

Discussion on Management and Open Mode of Chinese Scientific Research Laboratory Instruments and Equipment and Its Positive Promotion Effect

Xiang Zhao^{1,*}

¹State Key Laboratory of Advanced Technology for Materials Synthesis and Progressing, Wuhan University of Technology, Wuhan, Hubei 430070, China

*Corresponding author. Email: wut973@163.com

ABSTRACT

The rapid development of scientific research laboratories brings about challenges to the planning formulation and overall layout of public instrument and equipment platforms. Correspondingly, problems such as imperfect spatial layout and planning, ineffective integration of hardware resources, decentralized operation of equipment operation and maintenance, unreasonable management and use of professional and technical personnel and inadequate use of equipment platforms to promote academic exchanges and open sharing emerge. This article puts forward specific suggestions for the establishment mode of scientific research laboratories on the public instrument and equipment platform from the aspects of equipment centralized and decentralized management, the effective combination of professional and technical personnel platforms and directions, laboratory safety access and training, etc. It also discusses the positive role of the construction model in promoting laboratory academic exchanges, supporting equipment purchase and maintenance, improving scientific research teaching and personnel training, and giving full play to the advantages of professional and technical personnel.

Keywords: scientific research laboratory, instrument and equipment platform, equipment management, opening and sharing, positive promotion effect

I. INTRODUCTION

Due to the many different attributes, tasks and teaching and specialized equipment public service platforms of scientific research in scientific research laboratories, their equipment management and open operation have their own characteristics. Regardless of whether it is a laboratory at the national level or a laboratory built by a provincial ministry, although scientific research is the main orientation, it is the responsibility of scientific research facilities and instruments to be open to the public. In recent years, as the country continues to increase its support for scientific research, the scale of scientific research facilities and instruments has continued to grow, but the problem of low utilization and sharing of scientific research facilities and instruments has also gradually become more prominent. Therefore, the state issued the "State Council's Opinions on the Opening of Major National Scientific Research Infrastructures and Large-Scale Scientific Research Instruments to the Society"

Guofa [2014] No. 70 document (hereinafter referred to as "Opinions"), which requires that the opening of scientific research facilities and instruments to the society be accelerated to further improve the utilization efficiency of scientific and technological resources [1]. According to the spirit of the "Opinions" and the requirements of the supervision team of the Central Reform Office, the Ministry of Science and Technology and the Ministry of Finance organized and carried out an open and shared evaluation and assessment of scientific research facilities and instruments in central universities and research institutes in 2019. The assessment involved a total of 25 departments, 344 units, and a total of 42,000 pieces (sets) of scientific research instruments with an original value of more than 500,000 yuan. The average annual effective working hours of the participating scientific research instruments are 1440 hours, and the average external service hours are 240 hours [2]. Some of these units have problems such as low equipment utilization and inefficient sharing, which has resulted in the idleness and waste of national resources and are required to be rectified and reformed. To do a good job of opening and sharing of large-scale instruments and equipment in

CLC number: G647. Document identification code: A

scientific research laboratories, it's necessary to distinguish its own different equipment operation management characteristics and difficulties, find out the main problems and causes in opening and sharing, improve the open operation management system with the characteristics of scientific research laboratories, promote academic exchanges and cooperation in laboratories through opening and sharing, promote the cultivation of talents, the transformation of scientific and technological achievements, and the combination of production, teaching and research, improve the use efficiency of large-scale instruments and equipment and enhance the scientific research laboratory's scientific research radiation ability and service level.

II. DISCUSSION ON THE ESTABLISHMENT MODE OF THE PUBLIC INSTRUMENT AND EQUIPMENT PLATFORM OF SCIENTIFIC RESEARCH LABORATORY

A. The rapid development of scientific research laboratories' impact on the construction of public instrument and equipment platform

