the fast neutrons needed.

2.3 Future Moderator Development

As with the initial operation of any large scientific facility, the first five years of TS2 operations provided some unexpected insight, into its operational characteristics, in particular issues were experienced with the running of solid methane in the moderators. As an outcome and as part of the continued investment and development in the facility a programme was initiated to look into development of the current and future moderator concepts, both to improve operational running and potentially improve scientific output. This development and potential changes may result in changes in moderator geometry, orientation or both, plus possibly other more radical adjustments. With beryllium being a difficult and expensive material to work with and dispose of, it is far from ideal to have to discard large volumes of viable material should it need to be replaced. To gain the greatest possible flexibility with the minimum impact (loss of beryllium surrounding the moderators) on the existing instruments, the idea of exchangeable sections and 'buckets' was employed.

2.4 Operational Experience

Following initial 5 years of operation and the successful running of the day one instruments the operational experience gained from the running of the new target station highlighted some areas of potential improvement for the reflector assembly. It was also accepted that during the construction of original reflector assembly, in order to meet tight and challenging project deadlines, concessions were made in the design and construction.

One such concession was made on the original specification for the nickel-plating of the beryllium blocks, set at 50μm. At the time Materion had an issue with plating on one of the large blocks having cracked, so they were allowed dispensation to use ~20μm plating thickness instead. During commissioning of the target station water leaks were experienced in the void vessel, leading to a sub-optimal atmosphere and operational experience showed that running under these conditions that the reduced plating thickness was not enough. All new blocks for RAMP2 meet the 50μm specification.

Another such concession was made on the thickness of the cadmium decoupler for the lining of the flight-line grooves in the reflector. Due to space constraints and difficulties in manufacturing, it was not possible to achieve the 1.2mm thickness specified by the ISIS neutronics team, with 1mm being the thickest achievable. This was rectified in the design of RAMP2.

The original design of the reflector assembly was based around relatively large blocks of beryllium and there was a minor concern that should work have to be done on these in the hot cell, then they were towards to the upper limits of available space within the hot cell for several operations. This was previously decided to be an acceptable risk because of the low frequency for such work, however when the possibility came up for the reduction in size for many of the blocks as part of the project, the reduction in risk was also a supporting motivation to change.

3. Details of the Changes Made

3.1 Changes for ChipIR

ChipIR occupies the W1 beam port on the west side of TS2. To achieve the necessary spectrum of high energy neutrons it requires for its operation the RAMP2 reflector was designed to incorporate a direct line of sight to the target as shown by figure 3. Unlike any other beam line on ISIS ChipIR looks at a piece of beryllium sitting just above the target, rather than at a moderator. As can be seen from figure 3, this necessitated the design of a specially machined block featuring a smooth cylindrical bore, into the west half of the RAMP2 assembly. It is designed in such away that it could be removed and replaced in the future, maintaining a high level of flexibility and allowing for change in such

unlikely circumstances that the bore in the reflector for ChipIR has a greater impact on the other beam lines than predicted.

