

FREIA update for STAP October 2020

Since the last meeting the project has continued with detailed design, and has seen the engineering team grow. The project is preparing to launch a number of procurements for significant subsystems.

Impact of Covid-19

STFC's work-from-home policy continues, with staff attending site approximately once a week. At the moment this has not had a huge impact on design progress as most of the work is computer based and is possible remotely. Time on-site is targeted at hands-on tasks such as testing prototypes, which were at risk of becoming neglected.

We continue to see some delay to our procurements (see below) and the wider project to trickle down and impact FREIA

Early procurements

WFM chopper discs

The WFM chopper discs are one of the highest technical risks in the instrument and the contract with Airbus is progressing well with minimal impact from Covid-19. The design for the five Ø1.3m carbon-fibre chopper discs has been finalised taking into account optimisations in the manufacturing process, and the prototype disc is in manufacture. A rigid hub design has been developed, to increase the natural frequency of the torsion mode to well above the operating frequency.

The FAT is expected to be held in November, though due to Covid-19 travel restrictions it is unlikely that the instrument team will be able to physically join the tests. Following the FAT, the disc will be shipped to ISIS to await integration with the housings.

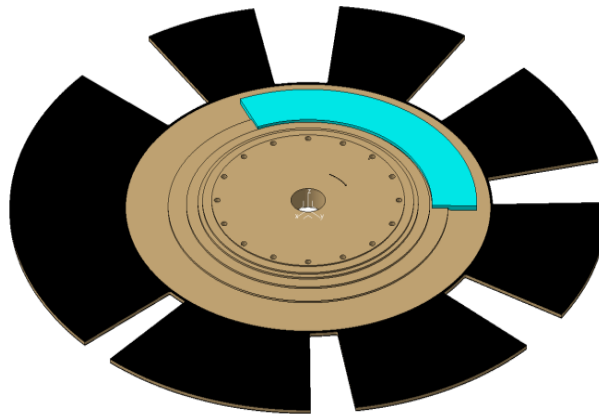


Figure 1 – Updated WFM1 disc design from Airbus. The central stepped profile has been refined.