Scientific research laboratories are different from specialized test and analysis centers and public equipment platforms. Scientific research laboratories' main tasks are to engage in scientific research. Their funding channels for equipment purchases mainly come from research project funds, discipline construction funds and horizontal cooperation funds. The purpose of equipment purchase is closely related to the needs of scientific research work, so the main purpose of equipment is to meet its own academic research and talent training needs. The laboratory establishes the main research direction according to its own development goals and positioning, and the research group (or study group) established according to different research content is the basic unit. Compared with foreign mature laboratories, the construction and development cycle of Chinese scientific research laboratories is relatively short. From the early start-up of mechanisms, weak equipment, talent pooling, and lack of major original achievements, all aspects are gradually catching up, and the development momentum is strong. Especially with the rapid growth of the national economy and the increasing investment by the state in scientific research, the configuration of large-scale laboratory equipment in the laboratory is also changing with each passing day, and the advanced level of large-scale instruments and equipment in many laboratories even exceeds that of similar foreign laboratories. The rapid development has also brought many problems. For example, the space layout and planning are sometimes not perfect, the amount of advance is not enough, and the lack of space has become a prominent problem; there are repeated purchases and advance purchases of instruments and

equipment to a certain extent, the demonstration is insufficient when purchasing equipment, and the hardware resources can't be effectively integrated, resulting in waste of funds and low equipment utilization; the operation and maintenance of equipment are scattered, and the role of public instrument platforms is not prominent; the management and use of professional and technical personnel are unreasonable, and there are still many deficiencies in using the equipment platform to promote academic exchanges and opening and sharing.

B. The establishment model of laboratory public instrument and equipment platform and its relationship with the research group

The scientific research laboratory has its own goals and positioning. Under the goals and positioning, the laboratory is composed of research groups with different research contents as the basic unit. Usually, the laboratory will all have a public instrument and equipment platform, and its relationship with the research group is generally affected and restricted by several factors.

The first is the type of equipment. The equipment can be divided into special equipment and general equipment according to the category, and can also be divided into large equipment and small equipment according to the amount of money. The attributes of general equipment are suitable to be placed on the public equipment platform, and the special equipment is mostly placed in the research group for management because of the small professional scope. Because of the large quantity and frequent use of small-scale general equipment, it will also be placed more in the research group; large-scale general equipment placed on a public platform is more conducive to use in all directions.

The second is the source of funds for the purchase of equipment. At present, the equipment of Chinese scientific research laboratories is still mainly purchased. Compared with developed countries, China's independent research and development capabilities of scientific research equipment are still insufficient; 985 and 211 engineering universities' independent research and development equipment only accounts for about 2% of its total equipment. Most of the instruments still come from purchases, and nearly 3/4 of the instruments purchased by 211 universities are imported from abroad [3]. Public funds for Chinese scientific research laboratories include operating expenses allocated by the state, special funds for large-scale equipment, scientific research business fees, and construction funds allocated by local and supporting institutions. The equipment purchased with public funds generally focuses on general equipment that can be used in multiple directions, and is mostly placed in public spaces after purchase. The project funds applied by each research

group and the equipment purchased by the horizontal funds for the transformation of scientific and technological achievements are highly targeted, and more of them are placed in each research group. There is also crossover. For example, a large number of general equipment jointly approved by multiple research groups will be placed on a public platform, and public funds will also support the purchase of special equipment in some key research directions.

What's more, it is the position of professional and technical management personnel. Some professional and technical personnel are affiliated with the overall public instrument platform of the laboratory, and some are also introduced for a certain research direction. The professional and technical personnel working on the public instrument and equipment platform are more responsible for similar instruments and equipment in the laboratory, such as electron microscope equipment and nuclear magnetic equipment. Professional and technical personnel working in each research group are involved in the daily management of the research group, mainly responsible for the equipment in the research group, and sometimes the equipment under management is not necessarily of the same category.

C. Suggestions on the establishment model of the public instrument and equipment platform of scientific research laboratories

The characteristics of Chinese research laboratories are compatible with the country's economic development, and its growth rate is very fast. Faced with the constantly updated scientific system, changing frontier research and hot spots and increasing social needs, the research direction, content, and experimental layout of the laboratory have changed accordingly, and have experienced a development process from small to large, and from weak to strong. The construction of laboratory public instrument and equipment platform should be adapted to local conditions and adapt to the overall development status, with a focus on scientific and effective integration and allocation of experimental research hardware resources, such as a multi-participation co-construction management model [4]; it's necessary to improve the utilization rate and sharing rate of instruments and equipment, work hard to actively develop the functions of instruments and equipment, promote breakthroughs in extreme research methods, and achieve an important supporting role for scientific research, academic exchanges and interdisciplinary research, in order to provide sufficient material foundation for breaking through scientific frontiers and realizing technological change.

