High Energy Photon Source

Address book

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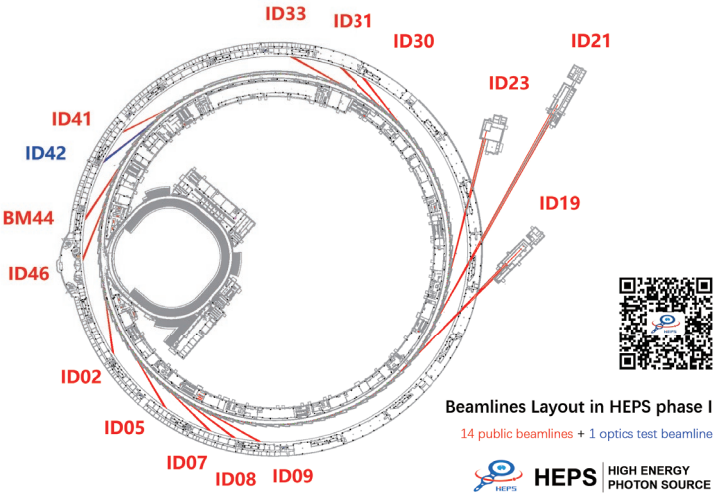
Overview

The High Energy Photon Source (HEPS), under construction since 2019, is located in the northern core area of Huairou Science City (HSC) and is one of HSC's large scientific facilities. When it is commissioned, HEPS will not only be the first high energy light source in China but also one of the brightest fourth-generation synchrotron radiation facilities in the world.

HEPS complex buildings resemble a magnifying glass, thus aptly symbolizing the role of HEPS as a powerful tool for characterizing the microstructure of matter. As one of the key projects listed in the 13th Five-year Plan for national major scientific and technological infrastructure construction, HEPS is an important platform for original and innovative research in the fields of basic science and engineering. The HEPS project, undertaken by the Institute

of High Energy Physics of the Chinese Academy of Sciences, comprises accelerators, beamlines and utility facilities. The estimated construction period is six-and-a-half years.

The storage ring of HEPS is 1360.4 m in circumference. Its electron energy is 6 GeV and its brightness is more than 1×10^{22} phs/s/mm^2/mrad^2/0.1%BW. By using a 7-Bending Achromatic (7BA) lattice, the horizontal emittance of the electron beam can surpass 60 pm·rad, which is the main feature of the fourth-generation diffraction limited light source.



Layout for the 14 public beamlines of HEPS Phase I

HEPS can accommodate more than 90 high-performance beamlines and stations. Phase I involves construction of 14 user beamlines and stations for researchers in the fields of engineering materials, energy materials, environmental research, health studies and pharmaceutical development, and catalysts in the petrochemical industry, among others. HEPS will provide high energy, high brilliance, high coherence synchrotron light with energies up to 300 keV and more, with the capability for nm spatial resolution, ps time resolution, and meV energy resolution. While providing conventional technical support for general users, HEPS will also operate as a platform for in-situ and operando investigation of the real-time structural evolution of engineering materials using multiscale and multimodal X-ray probes, which will enable breakthroughs in the design and manipulation of such materials to meet the requirements of national development strategies and urgent core industrial needs.

Layout for the 14 public beamlines of HEPS Phase I

NO.	Beamline	ID Type	Energy Range [keV]	Beta F.	National Demands	Industry	Energy and Enviornment for sustainable development	Frontier Science Field	High Energy	Low Emittance	Used widely
1	Hard X-ray nanoprobe multimodal beamline	CPMU	50~170	Low	√	√	√		√	√	√
2	Engineering materials beamline	IVU	4.8-40	Low			√	√	√	√	
3	Structural dynamics beamline	CPMU	20~60	Low	√	√		√	√	√	√
4	Hard X-ray coherent scattering beamline	IVU	7-40	Low				√	√	√	
5	Hard x-ray High resolution spectroscopy beamline	IVU	7~25	Low	√			√	√	√	
6	High pressure beamline	IVU	20-50	Low	√			√	√	√	√
7	Hard X-ray imaging beamline	CPMU	10-90	Low	√	√		√	√	√	√
		Wiggler	40-300					√	√		
8	X-ray absorption spectroscopy beamline	IAU	4.8-45	High			√	√			√
9	Low-dimensional structure probe beamline	IVU	4.8-40	Low	√		√	√			√
10	Microfocusing x-ray protein crystallography beamline	IAU	5~18	High	√		√	√			√
11	Pink beam SAXS beamline	IAU	8~12	High	√	√		√			√
12	High resolution nanoscale electronic structure beamline	APPLE-KNOT	0.1-2	High		√		√		√	√
13	Tender x-ray beamline	BM	2.1~7.8				√	√			√
14	Transmission X-ray microscopic beamline	IAU	5~15	High		√	√	√			√