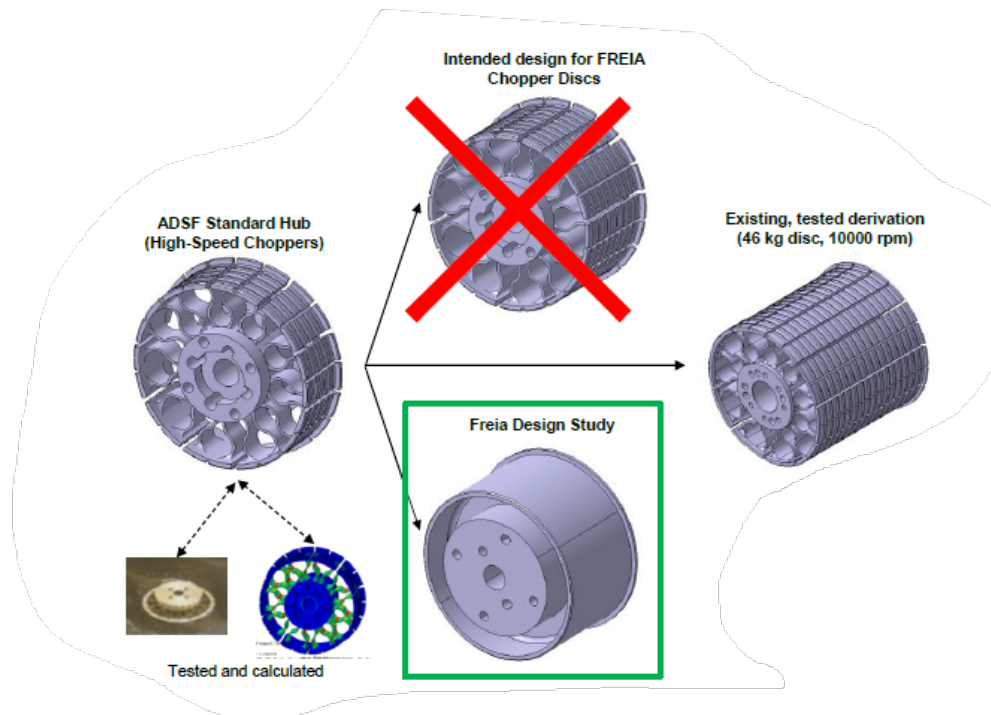


Figure 2 - Airbus' rigid hub design decision

SKF Chopper Drives

The SKF components for the chopper system are in high demand, and likely to become a bottleneck for later instruments. It was therefore decided to order the drives and spindles early, to ensure that the components would be available for testing the chopper system. Manufacture of the components is due to be completed in spring 2021.

NBOA

The monolith insert optics (NBOA) was ordered from S-DH at the beginning of March last year. Here the Covid-19 situation has had a significant impact because the development of the $m=4$ coatings for the elliptical surfaces had to be placed on hold throughout the spring and summer, as there were no neutron sources in operation to enable the vital reflectivity tests. Tests have now resumed at PSI, with samples also sent to ANSTO and BNC.

Prototyping of key design features has identified some areas of concern within the design and production methods. Specifically, the side walls and silicon wafers are experiencing greater waviness than specified.

The design originally proposed suggested that the silicon wafers used to create the channels in the guide are bent to the correct curvature by clamping at the top and bottom. However, the large height of the guide has meant that the wafers do not follow this curve in the middle resulting in a significant shape error that actually induces waviness in the wafers.

To solve this issue, it was proposed to change from truly-curved wafers to a polygonal approximation using 100-200 mm straight segments. This is based upon the fact that the McStas simulation of the instrument already makes this assumption. Therefore, the ideal flux quoted previously assumes this geometry – with ideal waviness. While not a perfect representation, the McStas implementation of

waviness can also be used to assess impact of real waviness in this scenario. These simulations show that use of straight sections as proposed should give at least a flux comparable to the baseline design, and any variation is less than 1% of the total flux.

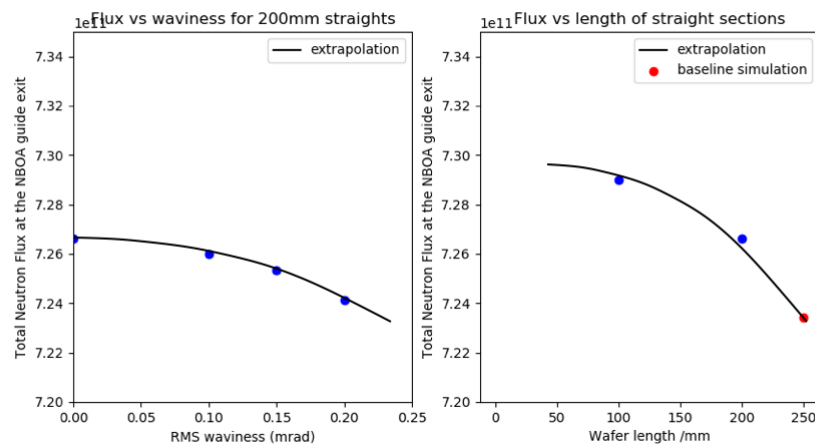


Figure 3 – Flux vs the waviness and length of straight sections making up the NBOA

A prototype of the straight wafer design was manufactured in the last week of September. The conclusion of the testing was that the waviness is much improved, compared to tests with curved wafers. RMS waviness values between 0.23 – 0.13 mrad have been achieved, compared to the specification of 0.15 mrad.

The side walls of the guide also posed a problem. The original design called for the connecting plates which join the 500 mm long substrates to be mounted in recessed pockets on the outside surface of the side plates. However, the machining process caused significant deflection of the inside surfaces which no longer followed the s-bend curve.

To mitigate this, the pockets have been removed so that the connecting plates are mounted directly on the outside surface of the substrates. This requires an update to the interface with the vacuum housing, which is the responsibility of ESS Target Group. An updated CAD model for this purpose is currently in work.

