Target and Dump Proton Beam Imaging Systems CDR

System Overview: updates since the PDR

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1. SCOPE

This document provides a brief update to the ESS target and tuning dump imaging systems (IMG) with respect to the status at the preliminary design review (PDR). For a general introduction to the imaging system itself please refer to the PDR overview document [ESS-066912].

This overview document refers when appropriate to the other documents in the Imaging Systems CDR using **red font**, and the CHESS number to identify the document.

The CDR is prepared in collaboration with the Imaging System in-kind partner, the Department of Physics, University of Oslo, Norway (Oslo), ESS. **ESS-0044049** describes the in-kind contract between Oslo and ESS. In addition sub-contractors to Oslo and ESS, the Cockcroft Institute and the University West, have also contributed to the CDR.

2. INTRODUCTION

The imaging systems have gone through significant design changes since the PDR, several of them based on the recommendations of the PDR review report [ESS-0078698]. In addition a large amount of detailing of all subsystems have been performed in order to arrive at designs for the target imaging systems and the tuning dump imaging systems. We now go through the subsystems one by one and discuss updates and changes since the PDR in more detail.

Formally there has been no requirement updates to the Imaging Systems, and **ESS-66920** remains the formal document for main requirements and interfaces.

3. TARGET OPTICAL SYSTEMS

The target optical systems, one for the target wheel (TW) and one for the proton beam window (PBW), have been **redesigned to a simpler system** than presented at the PDR. The systems now consist of 7 mirrors each, where all but the first mirror are flat. A commercial telephoto lens in an accessible no-radiation area is used for imaging. The first mirror is curved in order to provide the desired field of view, and some margin in order to ease tolerances. At PDR each system consisted of 11 mirrors, 8 of them non-spherically curved. The redesign is consistent with the PDR review report general recommendation *"In case of a required tradeoff chose the simpler and more robust option over a very sensitive and brittle solution even if the nominal performance of the latter appears superior*."

ESS-0149764 describes the updated target optical systems design and simulated performance. The resulting numerical aperture is approx. 0.001, which is very close to the value for the previous 11 mirror system design. In order to demonstrate performance and verify the design a prototype has been build up in Oslo, and found to fulfill the 1 mm resolution requirement and also match the simulated performance well. The prototype is as well described in **ESS-0149764**.

Mirror mounts were an open point at the PDR. A custom mirror mount, "Bendamount", has been developed by ESS for use in the imaging systems (as well as elsewhere). It is available with 3 or 5 DOF. The Bendamount is described in ESS-XXX, and is planned to be used for the six flat mirrors, and also for the tuning beam dump mirrors. For the first mirror, very close to the proton beam path, a simpler mount type with better heat transfer capabilities will be necessary, according to our studies. Studies of the thermal load for the simpler mount is documented in **ESS-0149765**, and indicates that thermo-mechanical deformations are within tolerances when considering this mount only. However, a final conclusion can only be made when full thermo-mechanical simulations of the PBIP are done, something which is outside the scope of this work package.

Since the PDR the dialogue with the ESS target and also the PBIP in-kind partners has been intensified. This has allowed to establish, in close dialog with partners, a set of what we believe is realistic tolerances, aiming to take into account errors from initial alignment (small), errors from installation of the PBIP and thermal expansion. The tolerance budget is documented in **ESS-0149766**. The final verdict on tolerances can only be made after the full PBIP design, including thermo-mechanical simulations, has been completed (outside the scope of this work package).

How, when and where to install and align the optical components has also been discussed with partners, and a plan, believed to be compatible with the PBIP schedule is documented in **ESS-0153500**. This document includes the discussion of the challenge of the first mirror, which is planned to have no degrees of freedom.

CAD files of the target systems optical components have been communicated to ESS and have been integrated into the ESS CAD models. This process is described, and the integrated models are illustrated in **ESS-0153782**.

4. TUNING BEAM DUMP

At the PDR only conceptual ideas about the tuning beam dump system were presented. The CDR design consists of two imaging systems. One system images the beam as it passed through a scintillator screen inside the beam pipe at a location upstream of the dump. The second system images the beam on the dump itself, using a mirror on the back side of the scintillator screen in order to capture photons from upstream.

In order to keep the optical systems simple, and not having to transport the light far from the tuning dump, the cameras are placed inside the main tunnel leading up to the dump. The optical paths for both systems consist of a couple of flat mirrors and a commercial camera lens. The components should be easily accessible and will then be easily aligned. Commercial moving stages, with a track record in accelerator facilities, have been identified to move screens in and out of the beam line. Up to three different screens may be switched in and out of the beam line. The tuning beam dump optical systems design is documented in **ESS-0150756**.