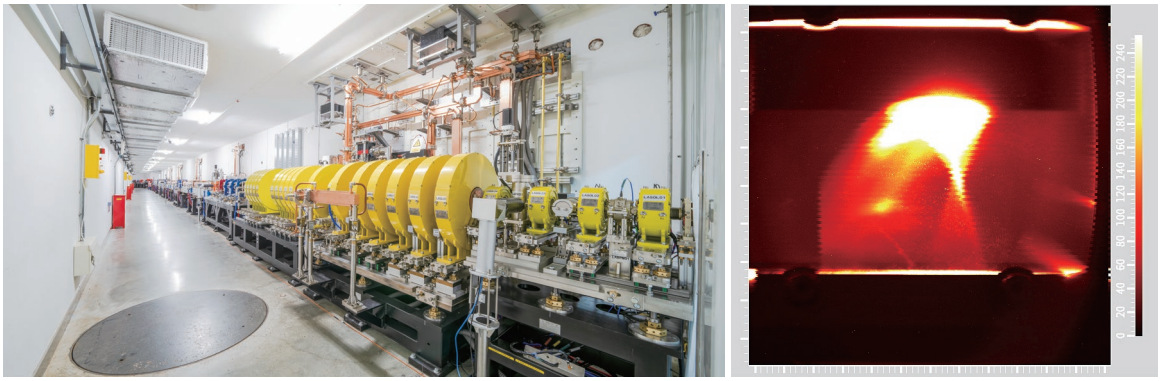
Construction progress

In 2023, equipment installation and electron beam commissioning at HEPS were carried out in an orderly and highly efficient manner.

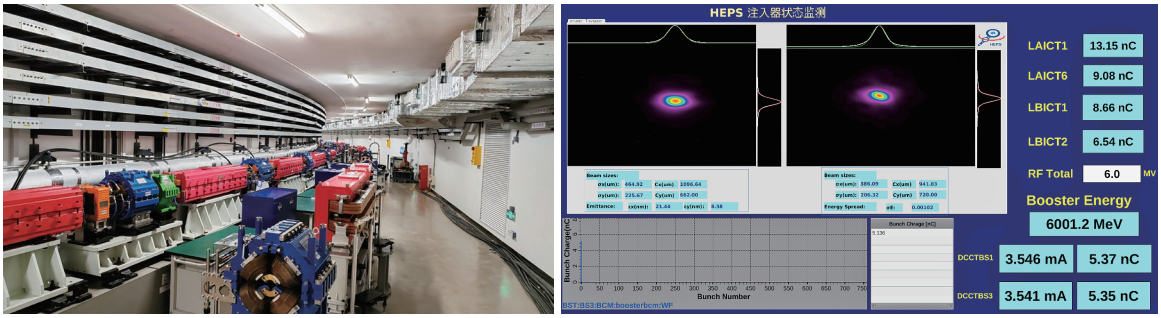
The Linac and the booster both passed the scientific and technical performance acceptance review organized by HEPS Project Management Department, with the electron beam energy accelerated to 500 MeV and 6 GeV separately. All parameters reached or exceeded design specifications, with the overall performance of the Linac and booster reaching the global advanced level. To meet the beam commissioning requirements of HEPS, a brand framework *Pyapas* was designed for high level applications (HLA) development. It is a full-featured development framework specifically designed for high-level physics applications, which can significantly enhance development efficiency. Based on this framework, HLAs for the Linac and booster were developed and successfully applied to beam commissioning and have achieved excellent performance, assisting beam commissioning operators in quickly achieving beam transmission throughout the entire system.