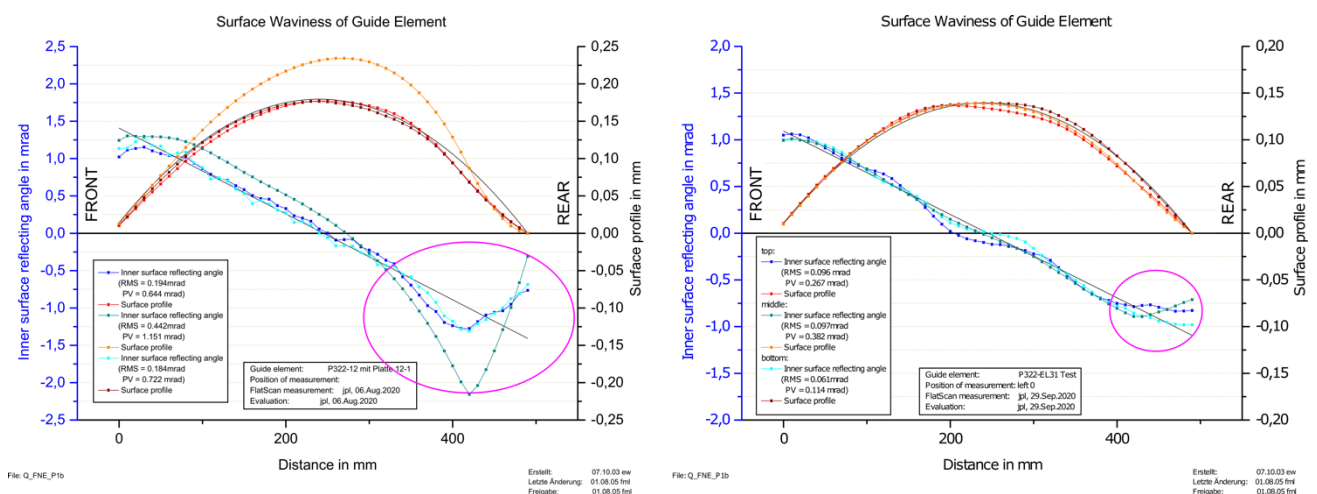


Figure 4 - S-DH FlatScan measurements: [left] prototype side plate with defect caused by connecting plate; [right] latest prototype shows the defect is greatly reduced.

Guide

Given the complexity of the FREIA guide, the baseline plan aimed at launching the guide tender in January 2020 in order to allow for the possibility of subsequent negotiations and still be able to place a contract in time to ensure that the critical interfaces are fixed in a timely manner. This is because many of the other instrument components are dependent on this design. For example, the lower vacuum houses which contain both chopper and guide components cannot be finalised without this information from the guide supplier. However, at the request of ESS, the guide tender was put on hold until July, in order to give priority to the first eight instruments. This represented a substantial delay to the project schedule compared to the baseline. Following pressure from the project team, it was allowed for the OJEU to be launched in May. Unfortunately, the tender concluded in July with no valid bids received.

Subsequent discussion with suppliers has identified that the ~250 mm height of the guide poses some uncertainty about the ability of the wafers to achieve the requested shape and waviness specification (see also current issues with the NBOA). We have therefore decided to allow the suppliers to carry out some in-house prototyping until mid-November. After receiving detailed proposals from the suppliers, we will make a decision on the approach for procuring the guide. We are considering all options for procuring the guide, within the constraints of the tightly controlled STFC procurement process.

As such, there is now a substantial delay to agreeing critical interfaces with the guide. We are currently in the process of re-baselining the plan to better understand the impact on the sub-TG3 review process for the rest of the instrument.

Detailed design progress

In general design is progressing well. In the last 6 months the project team has grown as engineering effort begins to transfer from LoKI.

Choppers

In addition to the five WFM discs above, the designs of the three Ø1 m WBC discs are in-work.

Preliminary FE analysis of WBC2 identified that the typical ISIS mix of boron-epoxy would be too heavy. As capacity to develop an appropriate coating process was significantly impacted by the site closure, it was decided to order the disc from Airbus. There was a significant cost saving from adding the new disc to the existing contract. The preliminary design of the disc was completed in August, and will be delivered in-line with the WFM discs.

