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Mechanical Optimization of the TR-XPES station of the SXP Instrument at the European XFEL

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Abstract. The TR-XPES (Time Resolved X-Ray Photoelectron Spectroscopy) setup is the first experimental station integrated at the Soft X-ray Port (SXP) instrument of the European XFEL. It has been developed to perform femtosecond time resolved photoelectron spectroscopy experiments on solid state samples in the soft X-ray photon energy range from 0.25 keV to 3 keV, generated by the SASE3 undulator system. A Pump-Probe Laser (PPL) colinearly propagating with the FEL into the experimental chamber is used to excite the samples. The laser pulses have the same time structure as the FEL beam for the two fundamental output wavelengths, 800 nm and 1030 nm, as well as for the second and third harmonics. Other wavelengths up to 15 microns can be generated with an Optical Parametric Amplifier (OPA) at reduced repetition rate. In this contribution, a mechanical optimization of the TR-XPES setup is presented.

1. Introduction

Photoelectron spectroscopy is one of the most valuable techniques to investigate the electronic, chemical, structural and spin properties of surfaces, interfaces and thin films. The implementation at SXP enables time resolved experiments with femtosecond resolution in a photon energy range not available so far [1]. The dedicated station, TR-XPES is located at the end of the SXP permanent components [2]. The main layout of the SXP instruments is shown in the Figure 1.

The permanent beamline components of the SXP Scientific Instrument are: alignment laser system (ALAS), Kirkpatrick-Baez X-Ray mirror focussing system (KB), photon arrival time monitor (PAM), laser in-coupling system (LIN) [2]. The TR-XPES experimental station is connected to the vacuum of the permanent beamline components through a DN40 gate valve. It is entirely integrated into the main control system [3]. The focused FEL and Optical Laser (OL) beams are coupled in and aligned to overlap at the sample interaction point of the TR-XPES station. Two OL systems are available to realize pump-probe experiments: the first laser system is a commercial 60 W fiber laser amplifier located in the SXP experimental hutch [4,5]. The second laser system is a custom-made laser developed by the EuXFEL laser group [6]. It has 2 outputs: 800 nm, 2 mJ at 0.1kHz, 15-50 fs and 1030 nm, 40 mJ at 0.1kHz, 800fs –1 ps. They enter the back of the SXP experiment hutch and they are propagated to the LIN laser table at a height of 1052.4

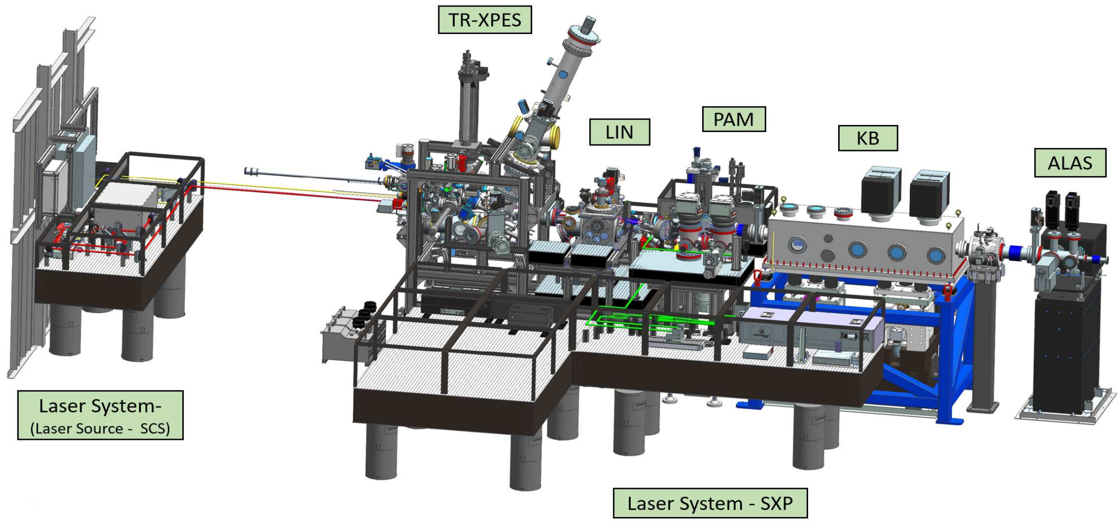

Figure 1. Layout of the SXP Instrument.

mm. A periscope system brings the laser up to the FEL beam level (~1440 mm) at a 15 degrees angle. After reflection on a holey mirror, they co-propagate with the FEL beam to be focused on the sample interaction point.

