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# COMMISSIONING-STAGES AND RADIO-PROTECTION CONCEPT FOR THE THz-LINAC BASED ACCELERATOR "AXSIS" AT DESY

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*Abstract*

The dedicated accelerator R&D facility SINBAD at DESY hosts the AXSIS accelerator. The AXSIS project is funded by the European Research Council to develop a compact source for attosecond serial X-ray crystallography and spectroscopy. For that purpose, in one of the arcs of the SINBAD facility and the neighboring laser labs, an accelerator research site is being constructed where a fully THz-driven accelerator (electron gun and linac, with a final energy < 30MeV) will be installed. The current status of the hardware installation of the electron beam accelerator is presented. Furthermore, the required radio-protection measures and maximum beam parameters are presented. In this contribution the commissioning plans and the staging of the beam operation for the accelerator complex will be shown and discussed in detail.

## INTRODUCTION

The attosecond X-ray Science: Imaging & Spectroscopy project (AXSIS) [1] has been initiated with the goal of demonstrating a compact attosecond X-ray light source based on a fully THz-driven accelerator. The accelerator will consist of a relativistic photo-injector driven by single-cycle THz pulses and a multi-cycle-driven THz LINAC which will accelerate the electrons to energies up to 30 MeV. The electrons will collide with a counter- propagating Joule-class laser beam which acts as an optical undulator to produce X-rays in the biologically relevant 4-12 keV range. All components will be driven by beams originating from a single driving laser system, ensuring intrinsic synchronisation as well as the possibility of sub-femtosecond resolution in pump-probe studies. The AXSIS project involves the development of four key and very challenging technologies:

- Joule-class lasers operating at kilohertz repetition rates;
- single- and multicycle THz sources in the millijoule to tens-of-millijoule range based on nonlinear difference frequency generation (DFG);
- THz- driven accelerator modules, including MeV-class photo-guns and tens-of-MeV-class LINACs; and
- efficient X-ray generation via optical undulation of MeV class electron beams [2].

The schematics of the AXSIS accelerator and X-ray production system is shown in Fig. 1. A sketch of the complete AXSIS area can be found in Fig. 2. The nominal AXSIS electron beam parameters after the linac are listed in Table 1.

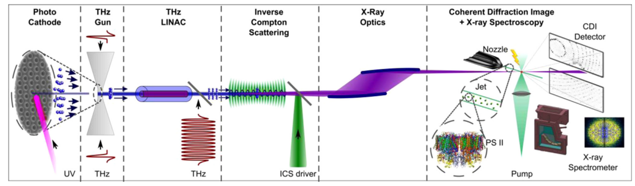

Figure 1: Schematics of the AXSIS accelerator and X-ray production system, including laser and user area.

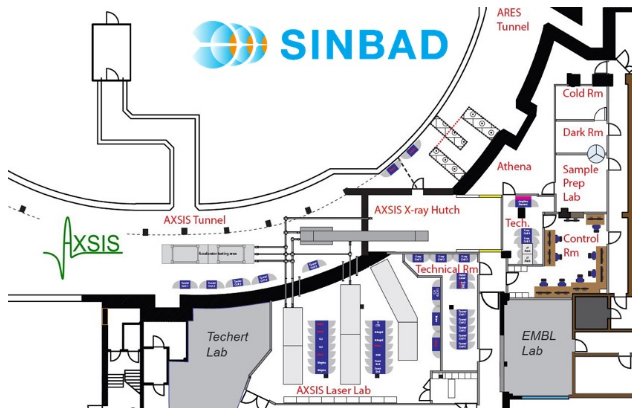

Figure 2: Sketch of the AXSIS area at SINBAD, including accelerator tunnel, X-ray hutch, laser laboratory, bio-labs and control room.

## AXSIS INFRASTRUCTURE

The AXSIS facility has been built up in the frame of the SINBAD accelerator R&D facility at DESY. For AXSIS an arc of the former DORIS tunnel is used and modified. The DORIS storage ring was removed and the facility was equipped with state-of-the-art infrastructure, including ethernet, water and pressurised air circuits, electricity and safety systems. An X-ray hutch, laser laboratory, bio laboratories (at the former Hasylab) and a control room is located next to the tunnel area. The tunnel and the surrounding laboratories are separated with massive concrete walls [3, 4]. The final AXSIS system will be installed on a 10 m long, 23 tons granite block located half in the X-ray hutch and half in

Table 1: Nominal Electron Beam Parameters After the Linac

| | Unit | Value |
|---|---|---|
| Beam energy | MeV | 30 |
| Bunch Charge | pC | 3 |
| Repetition Rate | Hz | 1000 |

