Risotto Fantasies to Synchrotron Facilities:

What do Truffle Risotto and Synchrotrons have in common?

The First Synchrotron Beamline of Türkiye: Turkish Soft X-ray Photoelectron Spectroscopy (TXPES) Project

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It was the year 2014, a date etched in the annals of my personal gastronomic history. I fortuitously found myself in the clutches of culinary enchantment, seated in a simple but charming seafood haven located in the outskirts of Palermo, Italy. The scent that encompassed me was nothing short of a cosmic aroma, an olfactory supernova, if you will. What I experienced on that fateful day of my ephemeral life was none other than the celestial delight known as the truffle mushroom risotto. I told myself: hold onto your electron accelerators, for you are about to embark on a journey into the terra incognita of the gastronomic spectrum. As I took that first heavenly forkful of risotto, a hidden quantum dimension of flavors was unlocked. The explosion of savory delights stimulated my taste buds in a manner that defied the laws of thermodynamics. As I was cruising in the realm of culinary organic chemistry, I realized the aroma of truffles presented itself as a molecular opera, with volatile compounds like 2,4-dithiapentane1 serenading in my nose. Such natural compounds, occurring in minuscule quantities, orchestrate an olfactory sensation that is nothing short of a sensory accentuation bordering the speed of light. Ever since that revelatory encounter, my taste buds routinely crave the unparalleled delight of truffle mushroom risotto. Till this day, I do not miss any opportunity that comes my way to reenact that fleeting moment when physics, chemistry, and biology converged to create a taste sensation that defies the bounds of our culinary universe.

Little did I know that akin to my culinary awakening, my scientific incitement regarding the experimental understanding of the electronic, crystallographic, and morphologic properties of nanomaterials would be triggered by a unique experience, the use of the high energy particle accelerators called synchrotrons. These colossal machines, reminiscent of interstellar racetracks for electrons, propel electrons to nearly the speed of light, setting the stage for a scientific spectacle of epic proportions. As a fruitful outcome of this relativistic circumvolution of electrons in a gargantuan vacuum ring reaching energies up to a few billions of eV (i.e., GeV), an incredible feast of light (predominantly in the X-ray region) with tunable wavelengths (10^{-2}-10^{2} nm) and immense intensities (>10^{14} photons s^{-1} mm^{-2} mr^{-2}) can be generated, whose photons can also be tweaked to confinements of infinitesimal quantities of time (> 100 ps) and position (typically > 20 µm). The vast experimental opportunities offered by these magical electron carousels was unlike that of the numerous conventional laboratory experiments that I have carried out in the past, where the former presented data quality and experimental flexibility unmatched by any ordinary spectroscopic/imaging/diffraction instrumentation.

In short, I have found my magic truffle risotto!

Now, I was spoiled. I had to put my hands on such magnificent synchrotron-based toys on a regular basis. The problem was, while there were about 70 synchrotron facilities around the world, they were almost always severely overbooked by a swarm of international researchers from all walks of science and technology carried out in academia and industry alike, and beamtime was as precious as gold or perhaps as tritium (one of the most expensive materials that money can buy[2]). Furthermore, I was also in a pickle as the part of the world where Türkiye is located -that is the bridge between Europe and Asia, extending towards Asia minor- had no synchrotrons nearby. Of course, I was not the only scientist in Türkiye with the desire to play with synchrotrons. As a matter of fact, there were earlier proposals to build a synchrotron in Türkiye dating back to the beginning of 1990's. Unfortunately, these far-sighted ideas geared towards the construction of a synchrotron facility in Türkiye (such as the one proposed by Dr. Esen Ercan Alp of Advanced Photon Source, Argonne National Laboratory, USA) were eventually dismissed due to the lack of political and financial support from the governmental funding agencies. Other early efforts in 2014 to acquire long-term (continuous) beam time in an existing synchrotron such as ALBA (Barcelona, Spain) initiated by small group of Turkish scientists including myself did not also materialize due to the lack of funding.

Meanwhile in 2006, Türkiye started to build its own free electron laser (FEL) facility which is a linear electron accelerator operating at 40 MeV, generating intense light beams in the infrared (IR) region. This

