

# High Magnetic Field Laboratory

## Steady High Magnetic Field Facility (SHMFF, Hefei)

### 2025 Annual Report



High Magnetic Field Laboratory, CAS  
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## Overview

High Magnetic Field Facilities (HMFF) Project was approved on January 25<sup>th</sup>, 2007, which was jointly applied by Chinese Academy of Sciences and Ministry of Education. The HMFF Project includes two parts: Steady High Magnetic Field Facility (SHMFF), constructed by Hefei Institutes of Physical Science, CAS; Pulsed High Magnetic Field Facility (PHMFF), constructed by Huazhong University of Science and Technology.

SHMFF started its construction on May 19<sup>th</sup>, 2008. Partial magnets of SHMFF have been open to users since October 28<sup>th</sup>, 2010. SHMFF passed national acceptance and was fully put into operation on September 27<sup>th</sup>, 2017.

SHMFF consists of a world-record 45.22 T hybrid magnet, five water-cooled magnets (42.02 T/ $\Phi$ 32, 25 T/ $\Phi$ 50, 20 T/ $\Phi$ 200, 27.5 T/ $\Phi$ 32 and 35 T/ $\Phi$ 50), four superconducting magnets (10 T/ $\Phi$ 100/ $\Phi$ 100, 20 T/SMA, 20 T/NMR and 9.4 T/MRI) and series of experimental systems (transport, magnetic, magneto-optical, extremely low temperature, ultrahigh pressure, STM-AFM-MFM combo, etc.).

SHMFF gives priority to original fundamental research, applied research with important application prospects and high-tech development to improve technical innovation in China, encourages users to undertake national and ministerial major research projects, and welcomes industrial users. Users have been playing a leading role in its operation and opening, which are conducive to feature scientific objectives, prioritize key research fields, and promote important scientific outcomes.

By the end of 2025, SHMFF has provided exceeding 714, 946 hours of operation time and executed more than 4100 approved user projects. Users from 228 organizations across the world have carried out research here, and have made series of important research achievements in materials, chemistry, biology science and other disciplines. The users have published over 3000 peer-reviewed journal articles, including dozens in Nature, Science, Cell and other top journals.

In 2025, SHMFF completed the operation task, and provided 54486 hours of operation time. 344 users' projects from 79 organizations carried out research projects and published 291 articles in peer-reviewed journals.

SHMFF focuses on three missions:

1. Advance magnet-related technology, stimulate invention and creation in high magnetic fields.
2. Perform the frontier research of physics, chemistry, biology and material under high magnetic fields.
3. Promote economic development such as pharmaceuticals, medical treatment etc.



## Research progress and results

### Research highlights

In 2025, SHMFF achieved a series of significant breakthroughs across multiple cutting-edge research fields, covering the exploration of novel quantum states, research on high-temperature superconducting materials, preparation of functional materials, manipulation of new magnetic storage technologies, elucidation of efficient catalytic mechanisms, and advances in the diagnosis and treatment of major diseases. The representative results are as follows:

#### **1. First Direct Observation of Bose–Einstein Condensation of Magnon Bound States**

Two-magnon excitations represent a novel class of bosonic collective excitations and serve as a fundamental cornerstone for understanding macroscopic quantum phenomena. However, experimental evidence has long been lacking. Leveraging the high magnetic field strength and exceptional stability of SHMFF, a research team led by Wu Liusuo and Mei Jiawei from Southern University of Science and Technology performed electron magnetic resonance measurements on the spin  $S = 1$  triangular lattice material  $\text{Na}_2\text{BaNi}(\text{PO}_4)_2$ . They achieved the first direct observation of Bose–Einstein condensation of magnon bound states. This study provides crucial experimental evidence for the field of quantum magnetism and offers new perspectives for understanding quantum phase transitions and “hidden order”. The results were published in *Nature Materials*. (Fig.1)