It's important to handle the relationship between centralized equipment and decentralized management. For some laboratories with relatively good conditions, a common space for large instruments and equipment

should be planned, and general large-scale equipment should be placed centrally. However, the contradiction of insufficient laboratory space in the rapid development of most laboratories is very prominent. Generally, it will be gradually resolved with the continuous expansion of research direction and talents. It is difficult to have a large space for the centralized placement of equipment. Often the priority is given to solving the problem of the research direction's occupancy, and the equipment is also scattered in each research group. Taking Wuhan University of Technology as an example, the two phenomena of centralized placement and scattered placement of equipment coexist, and the school has established a special materials research and testing center. The center is the school's public testing platform and shares some analytical testing equipment with the laboratory. The center has a batch of high-end precision scientific instruments such as high-resolution transmission electron microscope, X-ray photoelectron spectrometer, field emission scanning electron microscope, infrared/Raman spectrometer, gas-phase mass spectrometer, and liquid-phase mass spectrometer. The total value of the equipment is more than 80 million yuan, providing testing and analysis services for the laboratory. At the same time, the laboratory also has a considerable number of general and special instruments and equipment. Some large-scale instruments and equipment with public attributes are placed centrally, and most of the other equipment is placed in each research group. Regardless of where the equipment is placed, all equipment is incorporated into the public instrument and equipment platform, and equipment information is published online and realized to be open to the outside world.

It's necessary to achieve effective management of professional and technical personnel. For professional and technical personnel, the management mode combining the platform and the research group can be realized. For example, Namur University in Belgium has established various equipment platforms according to equipment categories, such as X-ray platforms. Some platforms have a centralized public space, and many platform equipment is also scattered in various departments and research groups. The laboratory equipment is divided into different platforms by category; the platform has technical personnel and management personnel, who are responsible for training, management and appointments; there are also small mechanical workshops and electronic engineers responsible for equipment maintenance; each department and research group have technical researchers in their departments who are graduated with a doctorate, mainly managing the equipment in the group and also cooperating with the platform for management. Some platform technicians such as analytical chemistry platform are graduates of

experimental technology, non-required doctors, and their working status is half in the group and half on the platform. The public platform and the research group jointly manage and use professional and technical personnel, which can better solve the contradiction of scattered equipment placement, different equipment attributes and different needs. A good management system and division of labor can effectively mobilize the enthusiasm of professional and technical personnel. For example, the opening of equipment at Johns Hopkins University in the United States has clear charging standards and reward and punishment mechanisms. Part of the test fee received is used for instrument maintenance and repair, and the other part will be distributed to the instrument exclusive staff according to the benefits of large instruments [5]. Professional and technical personnel can ensure that the working status of the equipment under management is constantly checked, and they can make overall planning and arrangement according to the equipment condition on the platform. If there is a problem with the equipment, it can be repaired in time, which can save equipment unattended time and ensure the normal work of the laboratory.

The sharing of scientific research laboratories is generally based on the principles of usage charges, cost sharing and non-profit [6]. The scientific and safe experimental management model, and the relationship between equipment use and maintenance, access and safety are the key points of the construction of public instrument and equipment platform. The laboratory public instrument and equipment platform must have a scientific and reasonable management model for personnel training, equipment appointments, daily maintenance and laboratory safety. It's necessary to establish a strict access system and training system, and personnel without training and authorization are prohibited from using the equipment. For example, all large instruments and equipment shared by the University of California, Los Angeles, Material Chemistry Laboratory are managed by professionals, but these staff are not responsible for testing. Users need to take part in training and examinations first, and obtain the entrance password of the instrument room and their own test account after passing the examination before they can use large instruments [7]. This is responsible for the equipment and for the safety of the experiment. Experimental safety is a hierarchical management model from school to laboratory to research group. Foreign universities such as Cornell University in the United States have special Environmental Health and Safety (EHS) committees that provide professional technical support and guidance for laboratories, including training services, laboratories and equipment layout services, waste management services, etc. [8]. The laboratory bears the main responsibility of experimental safety, and it must

be scientific and reasonable in all aspects. For example, it's needed to establish perfect platform information and perfect laboratory safety management system, including detailed introduction of each equipment, operating procedures, precautions, management personnel information, and classification management of chemical drugs, flammable and combustible, poisonous, toxic, and corrosive drugs, etc. At the same time, the platform should bear strict inspection responsibilities, conduct monthly or quarterly inspections, and rectify and reform laboratories that do not comply with safety regulations to ensure laboratory safety.