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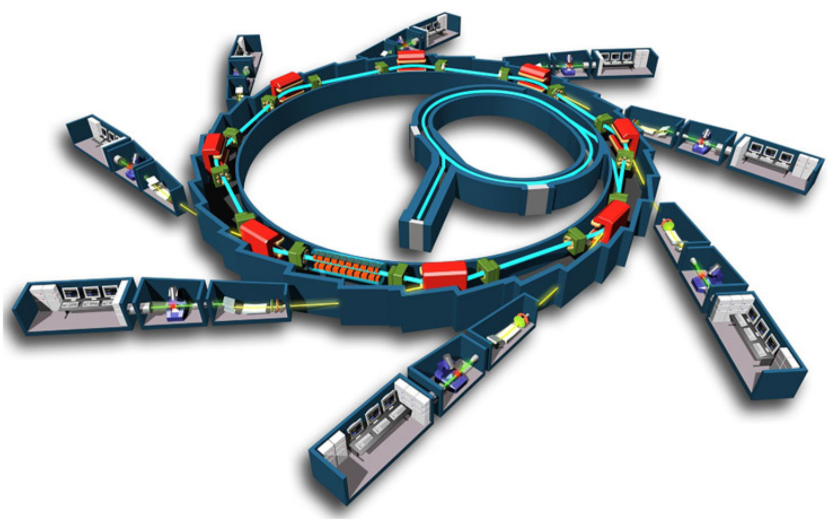
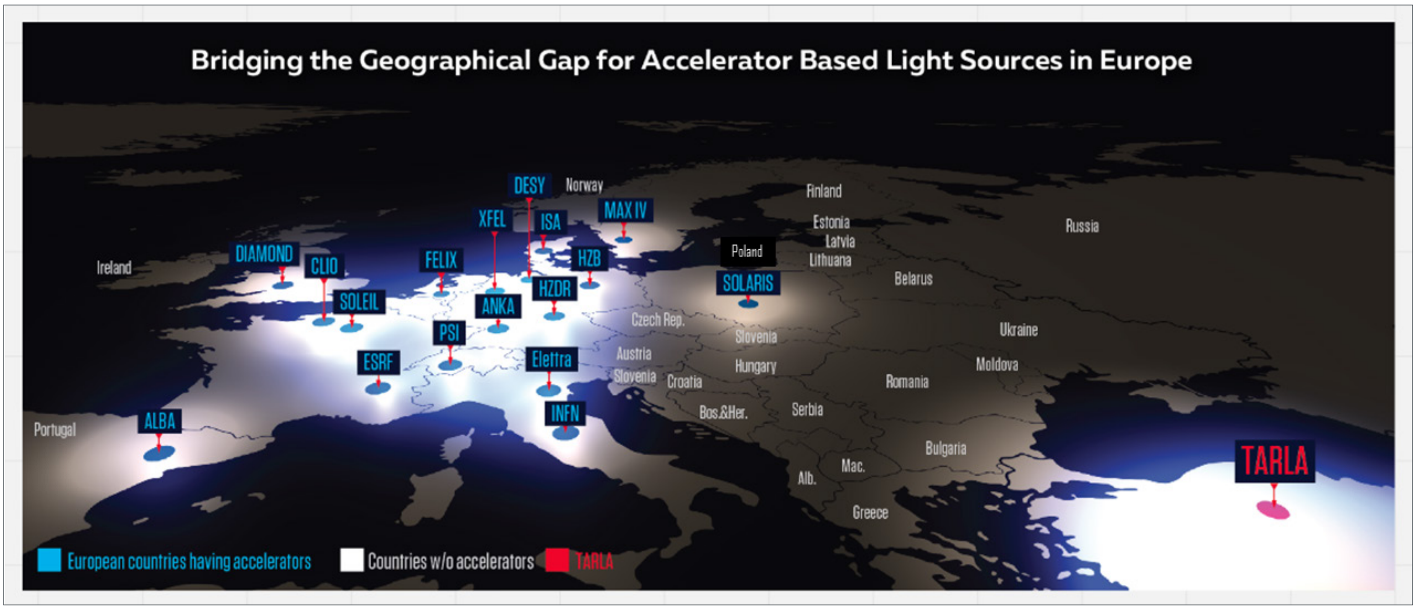
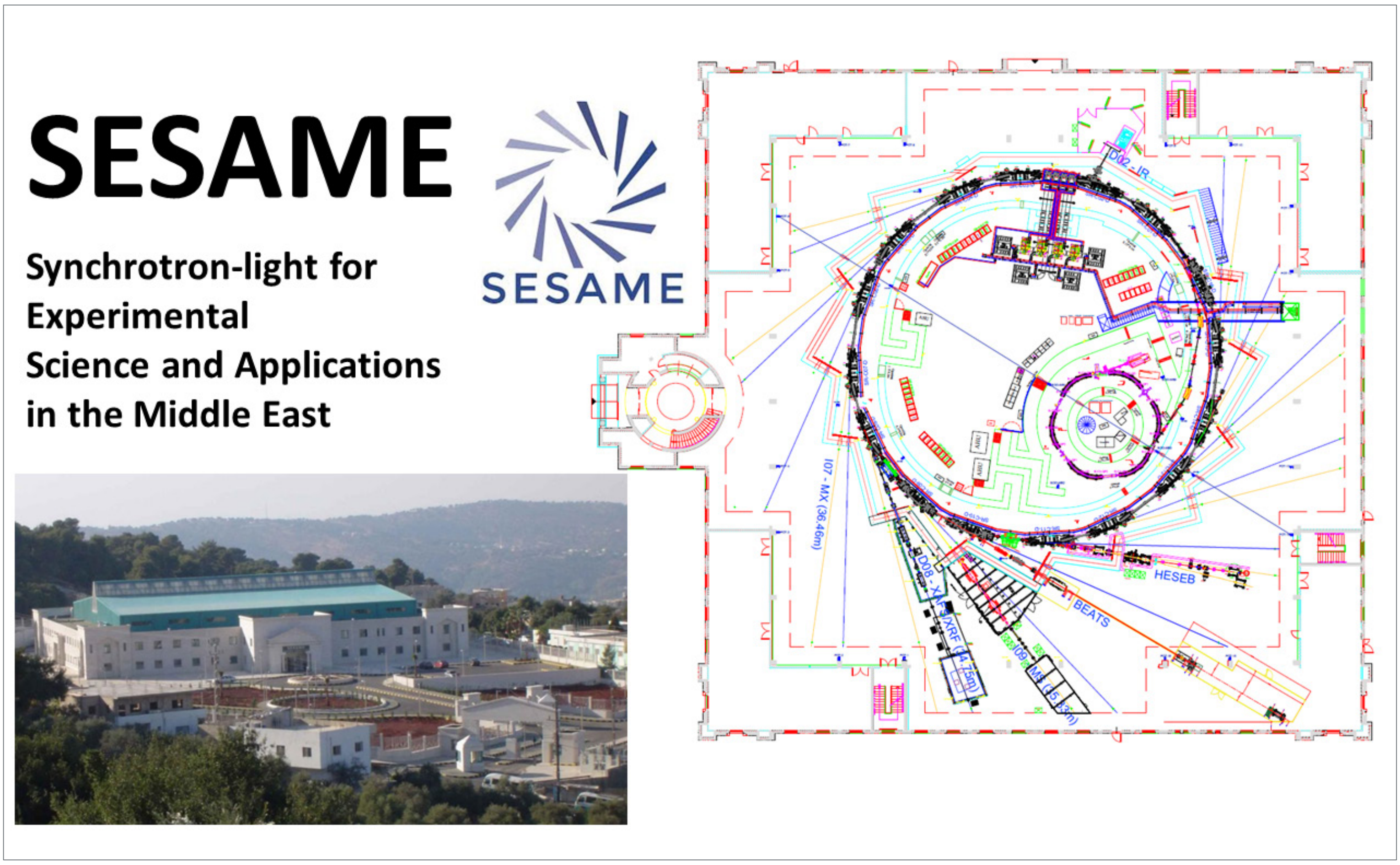


