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STATUS OF THE DEDICATED ELECTRON DIAGNOSTIC BEAMLINE AT AXSIS

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Abstract

AXSIS (Attosecond X-ray Science: Imaging and Spectroscopy) [1] is a compact, accelerator-driven X-ray source currently under construction at DESY Hamburg. It comprises a THz-powered electron gun and THz-driven linac for all-optical electron extraction and acceleration to several MeV with the goal of providing X-rays generated by inverse Compton scattering for photon science experiments. For the commissioning and characterisation of the THz gun and linac the facility includes a dedicated accelerator testing area, for which an electron diagnostic beamline has been designed and is currently under construction. The challenges imposed by the AXSIS project on the development of the diagnostics beamline are the wide ranges of bunch charge (15 fC to 3 pC) and energy (5 MeV to 20 MeV) expected from the THz-driven accelerator as well as the limited available space of only ca. 2.5 metres length. In this contribution we present an overview of the design and the current commissioning status of the electron diagnostic beamline as well as plans for future steps.

INTRODUCTION

The Attosecond X-ray Science: Imaging and Spectroscopy (AXSIS) [1] project is aimed at developing a compact (few-metre scale) source for attosecond X-ray crystallography and spectroscopy, based on a fully THz-driven accelerator generating electron bunches of up to 3 pC with energies up to 20 MeV and repetition rates up to 1 kHz. It is located at the dedicated accelerator research and development (R&D) facility SINBAD [2, 3] at DESY, its layout is shown in Fig. 1. The AXSIS site comprises two areas for the accelerator installation [4]: a massive granite block, on which the final accelerator and X-ray experiments will be set up, and a separate accelerator testing area for the commissioning and characterization of the individual components.

ELECTRON DIAGNOSTIC BEAMLINE

For the accelerator testing area an electron diagnostic beamline has been designed and built. It is located at the end of the available space as shown in Fig. 1, leaving upstream room for the installation of the accelerator components under test and the laser beamlines for generating the THz radiation driving the acceleration. Challenges imposed

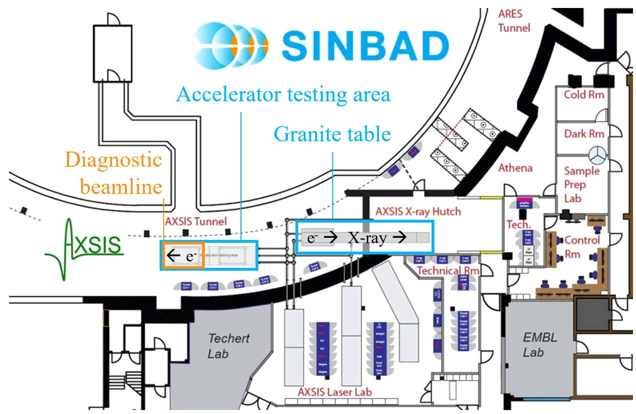

Figure 1: Floor plan of the AXSIS facility. The accelerator testing area with the electron diagnostic beamline and the granite table for the final accelerator installation are highlighted. "Figure 2" by [4, p. 3598], used under CC BY 3.0 [5]. Highlighting and annotations added to original.

by the exploratory R&D nature of the AXSIS project and the available space have been taken into account in the design of the electron diagnostic beamline:

- The wide ranges of bunch charge (15 fC to 3 pC) and energy (5 MeV to 20 MeV) expected from different potential devices for the electron source and acceleration. Table 1 shows the beam parameters for which the electron diagnostic beamline is designed.
- The limited available space at the accelerator testing area of 7.2 m × 1.5 m, requiring a compact design. For increased flexibility the diagnostic beamline is installed on few large base plates allowing for an easy relocation of the setup without the need for a complete disassembly.
- The aim to use proven standard and off-the-shelf components which are also routinely used at other facilities, for reasons of reliability and sharing of knowledge, reduced need for new engineering work, and existing tools for control system integration.