III. THE POSITIVE PROMOTION EFFECT OF PUBLIC INSTRUMENT AND EQUIPMENT PLATFORM'S CONSTRUCTION ON ALL ASPECTS OF SCIENTIFIC RESEARCH LABORATORIES

A. Mutual promotion between public instrument and equipment platforms and academic exchanges

The public instrument and equipment platform is not a physical space for centralized placement of equipment, but a platform for centralized management and full sharing. The purpose of centralized management is to promote full internal and external sharing. Generally, much equipment in Chinese scientific research laboratories are scattered in each research group. The management of equipment in the research group is mostly jointly managed by teachers and students; if the equipment is to be shared outside the group, it will require extra effort. However, the construction of a public instrument and equipment platform can reduce the burden of equipment management and maintenance of the research group, and liberate the teachers and students of the research group to devote more energy to scientific research. At the same time, it can also fulfill the national requirements for laboratories to serve the society and support technological innovation. Nowadays, the development of science and technology pays more and more attention to the fusion between disciplines. In addition to academic exchanges and integration, the country has also put forward higher requirements for industry-university-research cooperation. To realize the transformation of scientific and technological innovation, the country must transform the main body and method of scientific and technological development and effectively integrate scientific and technological forces. The use of public instrument and equipment platforms can break the physical barriers that hinder opening and break the ideological barriers. By doing so, teachers and students in different groups can easily use the equipment, and it can also promote academic exchanges and cooperation in different fields, effectively avoid the repeated purchase of large scientific instruments in adjacent areas, and improve the level of resource sharing services [9], including serving

the society and enterprises. The use of public instrument and equipment platforms can also promote direct communication between equipment management personnel and professional technicians, which is beneficial to improving the ability of using equipment, developing equipment performance, promoting advanced technologies and methods, and the test results and standards can also be improved. For example, the laboratory can regularly hold academic exchanges related to large-scale instruments and equipment. Relevant academic reports can be made on what the laboratory's large-scale equipment and special equipment have done, how to use, how much others have used, and how effective the sharing situation is and so on. The purpose is to promote communication and cooperation on the use of equipment, generate points of interest through cooperation, find an integrating point, promote the use efficiency of large instruments and equipment, encourage the possibility of cooperation in different research fields through equipment sharing, and jointly publish relevant results.

B. Favorable aspects for the purchase and maintenance of equipment

As mentioned above, due to the development characteristics and space limitations of Chinese scientific research laboratories, the placement of large laboratory instruments and equipment is likely to be scattered. Although the physical space is not always centralized, the establishment of a public instrument and equipment platform for centralized management can provide many favorable supports for the purchase and maintenance of laboratory instruments and equipment.

From the equipment purchase level, the establishment of a public instrument and equipment platform for centralized management can reasonably arrange the use time of similar equipment to maximize efficiency and minimize repeated purchases at the greatest extent. Taking the State Key Laboratory of New Technology for Material Compounding as an example, the commonly used scanning electron microscope (SEM) for material characterization is almost a necessary equipment for various research directions. Scanning electron microscopes of various sizes range from hundreds of thousands of yuan to several million yuan, and their functions are also numerous. For each direction, the usage rate of scanning electron microscopes is very high. People may use these equipment well or poorly and fully or not. Realizing centralized management of instrument and equipment platforms can reasonably arrange the use time of each scanning electron microscope on the whole, further improve the use of the machine, and achieve the most demand with the least equipment, thus avoiding the repeated purchase and waste of funding caused by buying a similar equipment in every direction.