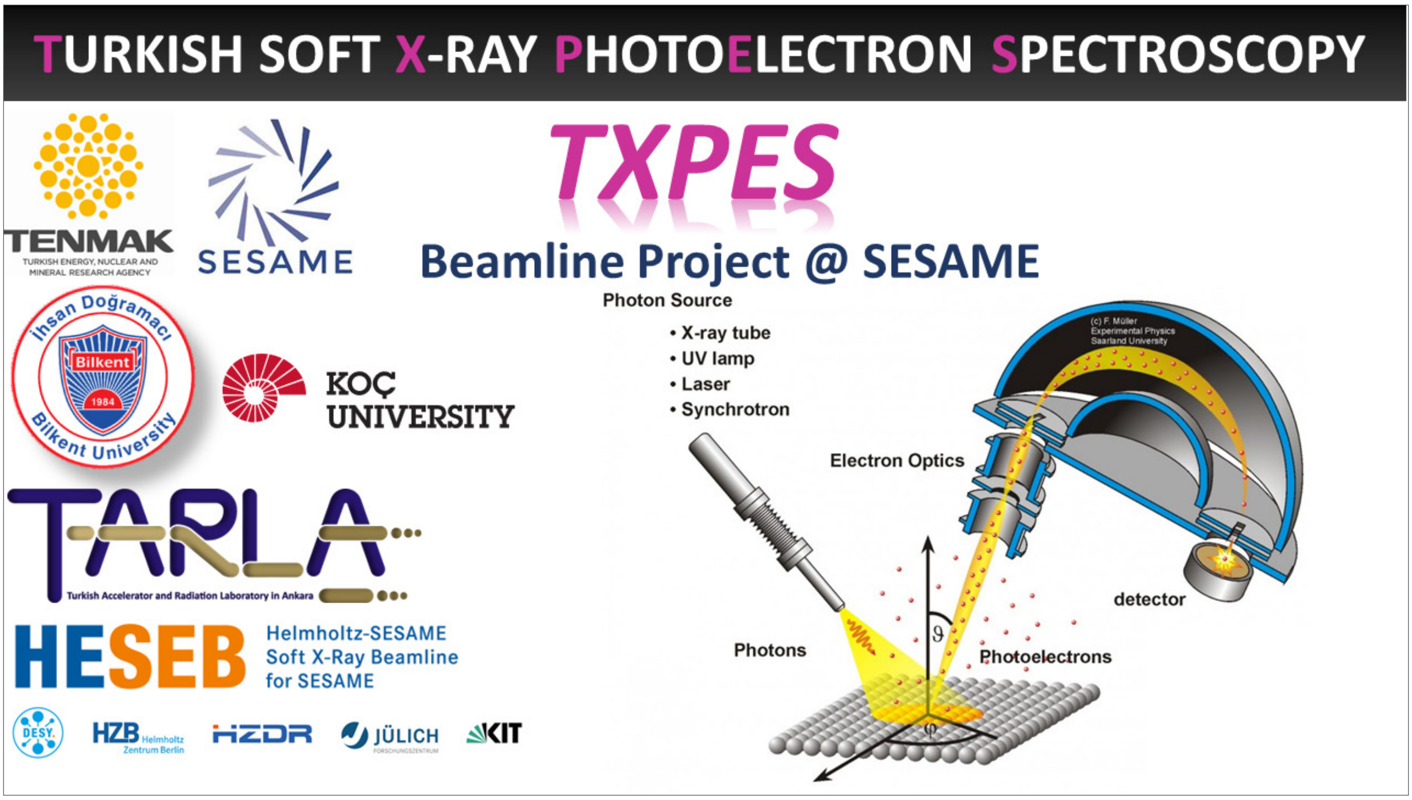
Left, truffle mushroom risotto. Right, simplified sktech of a typical synchrotron
(https://en.wikipedia.org/wiki/Synchrotron_light_source#/media/File:Sch%C3%A9ma_de_principe_du_synchrotron.jpg).