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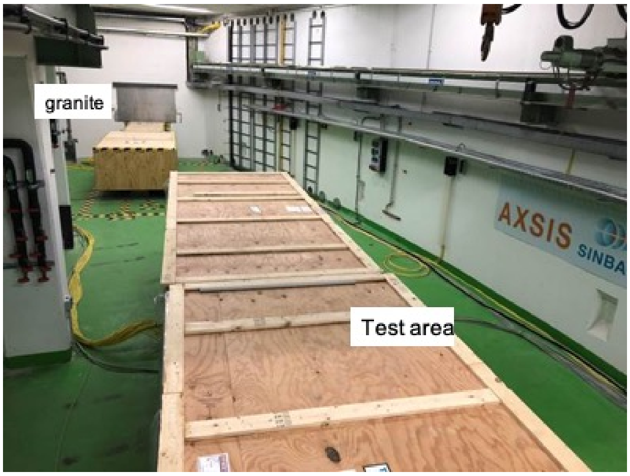


Figure 3: AXSIS tunnel area after the installation of the test area consisting of two optical tables from TMC (the granite block and tables are covered with wood shielding). The installation of cable trays and infrastructure is finished. The water and pressurised air pipes can be seen on the pillar to the right. Cables on the floor will disappear under a false floor to be installed by mid 2019.

Figure 4: Detailed view on the granite block. The hole to the X-ray hutch is closed with a 25 cm thick lead shielding. Tape on the floor illustrates the path of the laser beam lines to the test area and the granite block, to be installed mid 2019. Also these elements will be located under a false floor.

the tunnel. Due to space requirements for X-ray optics and installation of the granite the separation wall between X-ray hutch and tunnel had to be opened and was replaced where necessary by a thinner lead brick wall.

Two areas in the tunnel will be used for AXSIS: the granite and two optical tabfles with a total length of 7 m. All AXSIS parts will be tested and commissioned using the optical tables as it provides more space and better accessibility. At a later stage the final miniaturised version will be installed onto the granite block. The tunnel area at different construction stages is shown in Figs. 3 and 4.

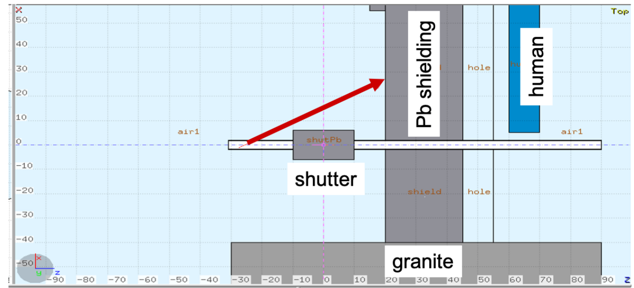


Figure 5: FLUKA simulation model, where the electron beam is bypassing the shutter and is directly sent onto the separation wall between tunnel and hutch.

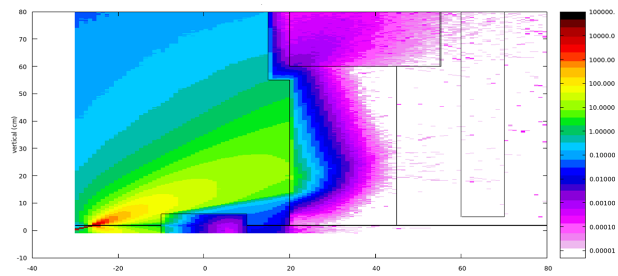

Figure 6: FLUKA dose rate simulation result for the above mentioned geometry. The dose rate will stay below 0.5 μSv/h in the X-ray hutch by using a 25 cm thick lead shielding.

## RADIATION PROTECTION SIMULATIONS

The thickness of the lead shielding in the hole between the X-ray hutch and the tunnel was evaluated with dose rate simulations performed with the monte-carlo tool FLUKA [5, 6]. For the simulation it was assumed, that the electron beam gets an erratic kick through a dipole and is sent directly onto the wall, bypassing the electron beam dump and the X-ray shutter and travelling through the beam pipe and the air. The simulation model is shown in Fig. 5. The beam path is indicated with a red dashed arrow. A human standing in the X-ray hutch is indicated with blue volume. The threshold of 0.5 μSv/h in the X-ray hutch should not be exceeded. Therefore, the thickness of the lead shielding with the above mentioned beam parameters was calculated to 25 cm. The results of the dose rate simulation is shown in Fig. 6.

## AXSIS OPERATIONAL STAGES

After the ongoing installation of laser, laser beam lines and the accelerator components on the test area AXSIS will be commissioned in stages. These stages are listed below:

- **Stage 0**: *Hardware commissioning, low power beam tests, performance optimization on the test side area and access without radio-protection interlock system.* In this stage the THz generation system and the THz gun will move from the CFEL test stand to the tunnel and the THz linac will be commissioned and characterised with a dedicated beam diagnostic line.