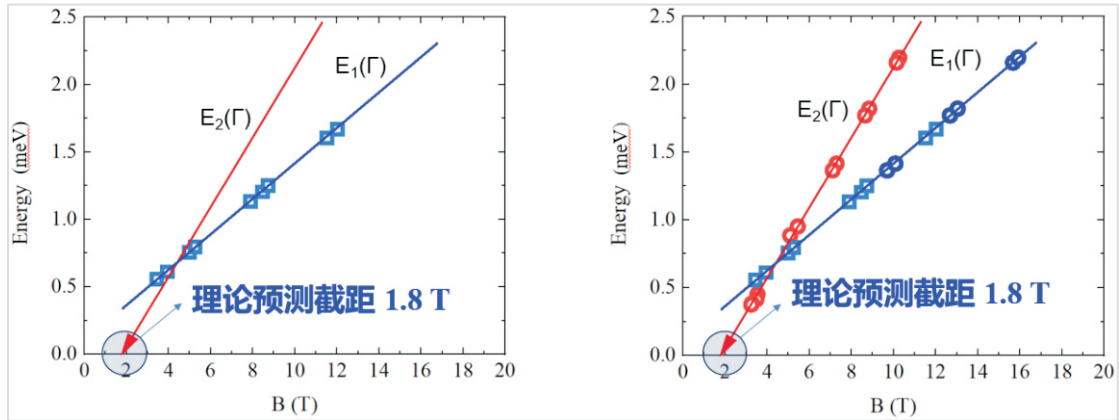


Fig.1. Excitation energies at different magnetic fields of single-magnon and two-magnon states

## 2. Realization of Novel Method for High-Density Reading and Writing of Thin-Films Crystal Directions Driven by Ultrahigh Magnetic Fields

Ferroelasticity, as one of the key ferroic properties of materials, has faced limitations in research and applications due to the lack of non-volatile and non-destructive control methods at the nanoscale. A team led by Peng Wei from the University of Warwick, in collaboration with Lu Qingyou and Meng Wenjie from the Hefei Institutes of Physical Science, CAS, utilized scanning force microscopy under the ultrahigh magnetic field (35 T) generated by a water-cooled magnet to reveal the magnetic anisotropy of  $\text{SrRuO}_3(111)$ . By applying local stress with an ultra-sharp tip, they achieved for the first time three-dimensional manipulation of ferroelastic domains and magnetic regulation at the nanoscale. This study opens a new pathway for low-power, mechanically programmable non-volatile nanodevices and also fills the gap in nanoscale magnetic imaging under extremely high magnetic fields. The results were published in *Nature Nanotechnology* (Fig.2)

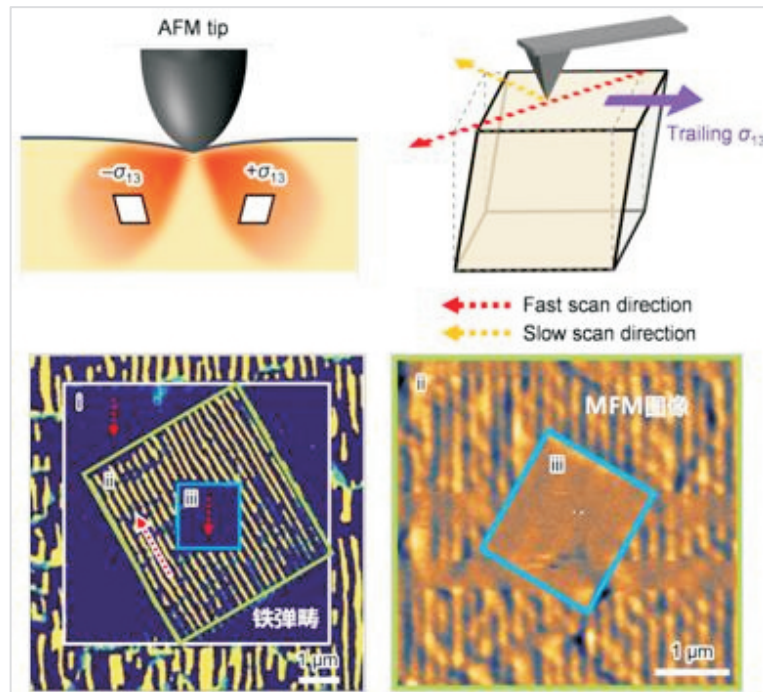


Fig. 2. Schematic diagram of shear stress distribution and magnetic force microscopy imaging under atomic force microscope tip loading