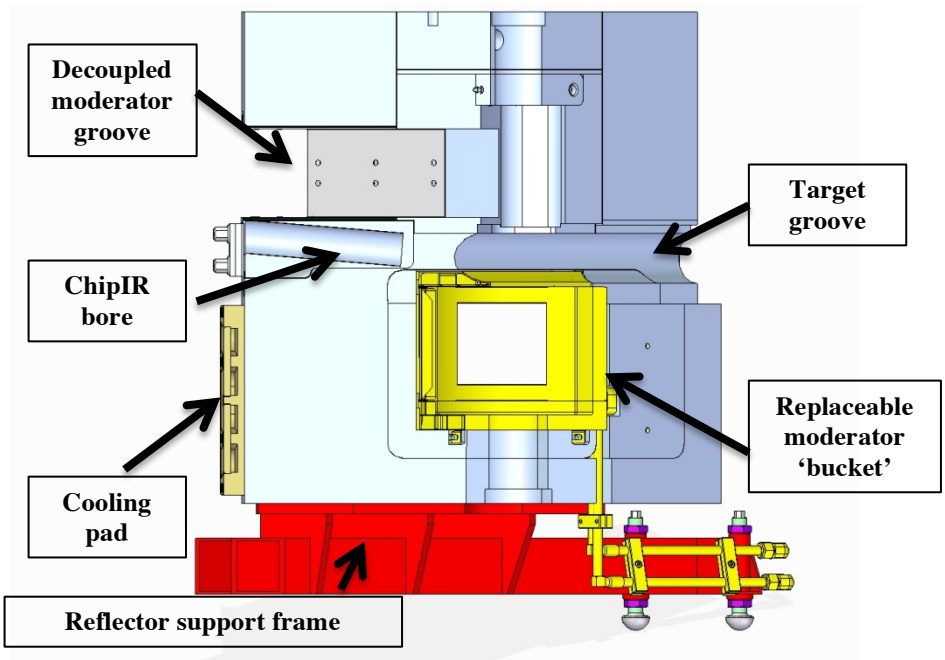

Figure 3. A section view through the west half of the reflector showing the modification made for the ChipIR beam line.

3.2 Changes for Larmor

As previously mentioned Larmor selected the E6 beam port and when this was originally installed as part of the construction of TS2 it was built with windows on the void vessel and 'torpedo tubes' such that a beam line on this port would be able to choose whether it viewed the upper (decoupled) or lower (coupled) moderators. Larmor selected to view the coupled moderator and this required the widening of the groove in the reflector from 53° to 64.4°. It also meant that the cooling pad and water piping that was located in that area needed to be modified as well, easily seen in Figure 4. The rerouting of the water piping also had the added advantage of reducing the backgrounds for the instruments facing the lower east section of the reflector assembly.

3.3 Changes for future moderator development

The basics behind the changes made in order to add flexibility to the reflector assembly for future moderator development and other geometry changes (such a flight line grooves), was to design in exchangeable sub-assemblies. The 'buckets' sitting closely around the moderators allow for dimensional and orientation changes to the moderators and on the west side there is a removable section for which will allow changes such as widening the groove for the lower couple moderator, as was done for Larmor (see above). The removable assemblies allow a much smaller amount of beryllium to be exchanged, saving time, cost and money both in the manufacture of a new piece and in the disposal of the old piece.

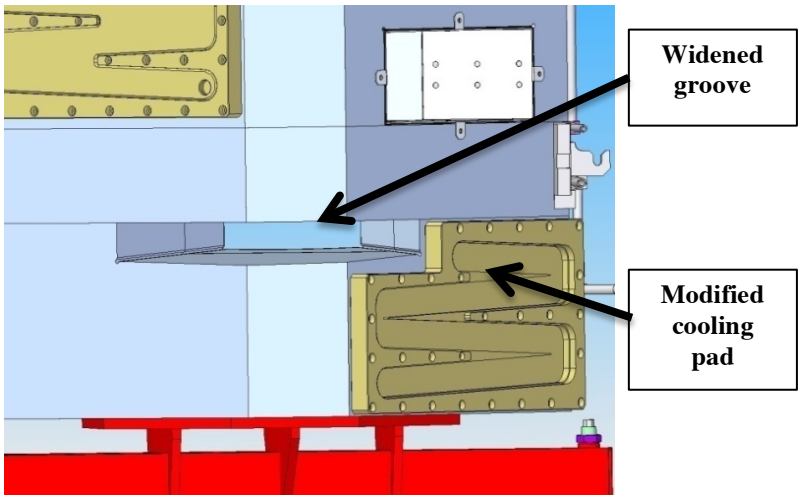

Figure 4. A CAD model view of the east half of the reflector showing the modification made for the ChipIR beam line.