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Table 2: Electron Beam Parameters for Access Without Radio-Protection Interlock*

| | Unit | Value |
|---|---|---|
| Beam energy | MeV | < 1 |
| Bunch Charge | fC | < 500 |
| Repetition Rate | Hz | < 100 |

*All values must be simultaneously satisfied.

- **Stage 1**: *Energy and intensity ramp up on the test side. No access to the tunnel during operation.*
  In this stage the electron beam parameters will be ramped up to their nominal parameters.
- **Stage 2**: *First X-rays in the tunnel. No access to the tunnel during operation.*
  In this stage the ICS hardware will be installed and the X-ray production will be commissioned and characterised.
- **Stage 3**: *Commissioning of X-ray experimental area on the granite. No access to the tunnel during operation.*
  In this intermediated stage the full setup will be optimised and installed onto the granite block. First X-rays will be sent to the X-ray hutch. To do so, the lead shielding has to be modified, shutters and safety systems will be upgraded.
- **Stage 4**: *Commissioning of user operation, final stage of the AXSIS project, first users.*

Stage 0 and Stage 4 are illustrated in Figs. 7 and 8. Green indicates free access without radiation protection interlock, in this case the beam parameters have to stay under a certain threshold. The parameters are listed in Table 2. In case of beam parameters above the limit the interlock system will block the access to the tunnel area. During the first 3 stages the radio-protection shielding wall between tunnel and x-ray hutch is completely closed as only the test side will be operational.

## TIMELINE

The AXSIS laboratory will become operational during 2019. The experimental chamber for the THz gun and the THz linac is currently in production. The THz gun tests have been already performed at the CFEL lab. Most of the parts for the beam diagnostic line are ready for installation. The

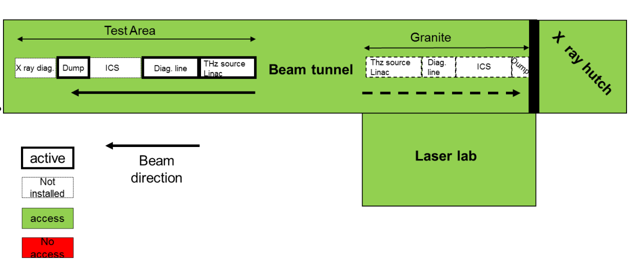


Figure 7: AXSIS commissioning stage 0: first hardware tests on the test side.

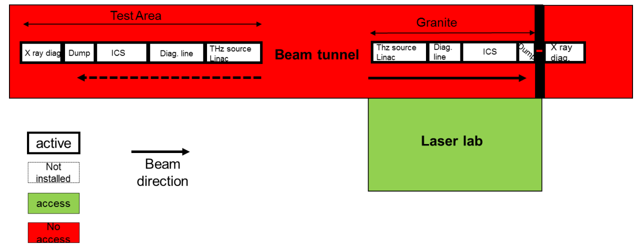


Figure 8: AXSIS commissioning stage 4, final stage for user operation on the granite block.

radiation protection interlock system installation is foreseen in winter 2019. The start of the installation of the electron beam line in the tunnel is planned for September 2019.

## CONCLUSION

The AXSIS project is currently at the end of its construction phase. The tunnel is fully equipped with the accelerator relevant infrastructure. Radiation protection studies were performed with the worst case machine protection scenario. The required shielding was designed accordingly and installed. A commissioning plan including several stages was developed. After the installation of the accelerator chamber and the installation of the laser beam lines the AXSIS facility aims for first electron beams in fall 2019.

## ACKNOWLEDGEMENTS

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## REFERENCES

[1] F. Kaertner *et al.*, "AXSIS: Exploring the frontiers in attosecond X-ray science, imaging and spectroscopy", Nuclear instruments & methods in physics research, vol. 829, p. 24, 2016. doi:10.1016/j.nima.2016.02.080

[2] N. Matlis *et al.*, "Acceleration of electrons in THz driven structures for AXSIS", Nuclear instruments & methods in physics research. doi:10.1016/j.nima.2018.01.074

[3] U. Dorda *et al.*, "SINBAD, the accelerator R&D facility under construction at DESY", 2nd European Advanced Accelerator Concepts Workshop, September 2015, Elba, Italy. doi:10.1016/j.nima.2016.01.067

[4] U. Dorda *et al.*, "Status and objectives of the dedicated accelerator R&D facility SINBAD at DESY", 3rd European Advanced Accelerator Concepts Workshop, September 2017, Elba, Italy. doi:10.1016/j.nima.2018.01.036

[5] T. Boehlen *et al.*, "The FLUKA Code: Developments and Challenges for High Energy and Medical Applications" Nuclear Data Sheets 120, 211-214 (2014).

[6] A. Ferrari, P.R. Sala, A. Fassó, and J. Ranft, "FLUKA: a multi-particle transport code" CERN-2005-10 (2005), INFN/TC-05/11, SLAC-R-773.