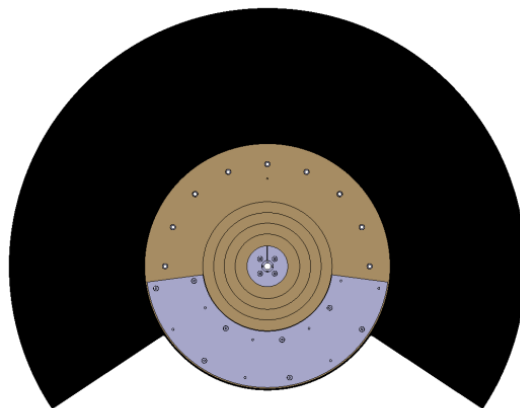


Figure 5 - Preliminary design of WBC2 from Airbus

In-house designs for WBC1 & 3 have passed preliminary FEA and will be designed using the typical ISIS aluminium & boron-epoxy construction. Due to the tall beam height there is limited space for the counterbalance – tungsten masses are proposed. Preliminary FE analysis identified that the vibration modes are below the operating frequency. The initial design of the WBC housings which will be compatible with both the ISIS and Airbus WBC discs is also progressing.

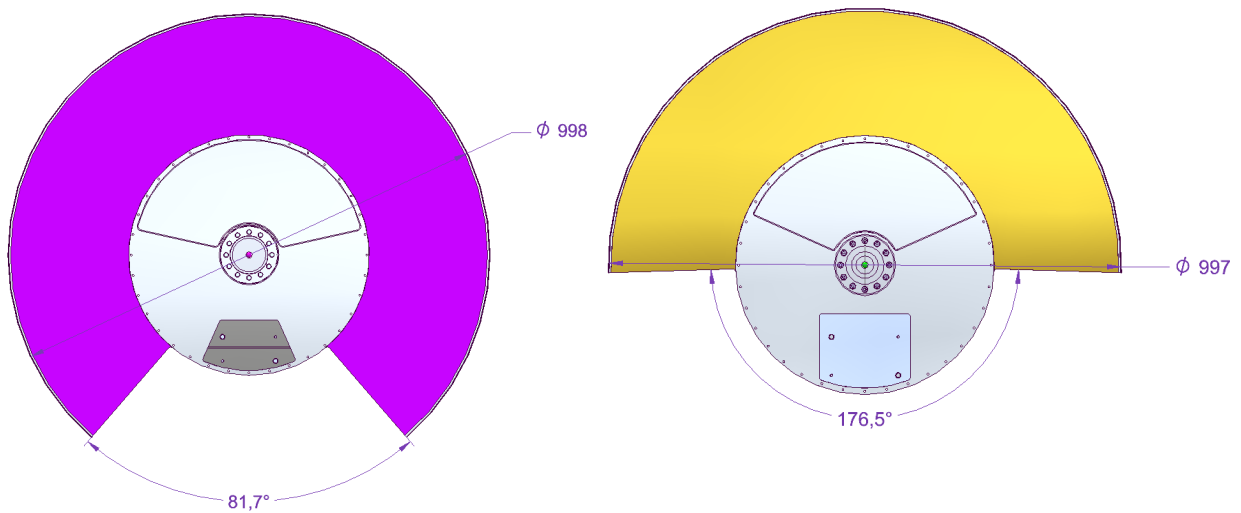


Figure 6 - Preliminary in-house designs of WBC1 & WBC3

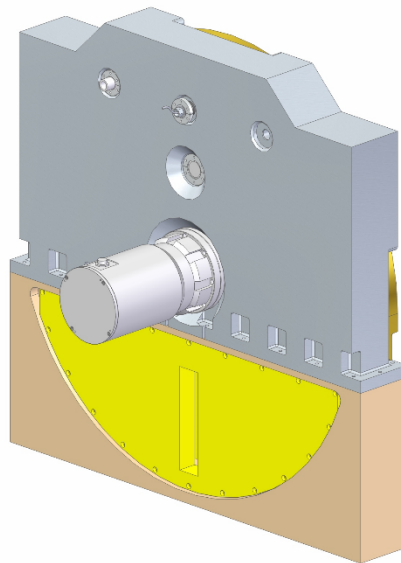


Figure 7 - Preliminary design of WBC housing

Detector Bench

Through an arrangement with Uppsala University, the design of the detector bench is progressing well.

