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MECHANICAL DESIGN AND INTEGRATION OF THE SXP SCIENTIFIC INSTRUMENT AT THE EUROPEAN XFEL

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Abstract

The European XFEL provides femtosecond X-ray pulses with a MHz repetition rate in an extended photon energy range from 0.3 to 30 keV. Soft X-rays between 0.3 and 3 keV are produced in the SASE3 undulator system, enabling both spectroscopy and coherent diffraction imaging of atoms, molecules, clusters, ions and solids. The high repetition rate opens the possibility to perform femtosecond time-resolved photoelectron spectroscopy (TR-XPES) on solids. This technique allows the simultaneous understanding of the evolution of the electronic, chemical and atomic structure of solids upon an ultrafast excitation. The realization with soft X-rays requires the use of MHz FELs. In this contribution, we present the mechanical design and experimental realization of the SXP instrument.

The main technical developments of the instrument components and the TR-XPES experimental setup are described.

INTRODUCTION

The SXP Scientific Instrument is designed as an open port were users' provided stations can be integrated [1, 2].

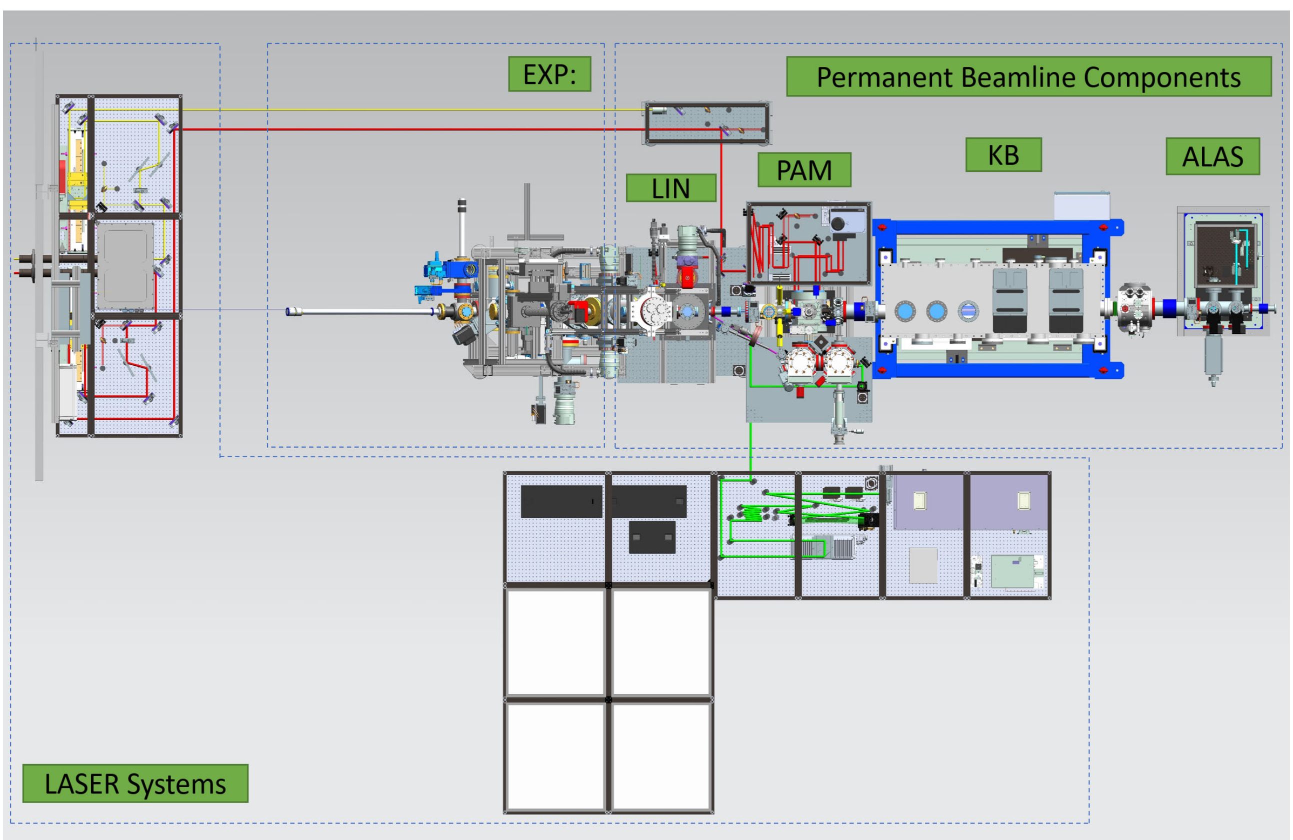

Figure 1: Layout of the SXP Scientific Instrument.