The main chamber is equipped with a momentum microscope photoelectron spectrometer that allows both real and k-resolved measurements. The sample is mounted on a custom-made hexapod that allows sample cooling and heating. The setup is further equipped with a preparation chamber, where sputtering and annealing of samples can be realized; a Low Energy Electron Diffraction (LEED) chamber: a load lock and a connection flange for vacuum suitcases. A 1 m long transfer arm is used to transfer the samples from the LEED chamber to the main chamber. In order to align the whole system with respect to the FEL beam, an alignment system is required. The first realization was done using manual adjustments.

The ancillary chambers (preparation, LEED, load lock, ⋯) have been reorganized in order to ease and speed-up the sample transfer to the main chamber. An automated alignment table has been developed to better optimize the chamber position with respect to the FEL beam. The alignment table will be able to move tens of mm with micrometre precision-range alignment. It will be built on an air-pad system to allow positioning the chamber at different positions along the FEL beamline.

2. TR-XPES experimental station

The TR-XPES experimental station has been developed to perform time resolved X-Ray photoelectron spectroscopy of solid-state materials in ultra-high vacuum conditions. The entire vacuum chamber of TR-XPES is divided into two main modules, separated by a DN63 gate valve: module 1: main chamber; module 2: sample preparation, Low Energy Electron Diffraction (LEED) chamber and sample delivery system. The full system is mounted on an Al profiles-frame. In the first integration the alignment system is manual. A motorized alignment system with granite blocks to automate the movement and increase the stability of the system is soon to be implemented. The movement will be realized using stepper motors with micrometr precision.

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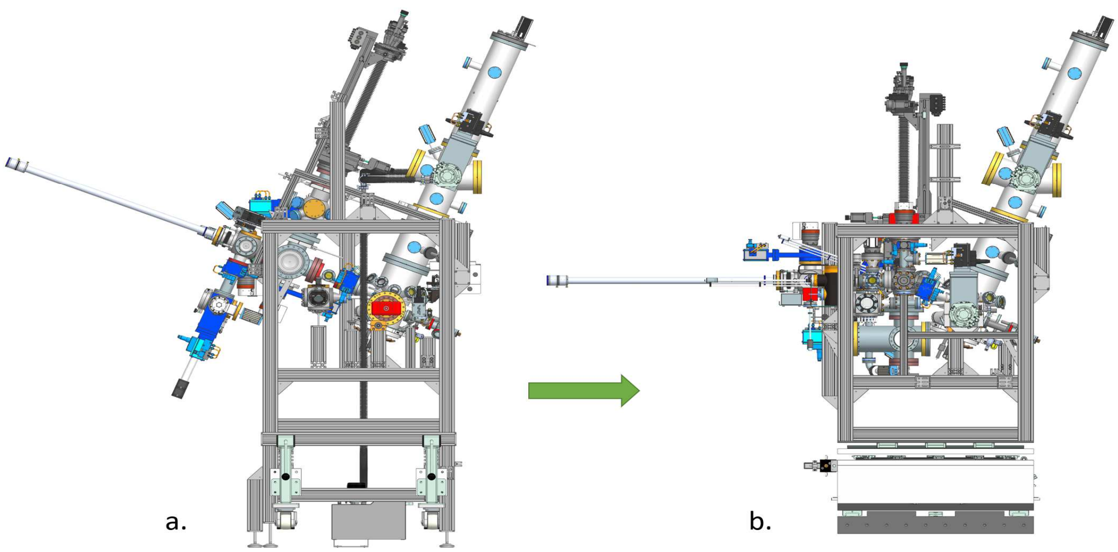

Figure 2. Side view of the TR-XPES station at the SXP Instrument.