The conceptual design of the bench features three screw-driven axes – one controlling the angle of the detector, and two to compensate for the offset between the sample and the pivot. This allows the detector to be positioned from 7.5° below to 21° above horizontal, and also allows for changes in the vertical location of sample position, which is necessary for operating with inverted geometry.

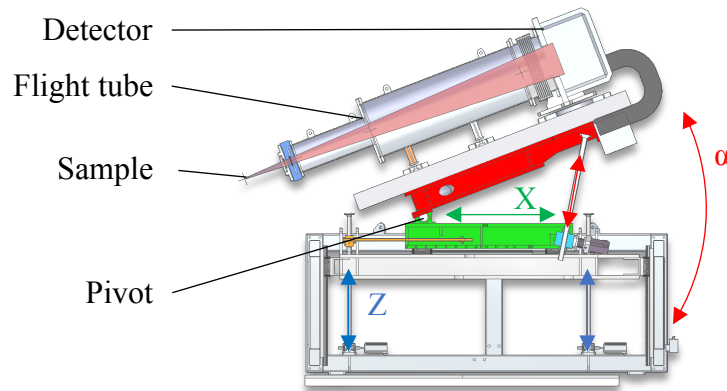


Figure 8 - Detector bench concept

Collimation System & Kinetics mode

In kinetics mode, a guide containing absorbers is placed between the two sets of slits. The principle of the guide is to separate the three different incident angles and avoid unwanted cross-talk between slits. However, since the S2 slits are small, it is impossible to get the guide partition close enough to perfectly separate the angles, which means there is a gap that could allow cross-talk between slits.

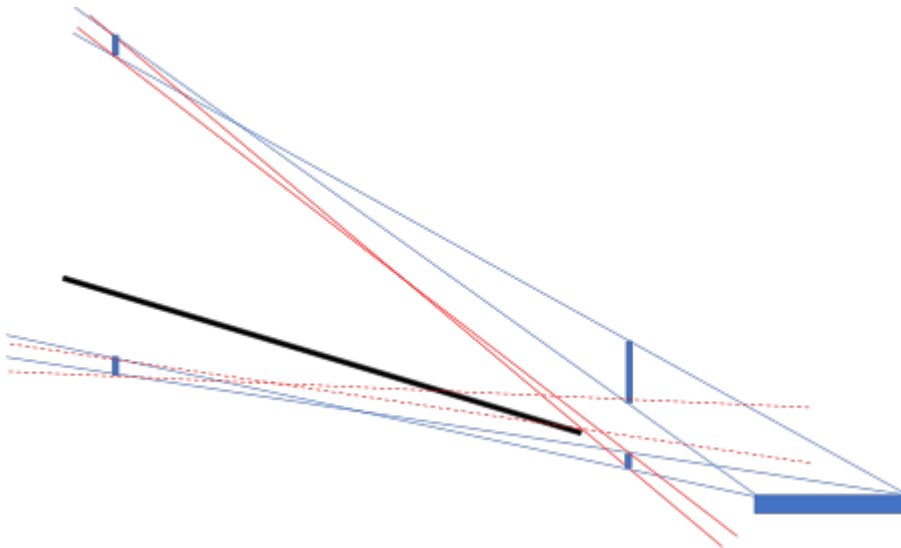


Figure 9 - Schematic representation of the potential cross-talk for two sets of slits with a partition separating them.

The cross-talk is most problematic where the slits are positioned at the limits of the intended range, and example of which is illustrated in Figure 8. The cross-talk neutrons may be relatively low intensity and not directed at the sample, but they are still likely to contribute to the background, although this may be mitigated to some extent by shielding around the sample environment.

It is clear that the closer the partition gets to the slit the better, but engineering constraints put a limit on this, which needs to be balanced against other factors such as the need to reduce the number of windows.

Following suggestions at the previous STAP meeting, a further concept design for the collimation changer has been developed, focussing on eliminating vacuum windows.