### 3. Record-Breaking Current-Carrying Performance Confirmed in Iron-Based Superconducting Wires

Iron based superconductors exhibit excellent potential for applications in medical and future large scale scientific facilities due to their high upper critical fields. Testing their performance under high background magnetic fields is therefore critical to fully characterizing their material properties. A research team led by Ma Yanwei from the Institute of Electrical Engineering, CAS, has developed an innovative strategy for constructing high-density flux-pinning centers—one that leverages an asymmetric stress field. When applied to fabricate iron-based superconducting wires, this approach yielded a dramatic enhancement in critical current density ( $J_c$ ). Utilizing SHMFF's unique large-bore, high-magnetic-field testing capabilities, the team measured the critical current of these wires under a 30 T magnetic field. The results confirmed a fivefold increase in  $J_c$ , with the final value reaching  $2.1 \times 10^5$  A/cm<sup>2</sup>. This breakthrough paves the way for the development of low-cost, high-performance iron-based superconducting wires. The results were published in *Advanced Materials* (Fig.3)

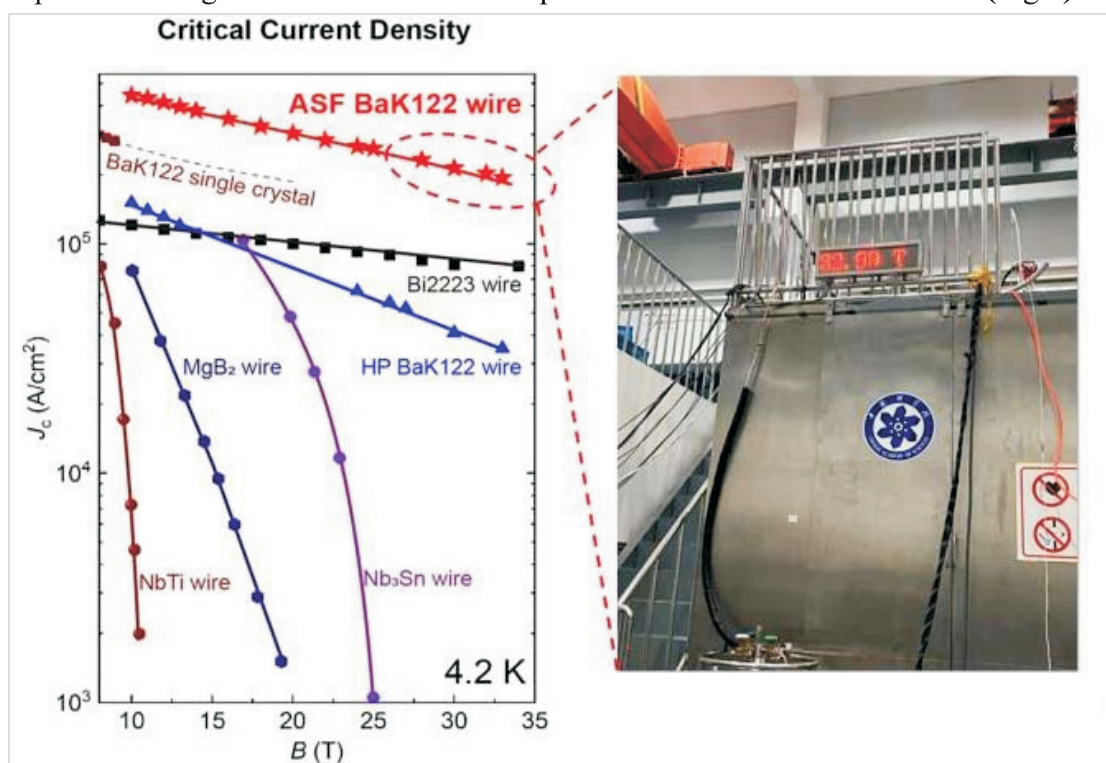


Fig.3. Electrical transport measurement under high magnetic fields of 25-33 T

### 4. Opening up a New Frontier in Asymmetric Electro-Enzymatic Catalysis

The development of technologies such as artificial enzymes and photoenzyme catalysis continues to push the boundaries of biosynthesis. Meanwhile, electrochemical synthesis, as an innovative tool in chemical synthesis, offers multiple advantages such as low cost, tunable electrode potential, and sustainability. However, how to utilize electrochemistry to drive enzyme catalysis and unlock novel non-natural catalytic modes remains a challenge. A team led by Huang Xiaoqiang at Nanjing University has integrated ferrocenemethanol-mediated anodic oxidation with ThDP-dependent enzyme catalysis, thereby unlocking a non-natural dynamic kinetic oxidative system powered by electroenzyme catalysis. Low-temperature electron spin resonance (ESR)