In figure 2, a section view of the TR-XPES experimental station is shown [7]: a) current mechanical integration. b) mechanically optimized design. The main chamber is made of steel with high magnetic permeability to screen the earth magnetic field. It is installed at a 68 degrees angle with respect to the FEL beam horizontal position. It is equipped with a time of flight momentum microscope equipped with a Microchannel Plate Delay Line Detector (MCP-DLD) detector. The sample is mounted on a sample receiver installed on a hexapod equipped with a cooling system that allows reaching temperature of 150 K when operated with liquid nitrogen. The whole system is operated in ultra-high vacuum (UHV), background pressure of $5\cdot10^{-10}$ mbar. It is achived by a combination of turbomolecular (TP), Non-Evaporable Getter (NEG) and ion pumps providing simultaneously vacuum from the main chamber and the column of the momentum microscope spectrometer. The vacuum level is precisely monitoring in chambers from atmospheric to UHV level via combined Bayart-Alpert/Pirani gauges. In-situ prepared samples require pre-characterization before experiments with the FEL. LEED and Auger are commonly used techniques to assess sample quality and preparation. The former gives information about the surface order, while the latter addresses sample stoichiometry and purity.

The sample preparation and delivery system at SXP were designed using a modular approach.

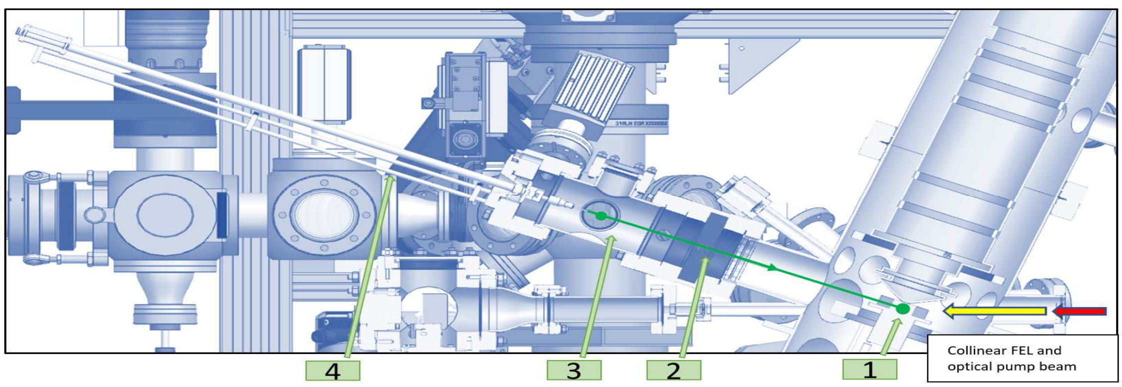

Figure 3. The section view of the TR-XPES experimental station.

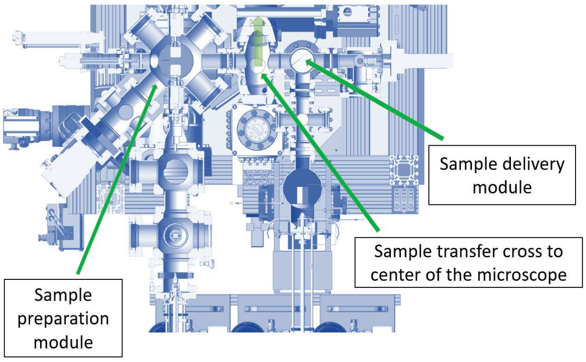

Figure 4. Top view of the optimized mechanical concept of the module 2 of the TR-XPES station.