FEL facility was constructed at the Turkish Accelerator and Radiation Laboratory (TARLA, https://en.tarla-fel.org) located in Ankara and allowed the gathering of a critical mass of interdisciplinary Turkish scientists interested in using accelerator-based light sources in advanced research problems relevant to physics, chemistry, materials, life sciences, and engineering. The former director of TARLA, Dr. Avni Aksoy (currently at CERN, Switzerland) managed to mobilize a select group of scientists in Türkiye to encourage them to exploit synchrotron facilities in Europe, particularly Deutsches Elektronen-Synchrotron (DESY, Hamburg, Germany). Thanks to the persistent efforts of Dr. Frank Lehner (Head of the Directorate's Office at of DESY), an important workshop was organized in Hamburg in 2015 to promote synchrotron-based research in Türkiye. Impetus generated by this event as well as other similar subsequent scientific exchange activities between TARLA and DESY led to the idea that it was now time for Türkiye to build its own very first synchrotron beamline.

Fortunately, stars were all lined up for this to happen. Though surprisingly not in Türkiye, but rather in Jordan. In 2002, UNESCO announced an international cooperative scientific venture called Synchrotron-light for Experimental Science and Applications in the Middle East (SESAME, https://www.sesame.org.jo) in Amman, Jordan which would be governed by 8 member countries comprised of Jordan, Türkiye, Palestine, Israel, Egypt, Iran, Greek Cypriot Administration of Southern Cyprus, and Pakistan[3]. Besides being an unprecedented