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Figure 1 shows the layout of the SXP Scientific Instrument is presented. It is divided in three distinct areas: the permanent beamline components (BLC), the laser system (LAS) and the experimental station (EXP).

- BLC: It consists of the alignment laser system (ALAS) and it is designed to pre-align all components prior to FEL experiments The Kirkpatrick–Baez (KB) X-ray mirror focusing system currently provides a FEL beam of 2 x 35 µm^2 (horizontal x vertical) using directionally fixed focus mirrors. The photon arrival time monitor (PAM) uses the spectral encoding technique on thin membranes to measure the relative arrival time and jitter between the FEL and optical pulses [3]. The membranes also serve as X-ray beam attenuators. The laser in-coupling unit (LIN), couples the optical pulses into the experimental station. At the end of the main experimental station an instrument beam stop (IBS) based on B4C and diamond is installed.
- LAS: Integrates the EuXFEL pump-probe laser with 800 and 1030 nm outputs and a 60 W, 1030 nm, 200 fs, 20 MHz AFS laser. The latter has been compressed to 40 fs using multi-pass Herriot cells. Several frequency conversion schemes, including an optical parameter amplifier allow pulses to cover the wavelength range from ~200 nm to ~15 µm [4].
- EXP is the experiment station area. The first realization will allow femtosecond time-resolved photoelectron spectroscopy on solids (TR-XPES).

In the following, the LIN and TR-XPES experiment station are described.

LIN – LASER IN-COUPLING SYSTEM

Figure 2 displays a section of the LIN model in the central plane of the FEL propagation.

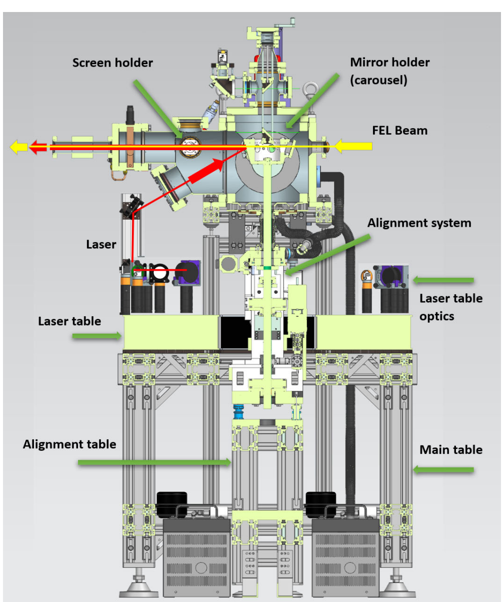

Figure 2: Central section of the LIN system.

It consists of two optical tables: one holds the vacuum chamber and the in-air optical mirrors. It has the laser beam height of 900 mm. The optical pulses are transported and focused by optics on the optical table.

A periscope mirror couples the in-vacuum beam through a flange with an optical viewport in a 15° orientation. The beam is reflected in the in-vacuum mirrors, which are installed in kinematic mounts with piezo motors at 15° with respect to the incident beam to produce a reflection along the FEL beam path. They are installed in a carousel that can accommodate up to 5 mirrors to cover the full range of laser wavelengths available on the instrument. The mirrors have a center hole that allows the FEL to propagate collinearly with the optical pulse.

The carousel is installed in a second breadboard decoupled from the main one to allow independent alignment and also to decouple the in-vacuum mirrors from the vacuum chamber. The latter is equipped with a vacuum system with a turbo molecular pump and a getter ion pump, viewports and electrical feedthroughs to control the in-vacuum kinematic mounts.

TR-XPES – TIME-RESOLVED X-RAY PHOTOELECTRON SPECTROSCOPY

TR-XPES is the first experimental station at the SXP instrument. It designed to perform femtosecond time-resolved photoelectron spectroscopy on solids. Figure 3 shows a central section of the entire station.

The system is divided into several chambers with different functionalities. The main chamber is made of mu-metal to avoid stray and earth magnetic fields. It houses a homemade momentum microscope-type photoelectron spectrometer [5] installed in a vertical configuration at 22° with respect to the FEL beam. The unconventional vertical mechanical configuration has required the definition of a specific support structure. It is made of Al and PEEK parts. The latter parts were required to ensure that all the electrostatic lenses of the momentum microscope were electrically-isolated from each other and from the chamber. The instrument beam stop (IBS) is installed in the back of the main chamber. The momentum microscope allows both spatially resolved photoemission electron microscopy (PEEM) and momentum resolved (angle-resolved photoelectron spectroscopy ARPES, X-ray photoelectron diffraction XPD) experiments. The electrons are detected by microchannel plate based delay-line (MCP-DLD) detectors. The samples are mounted on a homemade hexapod system equipped with a cryostat. The motors allow the sample to be aligned with micrometer precision over a range of up to 20 mm. The six degrees of freedom are organized in three sets: three motors are installed in the flange supporting the sample receiver. When they are moved in the same direction by the same amount, the sample is displaced vertically towards the axis of the momentum microscope. Moving them differently allows the sample to be tilted in two different directions. The second set of two motors is installed along the FEL beam direction. Moving them simultaneously by the same amount translates the sample linearly along the FEL beam. Moving them asymmetrically allows an azimuthal rotation up to about 3°. The sixth motor allows translation orthogonal to the FEL beam direction.