The storage ring installation work went smoothly, and the development of the magnet and pre-alignment, power supply and magnet girder were successfully completed. The main equipment of the storage ring was also successfully installed. The HEPS developed Mango Wiggler with an internationally original design, a special Delta type PPM wiggler to satisfy the requirement of large vertical field range for X-ray phase contrast imaging, also passed acceptance. In addition, the world's first merged four-row APPLE-Knot undulator was successfully developed and the magnetic field tuning was completed. The results of the horizontal test of the world's first 166 MHz SRF cavity module exceeded its design specifications. Furthermore, it was the world's first quarter-wave SRF structure to accelerate relativistic particles (beta=1) as a main accelerating cavity, and it achieved heavy damping of higher order modes.

Construction of the beamlines and end-stations has now fully entered the equipment installation and commissioning stage. The two front-ends equipment has basically all been aligned and installed . The most accurate measurement for an X-ray curved mirror has been achieved on the independently developed flag-type surface profiler. The HEPS-developed resonant inelastic X-ray scattering RIXS analysis crystal was tested on the beamline, and the first quick scanning monochromator in China achieved the higher stabil-



The electron beam of HEPS achieved more than 7 nC of bunch charge at 500 MeV via the Linac with the emittance of better than 0.06 nm·rad.



The electron beam of HEPS achieved more than 5 nC of bunch charge at 6 GeV via the booster.

Installation of the main equipment of the storage ring was successfully completed on Dec. 11, 2023.

ity. The first domestically developed X-ray thermal load chopper has been successfully developed, and the diamond XBPM and SDD detectors were fully independently designed. The hutches, personal safety interlocks, and utilities including cable, compressed gas, water and electricity for the first group of beamlines has been completed. instrumentation installation and commissioning for the first experimental station, belonging to the transmission X-ray microscopic beamline, is under the way. The construction of the second batch of beamlines were continuing.

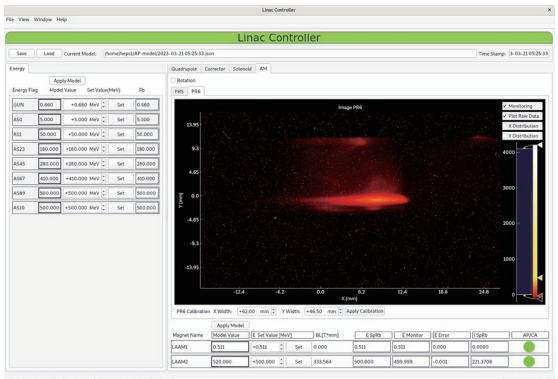
The scientific big data central software system and online processing software have been successfully developed. The AI for Science research on online analysis of massive synchrotron radiation diffraction scattering data has made progress, making significant contributions to the analysis and denoising of massive data on experimental methods such as diffraction scattering, CT imaging, and coherent scanning imaging. Furthermore, research results have been published online in important academic journals in the field, such as *IUCrJ* and *npj Computational Materials*.

Utility installation of water-cooling system and electricity supply has proceeded on schedule, and ancillary buildings have been completed and passed acceptance review. Among these, the guest house has already been put into use, providing strong support for the construction of HEPS.

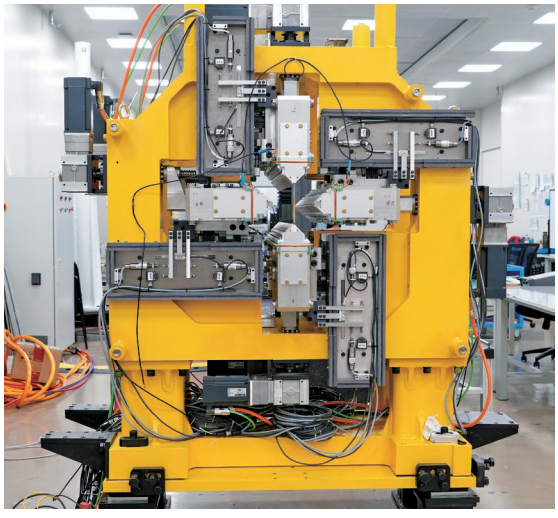
Aerial shot of the HEPS project site in September 2023.