LAYOUT

Figure 2 shows a drawing and Fig. 3 a photograph of the electron diagnostic beamline installed in the AXSIS tunnel. It is 2.5 m long and 1.5 m wide and comprises various elements for the diagnostic and manipulation of the electron

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Table 1: Design Beam Parameters for the Electron Diagnostic Beamline

Parameter	Unit	Value
Bunch charge	pC	0.015 … 3
Repetition rate	kHz	≤ 1
Momentum	MeV/c	5 … 20
Momentum spread	%	< 1
Transverse rms bunch size	mm	0.05 … 1
Transverse norm. emittance	µm rad	0.1 … 0.5

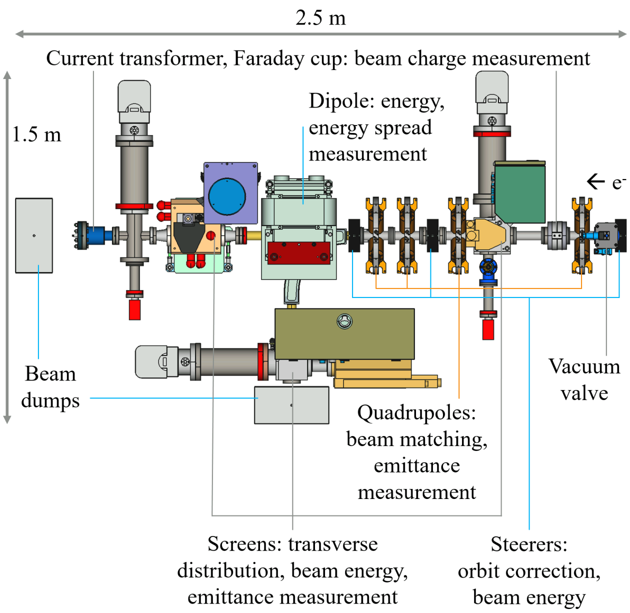


Figure 2: CAD model of the electron diagnostic beamline annotated with the positions of the individual elements. The beam enters from the right.

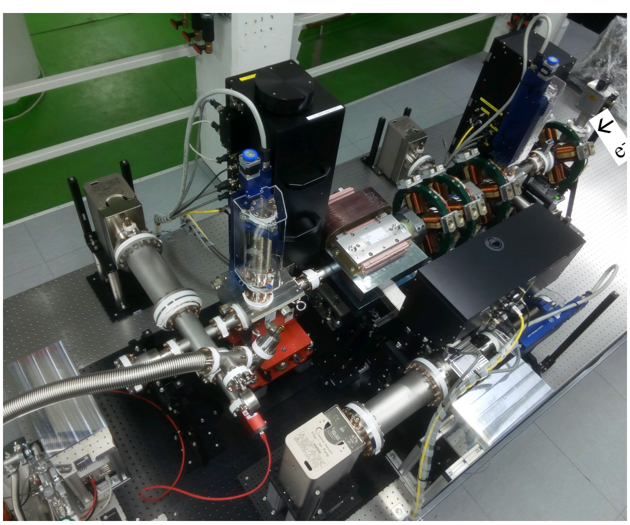
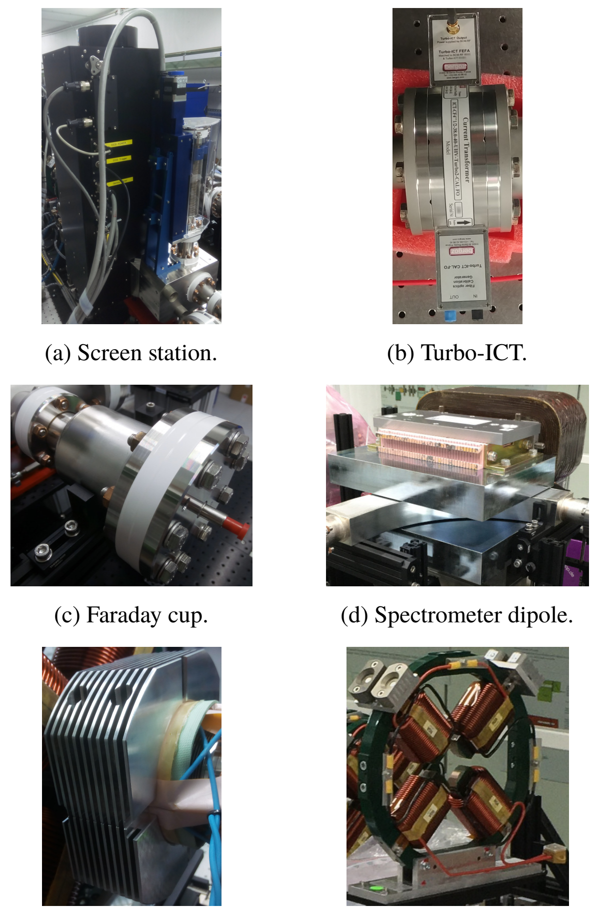


Figure 3: Photograph of the installed electron diagnostic beamline in the AXSIS tunnel. The beam enters from the top right.

beam as well as additional protective components. Figure 4 shows photographs of the individual beamline elements.