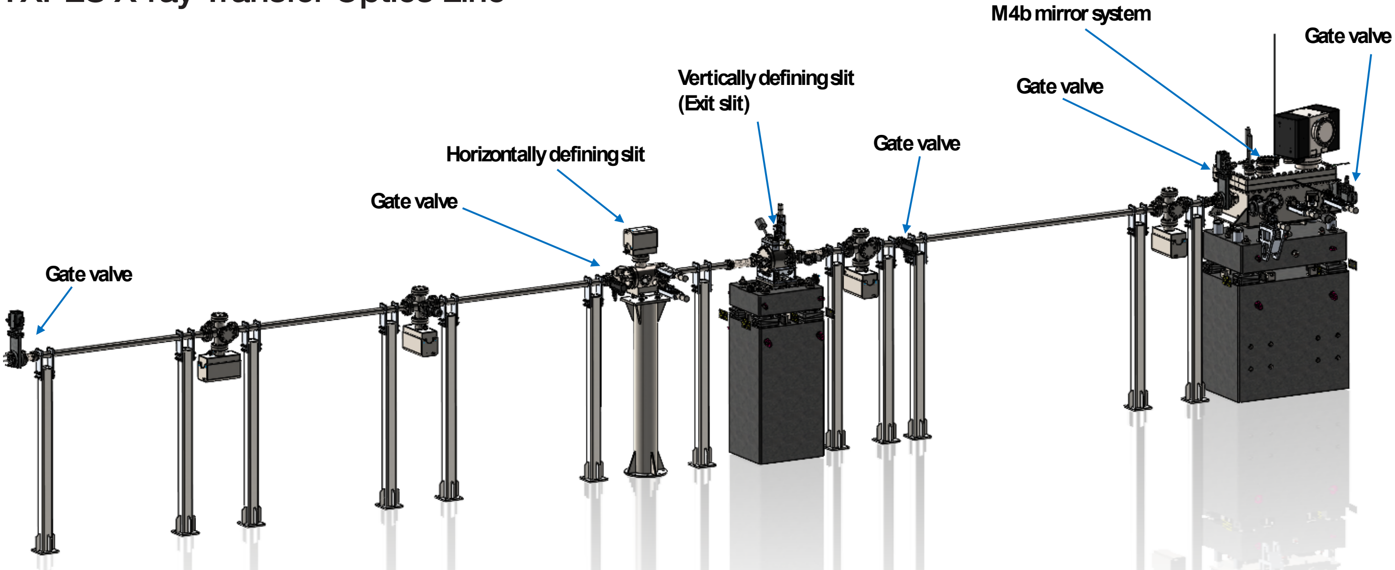
international scientific collaboration in the region, this was also a historical peace project where scientists from across the Middle East and Asia could sit around a table, discuss science, and work together as a unified team of researchers focusing on the same universal objective without the inertia of international politics. With the unrelenting support from the former/current SESAME Scientific Advisory Committee Presidents Dr. Zehra Sayers (Sabancı University, Istanbul, Türkiye) and Dr. Esen Ercan Alp, former/current SESAME Scientific Directors Dr. Giorgio Paolucci (currently at Elettra Sincrotrone, Trieste, Italy) and Dr. Andrea Lausi, as well as the SESAME Council President, Dr. Rolf Heuer (third former CERN Director-General) and SESAME Director Dr. Khaled Toukan, the idea regarding the construction of a beamline by a member country (i.e., Türkiye) gained significant traction. This also made political sense from the perspective of Turkish science, since as a loyal member of SESAME, Turkish government had already invested more than $12 Million in SESAME's cause to bring cutting edge science to the region. As the icing on the cake, the very first scientific article[4-6] of SESAME which became operational in 2017 was published in 2019 by a Turkish collaboration including our research group at Bilkent University Chemistry Department, Ankara, Türkiye and that of Dr. Ahmet Kerim Avcı from Boğazici University, Istanbul, Türkiye. And now, it was time for Turkish science to use SESAME even more effectively by adding the final set of bells and whistles.

Thus, in 2018 we commenced a Turkish project workgroup comprised of Turkish Energy Nuclear and Mineral Research Agency (TENMAK, formerly called Turkish Atomic Energy Authority, TAEK), Bilkent University, TARLA, Koç University, and Niğde Ömer Halisdemir University (NOHU). This core group of researchers included Dr. Avni Aksoy (TARLA), Dr. Erdal Recepoğlu (TENMAK), Dr. Sarp Kaya (Koç University), and Dr. Zafer Nergiz (NOHU), and myself, which were later joined by Dr. Mustafa Fatih Genişel and Dr. Zeynep Öztürk from SESAME, and Barış Yıldırımdemir from TARLA to kick-off the first historical effort towards the construction of a synchrotron beamline. Since the main experimental technique to be used in the beamline would be X-ray Photoelectron Spectroscopy (XPS) -a surface-sensitive X-ray based nanomaterial characterization technique which was originally explained by Albert Einstein in his Nobel prize-winning work- name of the project was determined to be the Turkish Soft X-ray Photo-Electron Spectroscopy (TXPES) project. XPS was not an unfamiliar technique for the Turkish scientific community as the first XPS instrument was installed and operated as early as mid 1990's at Bilkent University Chemistry Department by Dr. Şefik Süzer. TXPES beamline construction tasks were partitioned in two main work packages. The X-ray optics transfer ultra-high vacuum (UHV) line design and manufacturing efforts (which would be predominantly carried out in Türkiye using Turkish tech companies) are led by Barış Yıldırımdemir at TARLA and the XPS experimental end-station design and manufacturing efforts are led by Dr. Sarp Kaya at Koç University and myself at Bilkent University with the assistance from a commercial company in Berlin, Germany.