Aerial shot of the HEPS project site in December 2023.

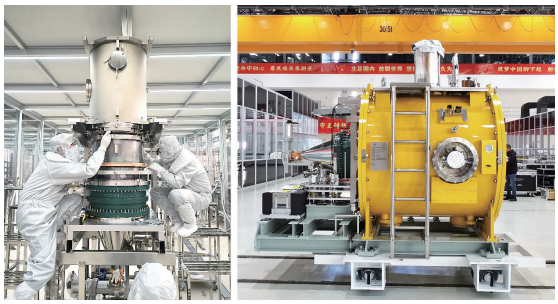
Installation of the water-cooling pipelines at the top of the storage ring tunnel has been basically completed.



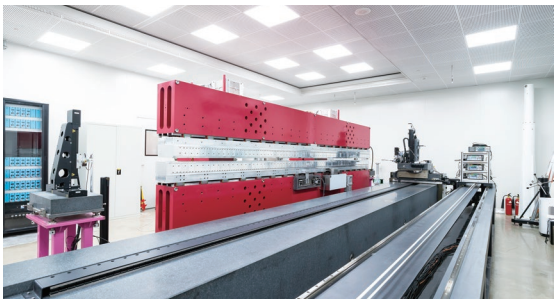
Physics-based beam commissioning applications based on *Pyapas*



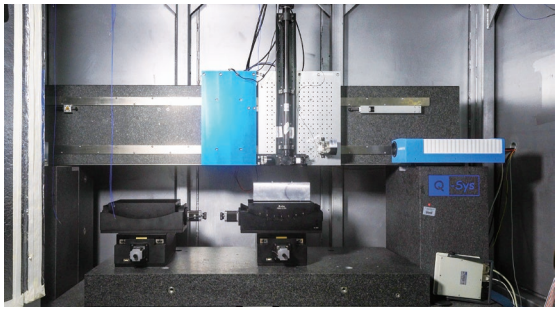
HEPS developed Mango wiggler passed acceptance test.



World's first 166 MHz superconducting accelerator module completed a high-power horizontal test at cryogenic temperature Nov. 20, 2023.