The establishment of an instrument and equipment platform is conducive to overall reduction of equipment maintenance costs. Equipment maintenance is generally divided into two major parts. The first is the maintenance agreement signed with the equipment company. For some particularly expensive instruments and equipment, because the equipment itself is very precise and sophisticated, it is difficult for the laboratory to achieve its own maintenance. Considering the time cost of maintenance and other factors, it is more advantageous to sign a maintenance agreement every year than to repair if something goes wrong. There are many large companies specializing in instrument manufacturing in the world, such as Thermo Fisher Scientific, JEOL, Carl Zeiss AG, etc. These companies sell a lot of equipment in China, and a school and a research laboratory will have multiple equipment from the same company. These companies have been operating in China for many years and are familiar with the Chinese market and needs. In the equipment purchase and maintenance, the same equipment will have different prices in different places, so it is very important to reduce costs through negotiation. Especially, this measure can obtain a favorable and reasonable price. Most often these companies will sell equipment at a very cheap price, but later maintenance will be expensive. If the purchase and maintenance of equipment are scattered, the company will also give different prices. The smaller the individual, the smaller the bargaining chip. If the entire platform or the entire school comes to negotiate with these companies, it can have a higher bargaining power to get a relatively favorable price. The other big part of equipment maintenance is daily maintenance and upgrading, which requires training of professional and technical personnel. It's also needed to track and check the operation status of all equipment at the entire platform level to reduce the incidence of failures, handle equipment problems in a timely manner and shorten maintenance waiting time. It can also propose more targeted and rationalized plans for equipment upgrades. All of these have a great advantage over individualized and decentralized management.

C. Positive promotion effect on scientific research teaching and personnel training

The state calls on scientific research laboratories to build a world-class public experimental research platform, strengthen the laboratory's public experimental research platform capacity building and management level improvement, respond to the general trend of deepening basic research and applied basic research and interdisciplinary research, promote the laboratory to focus on the research direction to scientifically and reasonably carry out the integration and allocation of the original experimental research hardware resources, and actively explore the functions

of instrument facilities and promote breakthroughs in extreme research methods, so as to provide sufficient material foundation guarantee for breaking the scientific frontier and realizing technological change.

Taking the State Key Laboratory of New Technology for Material Compounding as an example, the laboratory acquired the funding for scientific research instruments approved during the evaluation period and the school's "Double First-Class initiative" construction funding, and purchased a Double Cs-correctors TEM (model: FEI Titan Themis), ordinary TEM (model: FEI Talos F200S), focused ion/electron double beam scanning electron microscope system and other related equipment. The laboratory established a nano-microstructure research center, hired 5 full-time researchers in the direction of electron microscopy, and 4 senior laboratory technicians worked as technical support staff. The laboratory is built with the goal of becoming a first-class electron microscope center in China and foreign countries, drawing on good experience and models in China and foreign countries, forming an electron microscope research and service center with reasonable personnel structure, high-level research support, testing services, talent training and independent innovation. The laboratory supports the key materials research of the laboratory's characteristic research direction from the perspective of mechanism and nano-microstructure research, and at the same time provides technical services to other departments and society of the school. The construction of the platform provides important support for the research of structural and functional integrated ceramic materials, key materials for proton exchange membrane fuel cells, high-performance thermoelectric materials, high-performance vanadium nanowire lithium-ion battery materials, third-generation semiconductor substrates, epitaxial membrane materials and high-efficiency photocatalytic materials and so on, effectively realizing the dynamic correlation of the structure (interface, surface, composition) and performance (thermology, mechanics, electricity and optics) of the substance on the atomic scale, thus achieving dynamic characterization, processing, measurement and manufacturing of materials at multi-scales such as micrometers, nanometers and picometers. The center trains both master and doctoral students and is oriented towards undergraduate education. After the original professional and technical personnel came to the center, they have expanded from simple testing services to research, development and cooperation and their level of professional technology has been greatly improved.

D. It's conducive to giving full play to the advantages of professional and technical personnel

Establishing centralized management of public instrument and equipment platforms can give full play to the advantages of professional technicians, better