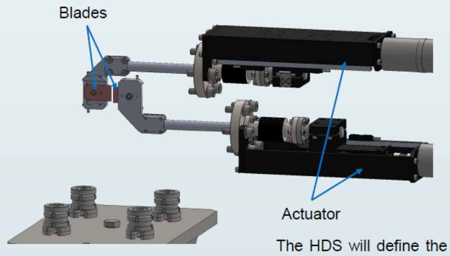
As the essential catalyst, our colleagues at DESY spearheaded by Dr. Frank Lehner launched a widely participated consortium called Helmholtz-SESAME Soft X-ray Beamline for SESAME in August 2018 with contributions from DESY, Helmholtz Zentrum Berlin (HZB), Helmholtz-Zentrum Dresden-Rossendorf (HZDR), Forschungszentrum Jülich, and Karlsruhe Institute of Technology (KIT). This project not only received a generous sum of € 3.5 M funding to construct the X-ray optics required to transmit X-rays from the SESAME electron storage ring to the point where the new Turkish beamline's construction would start, but also provided invaluable scientific assistance and consulting to the rather young and inexperienced TXPES project team. Particularly, critical technical support and contributions from Dr. Rolf Follath (Paul Scherrer Institut, PSI), Dr. Wolfgang Eberhardt (DESY), Dr. Wolfgang Drube (DESY), and Dr. Johannes Bahrdt (HZB) were truly instrumental.

Enjoying the vital backing of TAEK/TENMAK administration which is the official governmental entity in Türkiye regulating the official relations of Türkiye with SESAME, we were able to construct a scientific case to request about € 4 M funding for the TXPES project in February 2018. While the crucial

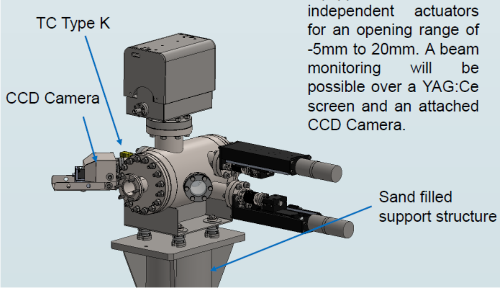
TXPES X-ray Transfer Optics Line



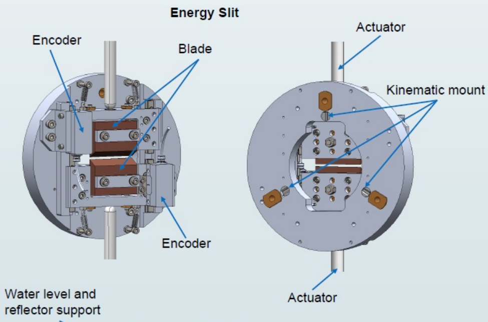
Horizontally Defining Slit



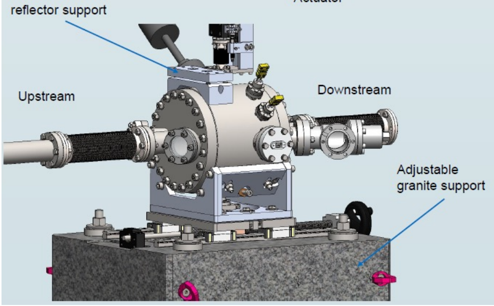
The HDS will define the horizontal dimension of the beam. It will be equipped with two independent actuators for an opening range of -5mm to 20mm. A beam monitoring will be possible over a YAG:Ce screen and an attached CCD Camera.



Energy Slit Unit

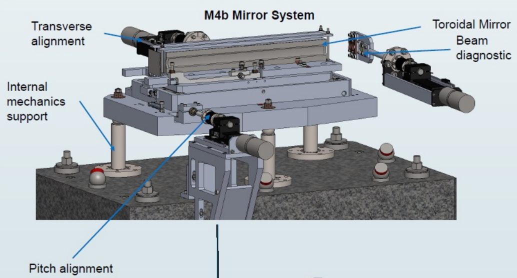


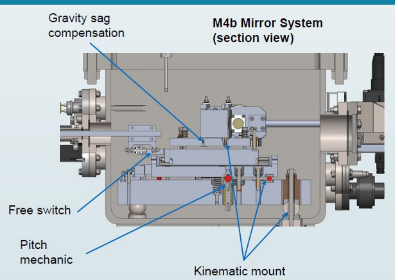
The energy slit unit will define the vertical dimension of the incoming beam. This will have an impact on the chosen energy, which will effect the experiments in the End Station. To rely on the results, it was a main objective to design a very precise blade alignment. For this purpose the encoder for the positioning of the blades were placed as close as possible next to the blades itself in vacuum. The system will be able to position the blades within 50nm. The two separate actuators will also allow a gap translation. To enable this features a different approach for the internal mechanics was chosen.