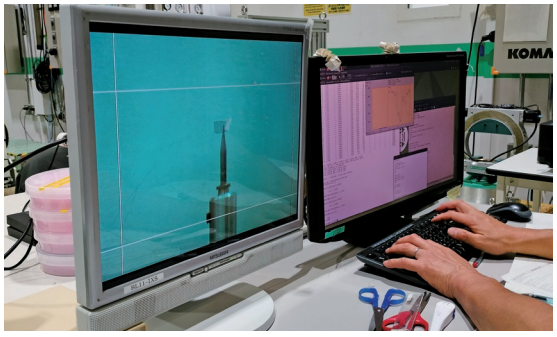


World's first merged four-row APPLE-Knot undulator was under test

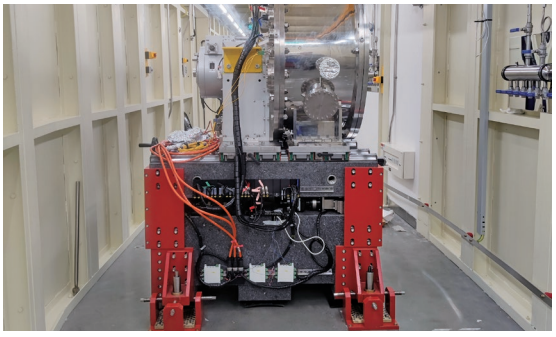


Independently developed flag-type surface profiler

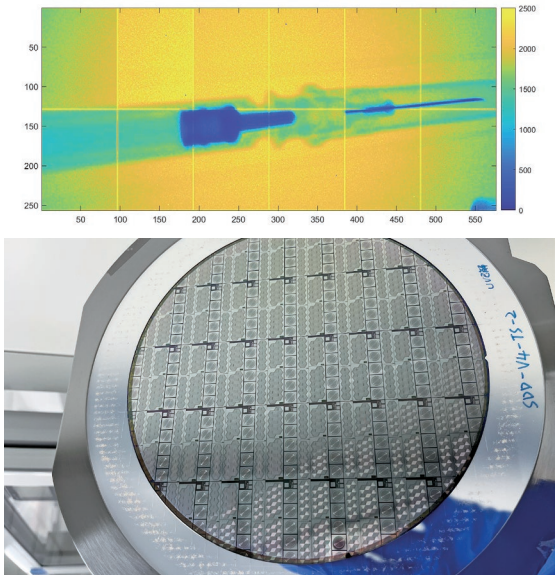
First domestically developed X-ray thermal load chopper passed factory acceptance test.



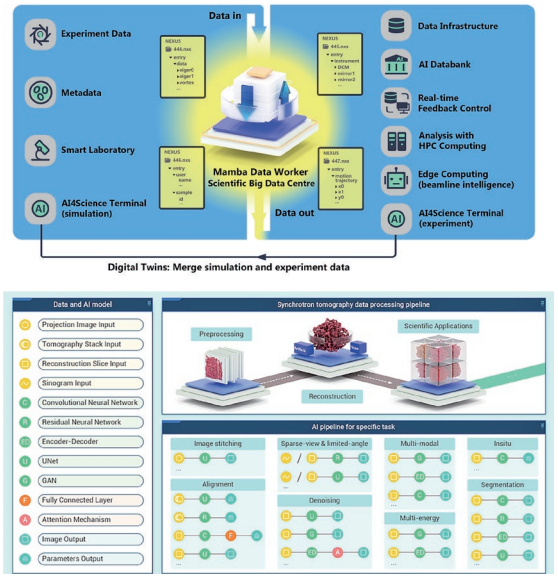
HEPS developed resonant inelastic X-ray scattering RIXS analysis crystal was testing on the beamline.



First quick scanning monochromator in China installed in hutch.



Diamond XBPM and SDD detectors.



Big data flow diagram and online processing software.

Cooperation and exchange

In order to learn from international advanced experience and better promote project construction, HEPS successfully hosted the 12th International Conference on Mechanical Engineering Design of Synchrotron Radiation Equipment and Instrumentation (MEDSI 2023) and the first National Symposium on Optics and Technology for Advanced Light Source (OTALS), providing a high-quality platform for exchange and cooperation among synchrotron photon sources and free electron laser facilities.

HEPS also signed a memorandum of understanding on cooperation with Sirius (a light source in Brazil) and sent two groups of beamline scientists to visit Sirius for cooperation and exchange, based on the joint statement on deepening comprehensive strategic partnership between China and Brazil.

In addition, international review meetings on radio frequency system, the end station design of two beamlines, and the nano probe beamline and the coherent scattering beamline, were held. A delegation was invited to visit the Diamond light source in autumn to discuss the development of the data acquisition software and AI implementation.

Furthermore, HEPS actively participated in the International Synchrotron Radiation Instrument Conference (SRI2024) hosted by German Electron Synchrotron Accelerator (DESY) and European XFEL, as well as online seminars and user meetings organized by internationally renowned light source organizations such as ESRF-EBS, APS, DESY, etc.

Chronicle of events

- **Jan. 13** HEPS booster installation completed.
- **Feb. 1** HEPS girder installation HEPS girder installation in storage ring tunnel started.
- **Mar. 14** The first electron beam of HEPS was accelerated to 500 MeV by the Linac.
- **May 18** HEPS linear accelerator passed performance test.
- **Jun. 5** HEPS linear accelerator passed performance acceptance.
- **Nov. 17** The electron beam of HEPS ramped up to 6 GeV via the booster, with all parameters reaching design specifications.