It contains: i) a preparation chamber equipped with an Ar^+ sputter gun and ports for evaporators. The samples/substrates are mounted in a 5 axes manipulator that allows cryogenic cooling (down to 20 K) as well as heating up to 1600 K; ii) A LEED chamber that will be equipped with a LEED-Auger apparatus to characterize in-situ prepared samples or to perform post-mortem studies after FEL experiments; iii) a load-lock to insert samples from air and iv) a port to install vacuum suitcases with externally prepared samples. In the first implementation, the LEED chamber was attached to the main chamber. A cross installed at the end holds the transfer bar with a grabber. On the other two available sides, the load-lock and a port for vacuum suitcases are available. The preparation chamber is installed on top of the LEED chamber on a DN100 flange. In the first implementation of the system, the main chamber was connected to the rest of the system via the LEED chamber. The latter was connected to a DN63 flange in the main chamber that is the one designed for sample transfer. The DN63 flange forms an angle of 22 degrees with respect to the FEL beam propagation direction (Figure 3). At the end of the LEED chamber, a UHV cube is installed. It holds a 1 m long transfer arm with a sample grabber pointing to the DN63 flange. Due to the 22 inclination angle, the top of the transfer arm is at a 2350 mm height, making the transfer of samples very cumbersome. Furthermore, the preparation chamber sitting on top of the LEED chamber is installed at a 22 degrees angle. While this allows the manipulator to run parallel to the momentum microscope, the whole system is between 1600 mm and 4500 mm above ground, which makes it difficult to access and use.

The current configuration of module 2 results from the decision to mount the spectrometer vertically to optimize the available space in the experiment hutch. This constraint did not allow to mount the main chamber in the designed horizontal configuration and defined the current arrangement. After commissioning the instrument, we have revisited the mechanical configuration of module 2. This contribution proposes a new organization of the module 2 components aiming to ease and speed the sample transfer process, to increase the accessibility and operation of the different parts and also to duplicate the sample loading and in-vacuum storage capabilities.

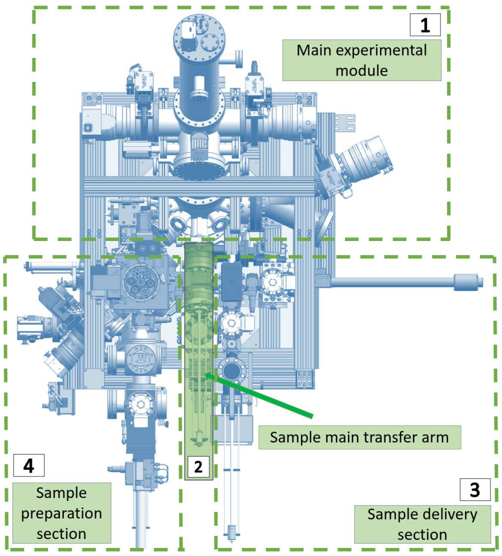

Figure 5. Top view of the TR-XPES

3. Optimized sample preparation and delivery system at the TR-XPES station

The optimization of the sample preparation and delivery system is constrained by the fact that the sample transfer is only possible through the

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DN63 flange positioned at 22 degrees with respect to the FEL beam. We started by optimizing this part which is also the most critical. It was done by substituting the LEED chamber by a DN63 cross with 3 DN40 ports, the "transfer cross" (Figure 3): where 1. Experimental sample, 2, Gate valve, 3. Sample transfer cross, 4. Sample transfer arm. The DN63 port facing the main chamber will be equipped with a 600 mm, easy to handle wobble stick. The port on top will serve to observe the samples during transfer. To this end a viewport and an optical camera will be installed.

The port on the right-hand side of the top view of the new system (Figure 4) will be connected to a DN63 extension cross with 3 DN40 ports. The one on top is a vacuum port equipped with a TP and a pressure gauge. The other two ports are equipped with DN40 automated gate valves. The port facing the "transfer cross" is connected to a load lock. The latter is made of a cube chamber with a TP on the top flange, a fast access door on the front side and a 600 mm transfer arm with a sample storage carrousel. This port is suited for samples that only need to be cleaved before entering the main chamber. The port at 90 degrees is connected to a 6-ways DN40 cross equipped with a TP and pressure gauge. It is prepared to host vacuum suitcases.

