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ABSTRACT

This is the fifth chapter of a six chapter report which discusses Chinese research and education in solid state physics, and their relations to technology and the other sciences. This specific chapter concerns the communication of information in the scientific community and the transfer of information to students and practical users (manufacturers). The number of different modes of communication (formal/informal, written/oral) and the number of channels are essentially uninfluenced by international boundaries. However, the roles and characteristics of these channels are quite different in China because of differing goals, conditions, and historical backgrounds. A brief narrative appraisal is provided on the following channels: exchange of personnel, seminars, conferences, research journals, reports, travel and publication outside China, and libraries. The transfer of technology from research to production mainly involves personal contacts rather than reports and publications. The student- faculty groups at factories, student instruction at universities, and university staff product developments bear directly on the transfer of research to factory production. The dependence on person to person contacts for technology transfer works well given the relatively small scientific and technical establishments, and the small amount of information transfer between specialties. (DAG)

Peoples Republic of China

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CSCPRC REPORT NO. 1

Solid State Physics in the People's Republic of China

A Trip Report of the American Solid State Physics Delegation

Edited by ANNE FITZGERALD and CHARLES P. SLICHTER

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COMMUNICATING THE FRUITS OF RESEARCH

A. INTRODUCTION

As was explained at the outset, our goal in China was to observe and try to understand Chinese research and education in solid state physics, and their relations to technology and the other sciences. In all of these activities communication of information is central -- the progress of research depends upon enlightened awareness of the state of knowledge throughout the world and on the critical reactions of scientists to each other's work. Education not only involves transfer of information, but also the training of students to be aware of and to use the available channels for obtaining information; technological innovations involve the passage of information from the world of science to that of the inventor, and from the latter to that of the manufacturer.

In our brief solid-state-oriented visit it was, of course, not possible to glimpse more than a fragment of the total pattern of scientific and technical communication in China. However, we did observe some interesting characteristics of Chinese communication channels, as well as differences (sometimes favorable and sometimes unfavorable) between these channels and those typically available in the United States and Europe. The account of our observations and reactions given in this chapter is divided into two major sections: communication and assimilation in the scientific community, and "technology transfer" (the coupling of scientific advances with the practical needs of the economy). We shall begin with the first of these, discussing in turn the communication among research workers within China and contact with developments in other parts of the world.

B. COMMUNICATION IN THE SCIENTIFIC COMMUNITY

The characteristics and relative roles of the various channels for oral and written communication of scientific information have been extensively analyzed in the West, especially in the physics community. Studies have been made both by scientists who use the channels being studied and by specialists in information science, who bring a somewhat different point of view to the field. We spoke with members of both these communities in China (i.e., with physicists and with librarians), but did not come into contact with any person who had done research on the communication process, nor did we learn of any such studies.

A number of different modes of communication, oral and written, formal and informal, are of comparable importance in supplying the information that American and European scientists need in their work, and these are connected together in a network of series and parallel relationships. Many of the channels are almost uninfluenced by international boundaries. As we shall now see, the roles and characteristics of many of these channels are quite different in China because of differing goals, conditions, and historical background.

COMMUNICATION WITHIN CHINA

Following are the various oral and written channels of communication about which we inquired.

EXCHANGE OF PERSONNEL We were told several times that transfers of people between institutions, and visits of several months or a year, are common and important mechanisms for diffusing awareness and know-how in the scientific community. For example, some people from Futan University are visiting the Institute of Metallurgy in Shanghai, in preparation for experiments using the Futan Van de Graaf accelerator for the study of solid-state problems; also, some Institute of

Metallurgy people will come to Futan. However, we did not have occasion to talk with any scientific workers currently taking part in such exchanges.

SEMINARS Both in universities and in research institutes we were told that intra-specialty seminars are frequent -- they are held every week or two. Often, such seminars are attended by workers in the same specialty in neighboring institutions; for example, seminars in such fields as relativity and quantum field theory often bring together people from various Peking institutions, such as the Institute of Physics, the Institute of High-Energy Physics, Peking University, and Peking Observatory. On the other hand, we did not hear much about seminars bringing together workers in the different physics specialties. Most of the meeting rooms that we saw, as well as the blackboard, paper-pad, and projection facilities in them, did not seem to have been planned for use with large audiences.

CONFERENCES We were told there has been no general national physics meeting (comparable to the American Physical Society meeting in the United States) in China since the Cultural Revolution. However, there seem to be a fair number of national conferences devoted to very specialized topics, to which any large institution doing work in those specialties is likely to send one or more representatives. We did not, however, hear of such meetings inclusive enough to be attended by a majority of the participants in a research project. A typical subject might be "Surface Passivation"; typical attendance might be 150 people.

RESEARCH JOURNALS As has been noted elsewhere in this report, the efforts of Chinese physicists, and of solid-state physicists in particular, have in recent years been strongly channeled toward the support of specific areas of technology. It is not surprising, therefore, that the proportion of their work which eventuates in scientific journal publication is considerably smaller than it is for the basic-research-oriented physicist population of some of the Western countries; in this respect, Chinese physicists are more like Western engineers. There seem to be only two Chinese journals devoted to physics to the exclusion of other sciences: *Wuli* (Physics), and *Wuli*

Xuebao (Acta Physica Sinica, which was formerly translated by the American Institute of Physics [AIP] under the title "Chinese Journal of Physics.")* The latter is the most important journal for publication of new research, the former containing a sizable proportion of non-research articles (such as quasi-popular and political articles). Publication of both journals is under the auspices of the Chinese Institute of Physics.