Due to the choice of placing the cameras in the tunnel an effort has been to quantify the expected radiation dose the cameras will receive, using FLUKA. The camera dose is minimized by optimizing the location. **ESS-0150754** describes the dose calculation assumptions and results. By placing the cameras as described in alcoves in the tunnel wall, as is assumed in the design document, the expected dose per camera stays below 20 Gray/year. We believe this allows for the use of standard Gig-E type digital cameras. More radiation-hard analog cameras may be used at a back-up option.

Close dialog has been held with ESS and partners for the tuning beam dump vacuum vessel in order to ensure compatibility between the optical system and the rest of the tuning beam dump. The corresponding interfaces are described in **ESS-0150758**.

5. PHOTON SOURCE DEVELOPMENT

At the PDR the main goals of the photon source development was 1) to reproduce the SNS coating, based on $Cr:Al_2O_3$, and 2) to identify and qualify better performing coatings, based on alternative chemistries. Since the PDR significant efforts, including beam tests at the Oslo Cyclotron and an irradiation campaign at the Brookhaven BLIP facility, have been undertaken, though no alternatives to the SNS coating has been qualified so far. Irradiation tests with low energy protons at DTU in Copenhagen are currently being investigated as a way to qualify radiation hardness. The current status of the luminescent coating development is described in **ESS-0150760**.

The updated plans to assemble the target in two halves imply that the target will have to be coated with a portable combustion spray system, probably when fully assembled and located at ESS Lund. This is the same spray technique as used at SNS, and for at least the first target the baseline is therefore to reproduce the $Cr:Al_2O_3$ coating used at SNS. There still remain technical challenges to be addressed in how to best design a (robotic) system that may coat the entire target, and how to ensure that requirements from target on temperature increase etc. are guaranteed to be fulfilled. For coating of the proton beam window, more sensitive to temperature increases, more modern plasma spray techniques may still be considered due to the small size of the window. The possible thermal spray processes, and considerations for their use for the imaging systems are described in **ESS-0150759**.

6. PROTECTIVE COATING DEVELOPMENT

A recent development, reported not too far ahead of the CDR, is the information about the failure of the imaging system at SNS due to eroded optical surfaces. The most probable reason is a vacuum leak leading to nitric acid due to radiolysis of humid air. At ESS a recent target design change from a 1 bar He atmosphere to a "poor vacuum" atmosphere means that there may be large amounts of nitric acid developing inside the monolith, covering optical components. As this is a significant system risk this is urgent to address. **ESS-0150766** describes our current understanding of the nitric acid issue, as well as ideas for a possible mitigation strategy, mainly consisting of considering a layer of protective coating.

7. ELECTRONICS AND SOFTWARE

Since the PDR camera types have been identified for the different systems, apart from that the overall electronics architecture has not changed significantly from the PDR. The architecture is described in **ESS-0150746**.

The functionality for the target systems has been defined. The functionality includes complex imaging processing algorithms, including correction of distortions and motion blur. These algorithms have now been developed conceptually, and have also been implemented in software. Overall functionality description and a description of key algorithms are found in **ESS-0150748**.

In order to ensure a synchronous next-pulse veto functionality the baseline strategy is to implement the time-critical steps in hardware (FPGA). Since the prototype of the ESS specified FPGA platform is not yet available for algorithm development, development has instead been done on an alternative platform in Oslo. Simulated and real performance of algorithms has been benchmarked on the Oslo platform. Comparing simulated performance with the ESS platform chip, an assessment can be made on the feasibility of performing the required time critical operations in FPGA. This FPGA benchmarking is reported on in **ESS-0150750**.

To develop FPGA algorithms and camera integration on a temporary platform, and then later, to the final platform when available, leads to extra work effort. A similar situation exists when developing control software on the top of the EPICS layer; the ESS ICS supported EPICS is not stable enough for use, leading to an parallel extra effort of maintaining a runnable EPICS version. These double efforts are gradually becoming a schedule risk. The status of the EPICS and FPGA support in the project is documented in **ESS-0150753**.

8. UPDATED PROJECT SCHEDULE

An updated discussion of installation milestones is described in documents **ESS-0153500** for the target PBIP systems, and **ESS-0150756** for the tuning dump systems.

The updates of the ESS commission schedule may lead to some imaging system milestones, as defined by the Oslo-ESS in-kind contract, being moved outside the contract time scope. Possible ways to adapt the Oslo in-kind contribution to the new ESS schedule are discussed in **ESS-0153770,** including remarks on the overall system schedules.

9. OTHER DOCUMENTS

The RAMI and risk analysis has been updated and is found in **ESS-0149762**, including the main table of risks, **ESS-0149762b**.

A Project Quality Plan document **ESS-0149763** has been completed according to the ESS template.

10. GLOSSARY

See: https://ess-ics.atlassian.net/wiki/display/BIG/Abbreviations

DOCUMENT REVISION HISTORY

Revision	Reason for and description of change	Author	Date
1	CDR	Erik Adli	2017-10-10