On the left-hand side (Figure 5), the "transfer cross" is separated from the preparation chamber by an automated DN40 gate valve. The latter is equipped with a sputter gun, the above mentioned manipulator, DN40 ports to install evaporators and a sample carrousel in a translation bellow. The DN63 flange in the preparation chamber perpendicular to the "transfer cross" will be connected to a double cube hosting a TP and a gauge and the 1 m long transfer arm previously used to transfer samples. The cubes will be equipped with a fast entry door and a wobble stick with carrousel to insert samples from air. The bottom flange of the preparation chamber will be connected to the LEED chamber that now is kept permanently under UHV conditions.

The final configuration of the TR-XPES system depicted in figure 3 allows us to differentiate 4 parts: Module 1, part one: the main chamber. In module 2, three parts can be distinguished: the transfer to the main chamber, part 2; the sample delivery system with load lock and port for vacuum suitcases, part 3. Finally, the sample preparation and characterization area, part 4, equipped with the preparation and LEED chambers. In Figure 6 the main components of the sample transfer, delivery and preparation system are displayed: 1. LEED – Low Energy Electron Diffraction, 2. Ion Sputter Gun, 3. Sample holder – in the cryogenic manipulator, 4. In-vacuum heater, 5. Main sample transfer arm – Wobble stick, 6. Load lock for the sample preparation system, 7. Transfer arm for the sample preparation system, 8. In-vacuum sample transfer suitcase,

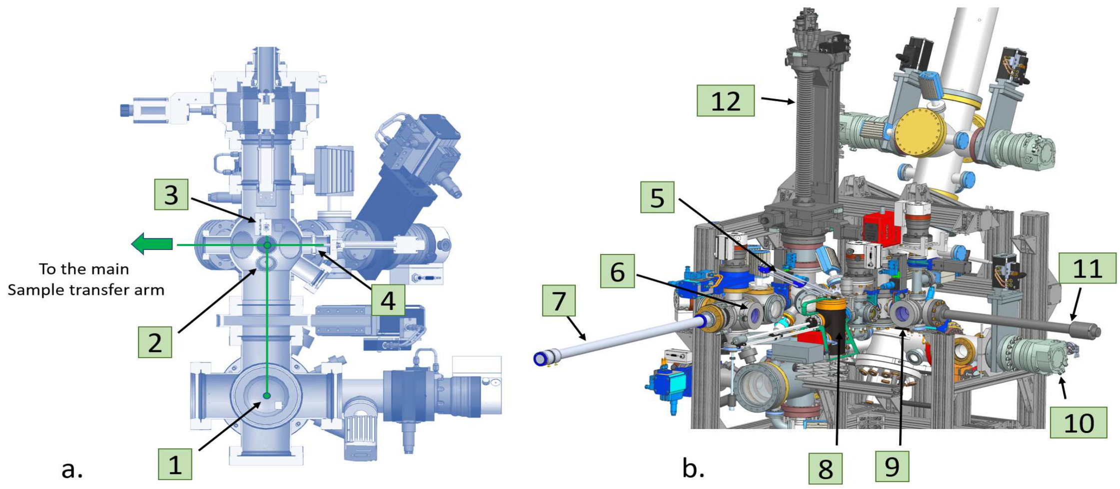

Figure 6. Individual components of the sample transfer, delivery and preparation system.

9. Main Load lock, 10. Side pumping system, 11. Sample-storage transfer arm, 12. Cryostat manipulator.

4. Summary

The TR-XPES experimental station at the SXP instrument of the European XFEL is dedicated to femtosecond soft X-ray photoelectron spectroscopy of solids. After the commissioning and first experiments were successfully performed, a mechanical optimization of the sample transfer, delivery and preparation system has been realized. The new design is based on all existing components from TR-XPES. The main feature of the new concept is a much simpler transfer system to the main chamber and the increase of capabilities for sample delivery and storage.

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