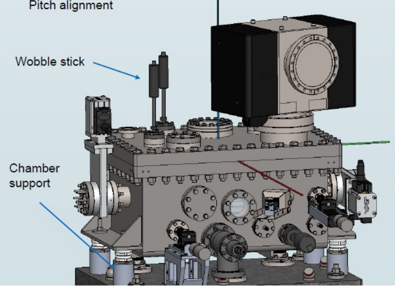


Energy Slit Blade Opening	
Range	0-2000µm
Resolution	50nm
Repeatability	100nm
Blade parallelism	< 1µm over 10mm blade width

M4b Mirror System



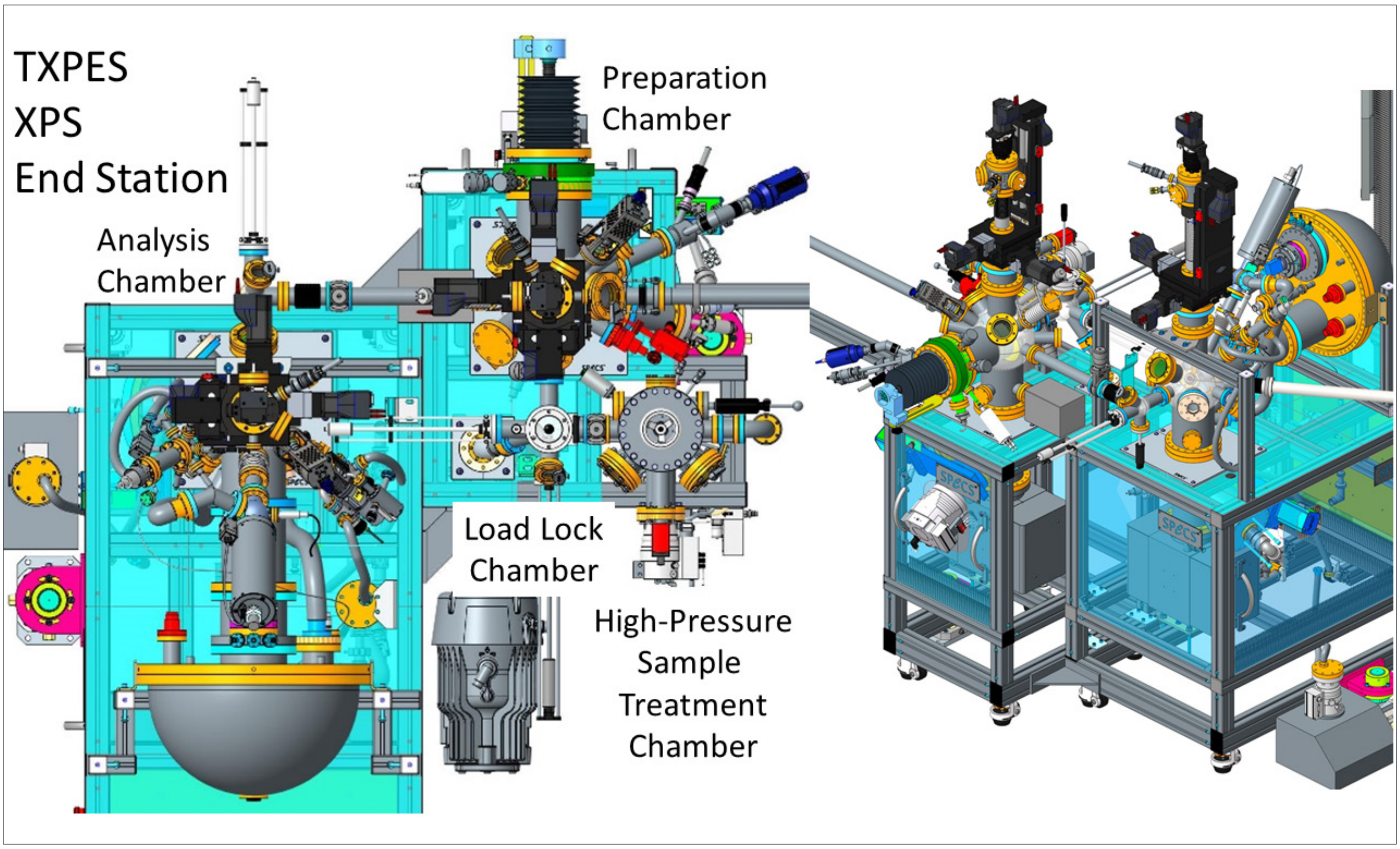




The M4b Mirror System will have two motorized and 4 manually adjustable alignment axis. The mounting of the electrically insulated Toroidal Mirror will be force free in order to avoid any mounting induced deformation for the precise manufactured optic. A kinematic mount will be maintained from the first base plate up to the mirror holder itself.
To compensate errors induced by gravity a spring loaded support for the electrically insulated mirror will be implemented