The preferred concept now features a large vacuum housing, which contains three translation stages allowing the various combinations of components to be achieved. The design eliminates the two vacuum windows between the end of the instrument guide and Slit 1.

There were concerns that this design would not be compatible with the minimal gap required between the separating guide and Kinetic Slit 2. Following optimisation of the engineering design, a gap of 60 mm from is now achievable, which means that this design concept is much more able to avoid the cross-talk issues outlined above.

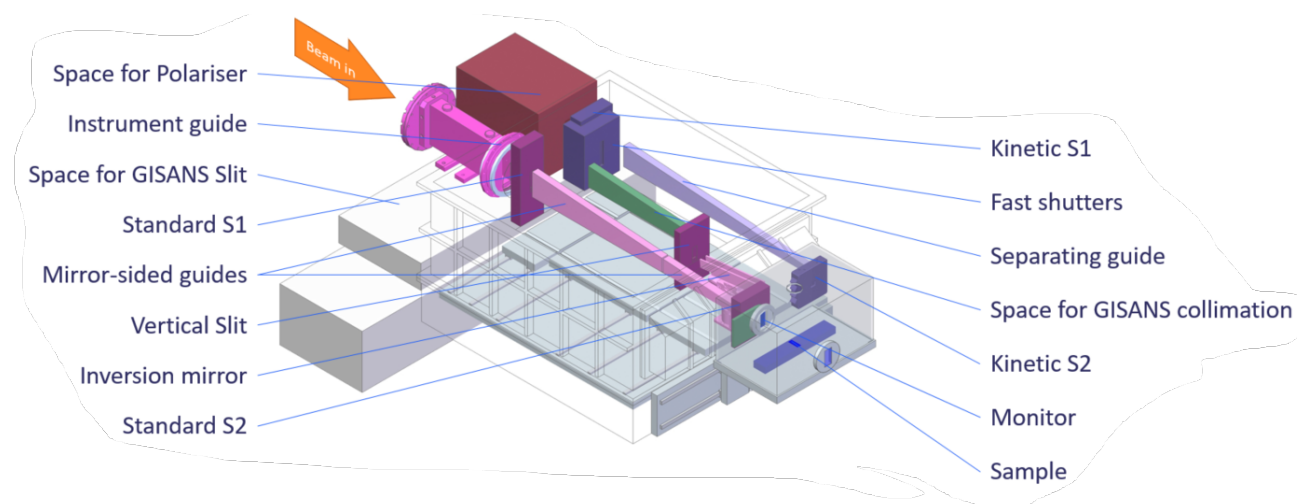


Figure 10 - Collimation system concept design

Out-of-scope Developments

Progress of the fast-shutter development

The fast-shutters are not within the scope of the instrument, and will be added later as an upgrade. However, we do have a VR funded project with Lund and Uppsala Universities to develop a conceptual design for this system. Following a further round of recruitment at Uppsala University, a mechanical engineer and a controls engineer are now available to work on developing the shutters, based on the initial work done at ISIS (in 2018). The next steps for the team are to further understand the project requirements, before prototyping a shutter mechanism and ultimately testing the prototype at ISIS. The work will also focus on the control system required to synchronise the mechanism with the ESS timing signal.

Sample Environment

The sample environment for FREIA is also not within the scope of the instrument but it remains crucial to the success of the instrument. There have recently been some opportunities for external Swedish funding of ESS instrument related developments, principally in the form of staff resources. We have applied to take advantage of these opportunities to deliver some of the sample environment needs for both of the reflectometry instruments at ESS.

One project potentially funded by Tillväxtverket would explicitly deliver the physical hardware for solid-liquid cells for ESTIA as well as enabling some important development studies that are required to enable both ESTIA and FREIA to reach their full potential. This would take advantage of the highly relevant experience of Adrian Rennie and build upon an existing strong collaboration already

established between the FREIA instrument and Uppsala University (the coincidentally named FREIA laboratory).

The other application is for funding for a post-doc from NordForsk, which will cover the development of a multi-channel solid-liquid cell to improve throughput and consistency of samples that require significant preparation (such as Langmuir-Schaffer coating.)