maintain equipment, reduce equipment damage, extend equipment life and reduce maintenance costs. Professional and technical personnel team is a necessary scientific research support team in the laboratory, which plays an important role in equipment management, both in China and foreign countries. For example, the French Ecole des Ponts ParisTech's (ENPC) Rock and Soil Mechanics Laboratory (CERMES) has a strong technical support team, which is composed of various outstanding talents. The team members have their own expertise and perform their duties. Among them, the chief engineer is responsible for overall planning and coordination; the senior technical staff has a clear division of labor, and is responsible for electrical appliances, circuit modification, instrument equipment design, processing and new functions to assist in research and development, and installation, docking and debugging of instruments with new digital acquisition control functions; the technical staff is responsible for the processing, installation and testing of equipment accessories [10]. The daily maintenance of instruments and equipment involves various technical requirements. Taking advantage of the centralized advantages of the team and platform is more efficient than simply finding someone responsible for the research team and can achieve lower maintenance costs. Professional and technical personnel working on the public instrument equipment platform can manage more similar equipment, effectively improve the equipment use time and utilization rate, and give full play to their strengths. At the same time, working on a public instrument and equipment platform can promote the communication between professional and technical personnel and scientific research personnel in different fields, and also help to formulate a different evaluation and promotion system from scientific research positions and mobilize the enthusiasm of professional technical personnel.

IV. CONCLUSION

Scientific research laboratories have their own characteristics in the management and opening and sharing of large-scale instruments and equipment. Its management and opening should conform to the goals and positioning of the laboratory, and serve for carrying out basic research and applied basic research, gathering and cultivating excellent scientific and technological talents, carrying out high-level academic exchanges, and building an important scientific and technological innovation base with advanced scientific research equipment. It's necessary to take an objective look at the problems that exist in development; management and opening up should be acted according to local conditions with both practical flexibility and rigorous scientificity; it's needed to further enhance shared concepts, innovate management models, and improve security mechanisms, solve problems in development,

continuously improve the openness and service level of large-scale instruments and equipment, and promote academic exchanges, scientific research cooperation and personnel training to serve social needs, national strategies and industrial transformation.

References

- [1] The State Council: Opinions on opening of major National Scientific Research Infrastructure and Large Scientific Research Instruments to the public.[S/OL] [2015-01-26] http://www.gov.cn/zhengce/content/2015-01/26/content_9431.htm. (in Chinese)
- [2] The General Office of the Ministry of Science and Technology and the General Office of the Ministry of Finance: The Notice on the open sharing of evaluation and Assessment Results of major scientific Research infrastructure and large scientific research instruments in institutions of higher learning and research institutes at the central level.[2019-11-19]. http://www.most.gov.cn/mostinfo/xinxifenlei/fgzc/gfxwj/gfxwj2019/201911/t20191120_150067.htm. (in Chinese)
- [3] Yang Wei, Liu Xinrui, Zhang Heda, Wei Tingting. Analysis of Research Instruments Sharing Problem in Key Universities [J], *Science and Technology Management Research*, 2019,39(04):72-78. (in Chinese)
- [4] ZHAO Ming, SONG Xiuqing, ZHU Yongwei, GUO Meifang, WANG andong, YANG Jinfu. Research on multi-mode operating mechanism for opening and sharing of university large-scale instruments and equipment [J], *Experimental Technology and Management*, 2019,36(01):12-15. (in Chinese)
- [5] WANG Fang, TIAN Hongwei, DUAN Tianlin, WANG Degui. Characteristics of Laboratories and Large Scientific Equipment's Management in Johns Hopkins Unvers [J], *Research and Exploration in Laboratory*,2018,37(10):258-261. (in Chinese)
- [6] Chen Hongxia, Liu Peng. Research on opening and sharing management system for large-scale instruments and equipment in colleges and universities [J], *Experimental Technology and Management*,2017,34(07):252-254. (in Chinese)
- [7] Wu Wei, Zhang Xiaoyun. Enlightenment of material chemistry laboratory management in University of California at Los Angeles [J], *Experimental Technology and Management*,2015,32(09):212-214. (in Chinese)
- [8] FAN Ziluan, ZHANG Hua, MENG Lin,WANG Zhenyu,YANG Xin ,WANG Lu. Research on Laboratory Management Model of American Research Universities — Take Cornell University as an example [J], *The Theory and Practice of Innovation and Entrepreneurship*,2019,2(14):130-131. (in Chinese)
- [9] XIE Yan-lin, LIN Qi-wen, LIN Wen. Management for open-sharing of large scientific equipment in university [J], *Laboratory Science*, 2017,20(03):175-178. (in Chinese)
- [10] SUN Wenjing, CUI Yujun. Laboratory Management and Operation Mode in ENPC and Its Inspiration [J], *Research and Exploration in Laboratory*, 2017,36(02):145-148. (in Chinese)