M4b Mirror System motion parameters				
Movement	Actuator	Resolution	Repeatability	Range
X (transverse)	Motor	50 nm	1 µm	±5 mm
Y (height)	Manual	10 µm	10 µm	±5 mm
Z (beam direction)	-	-	-	-
Roll (rot z)	Manual	1 µrad	3 µrad	±5 mrad
Pitch (rot y)	Motor	1 µrad	3 µrad	±5 mrad
Yaw (rot x)	Manual	5 µrad	20 µrad	±5 mrad

support from former/current TAEK/TENMAK presidents Suat Ünal, Dr. Zafer Demircan, and Dr. Abdülkadir Balıkçı, and TENMAK-NUKEN Director Dr. Veysi Erkcan Özcan provided the wind beneath our wings to have the project proposal accepted in late 2019, an unexpected financial crisis in Türkiye starting in 2019 led to the halt of the transfer of funds. Furthermore, there were additional bureaucratic and fiscal difficulties to be overcome which were associated with funding of a research laboratory outside Türkiye by the Turkish government, as this had not been done before. Such roadblocks put the realization of the TXPES project on hold until the spring of 2021. In spring 2021, an important political opportunity appeared along with a high-level government officer's visit to TARLA. During this visit, former TARLA Director Avni Aksoy and myself faithfully teamed together to deliver a quite concise and enthusiastic "elevator speech"



explaining why synchrotrons were indispensable for the science and technology of any developed country in the world, and more importantly, why we should be funding the TXPES project asap. Fortunately, our "elevator speech" worked like a charm and all of the roadblocks against the unlocking of the dedicated funds were slowly and gradually vanished, as if with the bountiful touch of a bureaucratic magic wand. The funds eventually arrived in the summer of 2022. One little bump on the road was a financial glitch associated with the currency type (i.e., Turkish Lira, TL) defining the total project budget. Since this roller-coaster project adventure that we have embarked on called TXPES started in 2018 and the funding was received in 2022, we actually lost a significant portion of our budget defined in TL due to the unfavorable changes in the currency exchange rates. Now we had roughly €2.0 M, Hooray ! Without any surprise, we had to make numerous significant technical amendments in the project. In other words, we were forced to remove many of the less critical hardware components, staff, and consumables as if slicing meat for a "döner kebap" sandwich. These meticulous efforts paid off and we were able to start the construction of the modified design of the TXPES beamline in 2022 (phew!).

As a result of the impeccable hardware design work of Barış Yıldırımdemir from TARLA with essential computational and simulation support from Rolf Follath (PSI) regarding X-ray optics, TXPES X-ray optical transfer line design was approved by an international group of experts constituting of Dr. Raymond Barret (European Synchrotron Radiation Facility, ESRF, France), Dr. Kawal Sawhney (Diamond Synchrotron, UK), and Dr. Jessica McChesney (APS, ANL, USA).

Meanwhile, the design of the XPS end-station was also finalized in 2023 and the manufacturing process has been started. Essentially, TXPES end station was comprised of a modular design which included: i) a load lock chamber for sample insertion, ii) a unique high-pressure chamber (HPC) to treat samples with elevated pressures (up to 10 bar) of gases and temperatures (up to 800 °C) which can be followed by subsequent XPS analysis without exposure of the samples to (uncontrolled) ambient conditions, iii) preparation chamber allowing low energy electron diffraction (LEED) analysis, e-beam dosers for evaporation of metals to grow ultra thin film/nanoparticle structures, quartz crystal microbalance (QCM), iv) analysis chamber comprised of UV/XPS benchtop photon sources, XPS and Low energy ion scattering (LEIS) energy analyzer, rastering ion gun for sputtering and LEIS, electron flood gun, and quadruple mass spectrometer (QMS). With its versatile modular design and its unique capabilities such as the HPC, TXPES system is expected to deliver to top-notch experimental possibilities to analyze nanomaterials with very high surface sensitivity, spatial and energy resolution that are of great value to interdisciplinary work in physics, chemistry, material sciences, and engineering. It is expected that the installation of the TXPES at SESAME will start at the end of 2024 and the commissioning will be complete in the spring of 2025.

If you had never tasted a delicious truffle risotto, chances are, you would never crave it. We are confident that once a larger community of Turkish and middle-eastern researchers performing internationally

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