For bunch charge measurements an integrating current transformer (ICT) is installed at the entrance and a Faraday cup at the end of the beamline. The Faraday cup is an in-house development by DESY which is also used at the ARES [6] linac at SINBAD, where a resolution of 100 fC has been achieved. It is expected that this value can be further improved by adjusting the read-out electronics and due to the shorter cable lengths at AXSIS (few metres) compared to ARES (few tens of metres). The ICT is a commercial product[1] featuring a measurement range down to 10 fC with a noise level of 10 fC or 1% of the measurement value, whichever is higher.



(a) Screen station. (b) Turbo-ICT.

(c) Faraday cup. (d) Spectrometer dipole.

(e) Dual-plane steerer. (f) Quadrupole magnet.

Figure 4: Photographs of the beam diagnostic and manipulation elements of the electron diagnostic beamline.

For the measurement of the transverse particle distribution, the beam energy with help of dispersive beamline elements, and transverse emittance with help of focusing beamline elements, three screen stations are installed. These are in-house developments by DESY [7] using scintillation crystals that can be inserted into the beam path by motorized actuators. The size of the imaged beam area is ca.

[1] Bergoz Turbo-ICT.

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5 mm × 5 mm with a pixel size of ca. 3 µm × 3 µm. Instead of the scintillation crystal a calibration target mounted on the same actuator can be inserted into the camera's field of view and illuminated by a light-emitting diode (LED) for calibrating the resolution. This type of screen stations is routinely used also at several other accelerators at DESY. The existing integration into the `doocs` [8] control system will be used.

For measuring the beam energy and the energy spread a dipole electromagnet can be used in combination with the screen station installed in the dispersive arm of the beamline. The positions of the screen stations in the straight arm and in the dispersive arm are chosen such that the path length of the electron bunches from the beamline entrance to both stations is the same. This allows for an easy comparison of the undispersed and dispersed beams, providing resolution information for energy spread measurements.

Three dual-plane electromagnetic steerers [9] along the beamline allow for orbit corrections and also beam energy measurements in addition to the dipole magnet. While using the massive dipole will result in higher precision than using the dual-plane steerers, such a measurement is time-consuming due to the cycling procedure required by the hysteresis of the big electromagnet. The dual-plane steerers are small air coils without hysteresis which can be driven faster than the large dipole and can be used for quick energy measurements by displacing the beam on a downstream screen. This method however does not allow for energy spread measurements.

Four quadrupole electromagnets can be used for beam matching via telescopic imaging from the entrance to the screen stations and for emittance measurements via quadrupole scans. All magnet types used in the electron diagnostic beamline are standard devices developed at DESY, which are routinely used also at various other accelerators on the campus. The existing integration of the magnet power supplies into the `doocs` control system will be used.

Additional protective components ensure the safe and robust operation of the electron diagnostic beamline. A vacuum valve at the entrance allows for the isolation of the beamline in case the upstream area needs to be vented, for instance if the tested accelerator components are to be exchanged. At the end of each arm a beam dump is installed for safe disposal of the electron bunches and radiation protection.

STATUS AND OUTLOOK

The design as well as the mechanical and vacuum installation of the dedicated electron diagnostic beamline at AXSIS are fully completed. All mechanical components for the diagnostic and manipulation of the beam – screen stations, ICT, Faraday cup and magnets – are mounted at their final positions at the accelerator testing area in the AXSIS tunnel. The optics and movers for the screen stations as well as the vacuum valve at the entrance and the beam dumps for radiation protection have been installed. A CAD model documenting the beamline layout including the support frames has been created and used as a basis for the installation.

All beamline elements have been mechanically aligned with respect to the beam pipe during installation. As soon as electrons will be injected into the system the fine alignment will be performed with beam-based methods. The magnets are mounted about the beam pipe allowing for a movement independent of the vacuum parts.

The vacuum system is completed and pumped down. At the time of writing the cabling of the getter pumps is ongoing. Thus, a mobile pump stand is currently used for evacuating the system, reaching a pressure well below 10^{-7} hPa.

The magnet power supplies as well as the control and readout electronics for the diagnostics devices have been installed in the AXSIS tunnel close to the accelerator testing area. Currently the cabling and commissioning of the individual subsystems is being finalized. As a next step, tests of the hardware and software for the motorized actuators as well as the image acquisition of the screen stations are planned. This can be done also without beam by using the calibration target mounted on the actuator with the scintillation crystal and illumination by an LED integrated in the screen station.

The magnet power supplies are ready for operation and the connections to the magnets are made. Tests and calibration of the magnet circuitry will follow next. The cabling of the ICT, Faraday cup and getter pumps is ongoing and planned to be finished in the next weeks.

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