of SHMFF experiments were carried out to and characterized the key radical intermediates generated during the electroenzymatic process. Furthermore, the concentration of these radical intermediates was quantified via spin-quantification methods. The origin of the radicals in the catalytic system was further confirmed through temperature-dependent ESR and power-saturation ESR approaches. This study establishes a new paradigm of “electricity-driven enzyme catalysis” for asymmetric synthesis and provides a novel route for the asymmetric biosynthesis of phenylpropanoic acid-based pharmaceuticals. The results were published in *Nature* (Fig.4)

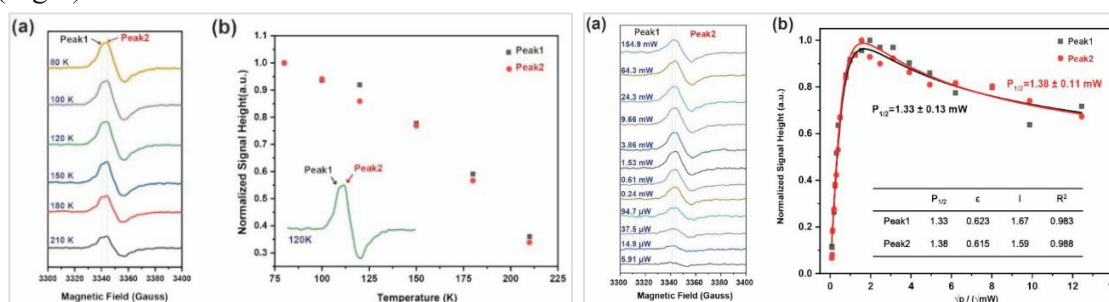


Fig.4. Comprehensive ESR experiments

## 5. Revealing the Novel Mechanism of Intrinsically Disordered Regions Remotely Driving Protein Functional Switching

Intrinsically Disordered Regions (IDRs) in proteins are regarded “useless tails” due to their lack of stable 3D structures. Leveraging the unique advantages of solution-state NMR technology in analyzing the relationship between protein dynamics and function, the research team led by Huang Chengdong at the University of Science and Technology of China (USTC) took the cancer-related chaperone protein Sgt2 as a model. For the first time, the team revealed that IDRs could achieve remote control of protein activity through conformational entropy regulation, breaking the traditional cognition that “regulation can only be achieved via direct contact or structural changes”. This discovery provides a brand-new perspective for the design of novel molecular switches. The results were published in *Nature Structural & Molecular Biology*. (Fig.5)

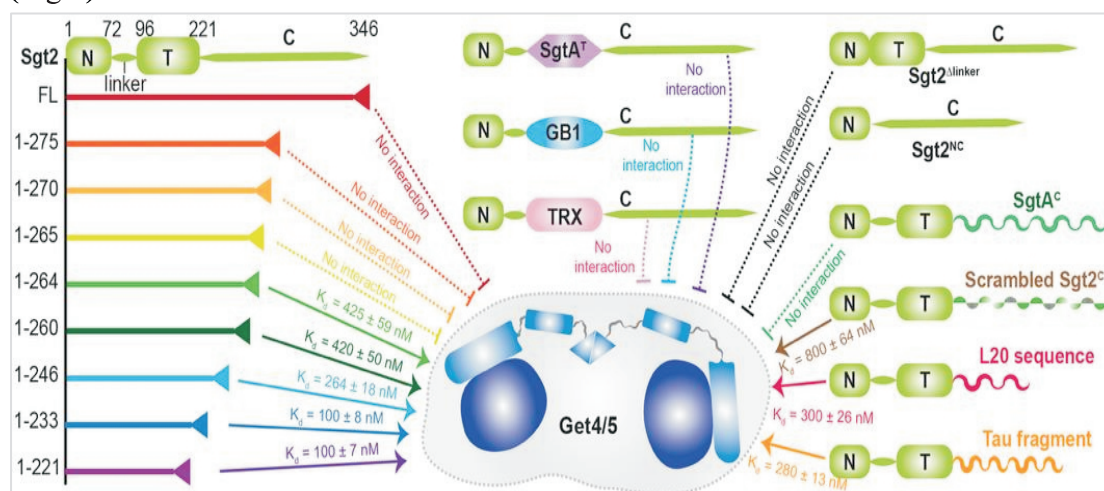


Fig.5. The auto-inhibitory effect of Sgt2 is determined by the specific sequence of its C-terminal intrinsically disordered region and is independent of the middle domain or other protein fragments