3.4 Operational improvements

The original TS2 reflector featured over ten different sizes of beryllium fixings, each specialised for a specific application within the assembly. In addition, due to the relatively low ductility of the beryllium bolts (when compared to standard engineering materials) the bolting philosophy was to fix each block to the next thus keeping bolt lengths relatively short and reducing the risk of several blocks being stuck together in the event of a beryllium bolt shearing. In the new design the opportunity was taken to modify the whole fixing methodology. Firstly, the overall number of bolt sizes was reduced down to three (short, medium and long), thus reducing the remote tooling requirements and making it far easier and quicker to visually identify specific bolt types. Secondly, the way in which the assembly was fixed together was changed with long through bolts being used in the corners to connect through all the outer blocks, again reducing the total number of bolting operations required. These bolts are made from nimonic 80A due to more desirable mechanical properties and the beryllium bolts that were kept for use in more 'neutroncially sensitive' areas had their design changed to make use of the fact the beryllium is relatively brittle. The redesign added an intentional weak area just below the head of the bolt so that should the bolt fail it would do so at this location and thus always allow the two blocks bolted together to be separated.
The opportunity was taken to rectify nickel- and cadmium decoupler thicknesses. In addition, a coupled moderator also been changed as part of the work with the unused solid methane section having been removed from the internals because of operational issues and with scientists having been able to adapt to using the flux and spectrum from Liquid H_2 section of the moderator.

4. Build-up, testing and installation

Materion (formerly Brush Wellman) was selected as the supplier for the beryllium, with a British company, GSI Exotec, selected as a sub-contractor for the machining and plated of the individual blocks that make up the reflector assembly. This meant that the near net shaped beryllium blocks were shipped from the USA to the UK where they machined and plated. To ensure that the specified plating thickness was achieved for all pieces, a reference piece of accurately known prior geometry was plated with each batch and then measured to confirm the depth of nickel achieved. Unfortunately as a consequence of Materion being the main contractor and export regulations, all the finished blocks had

to be shipped back to the USA so that they could finally be sent back as the finished assembly. This meant additional time and expense.

The beryllium components were received on site 9 months before the date set for installation, thus allowing time for assembly, alignment and characterisation work. A replica supporting frame also had to be designed and built, to have the most representative conditions possible. An advantage to having such a frame is that it can also be used for training and testing purposes in the future. Time and care was taken to perform as much preparation for the installation outside of the remote handling cell.

5. Summary

To summarise, since its initial conception in 2009, the RAMP2 project has designed several important changes to the ISIS TS2 reflector assembly, in order for it to continue to best serve the operation of the facility for many years to come. The main changes made are listed below:

- Widening of the coupled moderator groove and associated changes to the water cooling pad and coupled rerouting of the water pipework for the Larmor instrument;
- A bore into the reflector to allow a specific fast neutron flux into the ChipIR instrument;
- Replaceable 'buckets' around the coupled and decoupled moderators to allow for potential future changes and moderator development;
- Improvements to the mechanical fixings within the reflector;
- Corrections to out of specification thicknesses for some nickel plating and cadmium decoupler.

The RAMP2 reflector assembly was successfully installed in the 2014/2015 long shutdown and as of writing this paper, is currently going through final checks before target operations commence again in early 2015.

6. Acknowledgements

The work presented here in this paper and in the accompanying presentation is the combination of a great deal of time and effort by a large number of ISIS' staff. I would like to acknowledge the main contributors to the project here (listed in alphabetical order); Stuart Ansell, David Bellenger, Julius Bullock, Lester Clarke, Daniel Coates, Matthew Fletcher, David Haynes, Sean Higgins, David Jenkins, Leslie Jones, Eamonn Quinn, Andy Robinson, Chris Russell, Graham Wallace & Peter Web. It is due to the dedication and commitment of its' staff such as those listed above that ISIS remains such a productive and scientifically important facility.