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The main chamber is connected to a chamber equipped with a low energy electron diffraction (LEED) system and a transfer bar with a one-meter arm. It is used to load samples into the main chamber and the preparation chamber. Samples can be loaded through a dedicated load lock or from a vacuum suitcase. The load lock is a DN63 cube equipped with a transfer bar and a sample loading stage that allows the installation of up to five samples in omicron type sample holders. The latter allows users to bring their own prepared samples. A preparation chamber is installed on top of the LEED chamber. It has a spherical shape to ensure that all flanges are facing its center. It is equipped with basic equipment to prepare samples by sputtering and annealing. It has a series of DN40 viewports prepared to install different types of evaporators. The samples are hosted on a manipulator with four degrees of freedom: X, Y, Z and azimuthal rotation. A cryostat allows samples to be cooled down to 20 K. The sample receiver is equipped with an e-beam heating station reaching temperatures up to 1600 K.

The entire system is installed on an Al support that can be aligned manually. In a second step. the system will be installed on an automated alignment system.

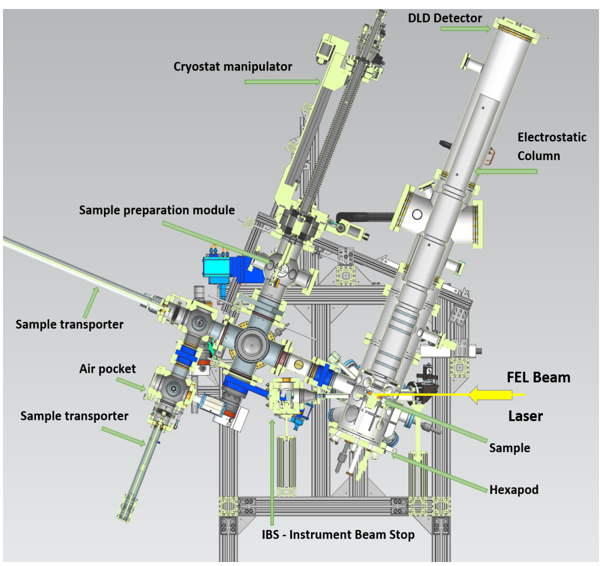

Figure 3: Central section of the TR-XPES experiment.

CONCLUSION

This contribution presents the mechanical design and experimental realization of the SXP instrument. The instrument is organized in a series of permanent components along the FEL beamline, an optical laser system that uses both the central EuXFEL pump probe laser and the experimental station area. The laser in-coupling system and the first experimental station, TR-XPES, developed to perform femtosecond time-resolved photoemission experiments, have been described.

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REFERENCES

[1] M. Izquierdo, “Technical Design Report: Scientific Instrument Soft X-Ray Port (SXP): Part A - Scientific cases”, European XFEL, Schenefeld, Germany, January 4, 2022.

[2] P. Grychtol, N. Kohlstrunk, J. Buck, S. Thiess, V. Vardanyan, D. Doblas-Jimenez, M. Izquierdo, *et al.,* “The SXP instrument at the European XFEL”, *J. Phys.: Conf. Ser.*, vol. 2380, p. 012043, 2022. doi:10.1088/1742-6596/2380/1/012043

[3] P. Grychtol *et al.*, “Timing and X-ray pulse characterization at the Small Quantum Systems instrument of the European X-ray Free Electron Laser”, *Opt. Express*, vol. 29, p. 37435, 2021. doi:10.1364/OE.440718

[4] P. Grychtol, , V. Vardanyan, D. Doblas-Jimenez, and M. Izquierdo, “The Laser Infrastructure at the SXP instrument of the European XFEL”, *J. Phys.: Conf. Ser.*, vol. 2380, no 1, p. 012114, 2022. doi:10.1088/1742-6596/2380/1/012114

[5] D. Kutnyakhov *et al.*, “Time- and momentum-resolved photoemission studies using time-of-flight momentum microscopy at a free-electron laser”, *Rev. Sci. Instrum.*, vol. 91, p. 013109, 2020. doi:10.1063/1.5118777