## Publications & Awards

Prof. Huang Xiaoqiang (Nanjing University) made a breakthrough in “optically activated artificial enzymes” research based on SHMFF. His work was awarded the 2025 “Xplorer Prize” and 2025 “Tengchong Outstanding Young Scientists Award, China”. The High-Field Magnet Technology Team has been awarded the 2025 “China Youth May Fourth Medal”.

Number of Publications and patents related to SHMFF in 2025

SCI/EI	Number of awards received at/above the provincial or ministerial level	Authorized patents	Pending patents	Software copyrights	Nature Index Journal publications
283	1	46	48	1	100

## Operation

In 2025, SHMFF served users from 79 universities and institutes, covering 344 projects. Planned running time is 52446 hrs, and actual running time is 54486 hrs.

	HW/WM	SM3+NMR	SM4+MRI
Planned time(hrs)	2100	8184	2480
Actual time(hrs)	2359	8186	2495

	Planned time (hrs)	Actual time(hrs)
SM1	2920	3202
SM2	6552	6816
PPMS	6600	6744
Cryostat	800	803
MPMS	7440	7776
ESR	1250	1376
Raman	900	984
FTIR	790	799
XRD	1120	1132
Extreme Low Temperature Transport System	2100	2174
Ultra-pressure Physical Measurement System	1070	1158
STM-MFM-AFM Combo	7140	7350
Condensed Nuclear Magnetic Resonance	1000	1134

## Scientific & technical personnel and talent training

CHMFL has a total of 211 employees including 56 professors, 64 associate professors, and 91 other administrative or technical staff. CHMFL also has 38 postdoctoral fellows and 348 graduate students.

Total number of facility staff	Classified by positions			Classified by professional titles			Students			In-house post-doctor
	Operation & maintenance staff	Researchers	Others	People with senior professional title	People with medium professional title	Others	graduated Ph.D	Graduates master	Post-graduate in progress	
211	120	83	8	120	80	11	31	38	348	38

## Cooperation and exchange

Domestic and international cooperation and exchanges were carried out successfully in 2025. Scholars and experts were invited to visit SHMFF and gave academic presentations. The numbers of forums in recent five years are listed below:

Year	2025	2024	2023	2022	2021	2020
No. of presentations	22	24	24	12	9	7

Professor Mladen Horvatić, head of the NMR Laboratory at Laboratoire National des Champs Magnétiques Intenses (LNCMI) in France, visited SHMFF in May. Sheng Zhigao, Pi Li and Zhang Xin, deputy directors of CHMFL also visited Laboratoire National des Champs Magnétiques Intenses of France in October. The two laboratories conducted in-depth exchanges in magnetic technology, scientific research management, and NMR through mutual visits, laying the foundation for future cooperation.



Fig. Mutual Visits between CHMFL and LNCMI

## Chronicle of events

- Apr. 30 “The High-Field Magnet Technology Youth Innovation Pioneer Team” was awarded the “China Youth May Fourth Medal”.
- May 6 The Project Launch and Implementation Plan Review Meeting for the National Key R&D Program project, “Research on Physical Properties and Regulation of Novel Low-Dimensional Electronic Materials under High Magnetic Fields”, was held.
- Jun. 19 The Project Technical Achievement Evaluation Meeting for “the Ultraviolet-Visible Spectroscopy and Microscopic

Imaging Test System in Steady-State High Magnetic Field Extreme Environments” was held.

- Sep. 1 The preliminary design and investment estimate for the “Steady High Magnetic Field Experimental Facility Instrument and Equipment Upgrading Project” were approved.
- Dec. 19-21 The 1<sup>st</sup> National Academic Conference of High Magnetic Fields was held in Wuhan.
- Dec. 27 The meeting of the SHMFF User Committee was held.