Besides the two physics journals just mentioned, there exist a number of journals that span a number of scientific fields and that publish physics papers as well as others. The best known of these, at least in the West, is *Scientia Sinica,* which is published in China in an English version as well as in Chinese. Mention was made in one of the discussions at the Institute of Physics of a letter journal serving all the sciences, but we have not learned more about it. Finally, many of the nation's universities and institutes publish their own journals, some covering all natural sciences, some dealing only with physical sciences and engineering. The library at the Institute of Physics had about a dozen such journals on its shelves.

Most of the physicists we queried on the subject of publication indicated that *Wuli Xuebao* was the most favored journal for publication of significant new research results. This impression is roughly confirmed by a study of references in samples of papers in *Wuli Xuebao*: 5 of 14 references to Chinese work published since the start of 1970 were to papers in *Wuli Xuebao*. Unfortunately, the numbers are small, and one must allow for the well-known tendency of articles in a given journal to cite the same journal. About all we can conclude is that *Wuli Xuebao* probably publishes a sizable fraction of the new physics research results that are formally published in China. But this fraction is rather small, only a couple of score articles per year, in all areas of physics. One is tempted to infer that it is limited not only by the fact that the overall scale of research work is as yet rather small, but also by the fact that formal publication is a much less important channel for communicating the results of physicists' work in China than it is in the United States and Europe.

Despite these differences in communication patterns, *Wuli Xuebao* is, in many ways, similar to the physics journals of the rest of the world.

*The AIP was unable to continue this translation, as of January 1976, in the absence of a subsidy.

It has an editor-in-chief (J. S. Wang of Peking University) and an editorial board of about 50 physicists, a fraction of whom constitute a steering committee for actual administration of the journal. The other editors help with the processing of manuscripts by performing such tasks as collecting referees' opinions. Refereeing, authors' revisions, and ultimate acceptance or rejection, all seem to take place in very much the same way as they do in Western journals. As with the latter, a sizable majority of the papers submitted -- perhaps three fourths or so -- are ultimately accepted, at least in solid-state physics. Before the Cultural Revolution, *Wuli Xuebao* paid authors of articles. It does not do so now. It publishes brief communications (letters) as well as full papers; it also publishes occasional review articles. (There seems to be no journal of Chinese physics devoted purely to review articles.)

As for the economics of publication, the philosophy of *Wuli Xuebao* (and presumably of Chinese journals in general) seems to be to subsidize pre-run expenses and to market the journal at essentially run-off cost. This makes it easily available not only to groups and institutions with a peripheral interest in physics, but also to individuals; if the circulation can be correctly gauged from the figure of 15,000 copies that we were given as the size of a printing, this policy is very successful. Time delays (from submission of an article to publication) are comparable with those in many Western non-physics journals, being often more than a year, but are rather longer than those in many Western physics journals.

REPORTS A large part of the work in solid-state physics now being done is recorded only in reports, whose distribution outside the initiating institution is limited to those groups known to be interested in the subject of the reports. Identification of such groups or individuals seems to occur mainly via the "grapevine," including especially the assumption of responsibility by administrators to ensure that adequate liaison is maintained between potentially related activities. There seem to be no central master lists of reports, such as those available in the United States through NTIS, STAR, and so on, nor is there any automatic distribution of reports to libraries of large institutions. However, we were told that "major" reports are mentioned in the title listings of current literature for specific subdisciplines (see the discussion of secondary services below), and that these sometimes prove quite useful.

CONTACT WITH WORK OUTSIDE CHINA

TRAVEL At present, there seems to be essentially no attendance by Chinese physicists at international meetings. As for extended visits for study or research, we were told that there are a few Chinese physicists currently on assignments in Europe. The only other scientific travel of which we are aware is that of delegations, like the one in solid-state physics that visited the United States in the spring of 1975. These, of course, do not provide intimate working-level communication, as sabbaticals and more focused research visits do, although they are very valuable in providing perspective and in paving the way for the latter.

PUBLICATION ABROAD Chinese physicists do not seem to publish any of their work in foreign journals, even in the form of preliminary announcements. Thus, they miss out on such benefits as correspondence and reprint exchange, to which such publication might lead.

CENTRAL ASSISTANCE TO THE DISTRIBUTION OF FOREIGN PUBLICATIONS A large number of foreign journals -- no doubt the great majority of important ones in physics -- are centrally reprinted in China for low-cost circulation. Libraries in research institutes and universities have several possible channels for obtaining foreign journals: they can subscribe to the reprinted version; they can obtain the original publisher's version by subscriptions centrally processed in Peking; or they can negotiate directly with the foreign publishers. Presumably each library will adapt its use of these channels to the needs of the community it serves, striking the requisite balance in speed, convenience, and economy.

We did not learn of any foreign journal being regularly translated into Chinese for circulation in China, in the manner in which the AIP serves Western readers by translating leading Soviet journals and, formerly, *Wuli Xuebao*. However, a few books of especially wide use have been translated from English or Russian into Chinese.

SECONDARY SERVICES As far as abstracting and indexing services are concerned, Chinese physicists seem to rely primarily on the material gathered by services in the various Western countries and in the Soviet Union. We were told, however, that they reprocess much of this material centrally, translating it into Chinese and arranging it in title listings for specific subfields of physics, including in these listings some Chinese-generated material not in the foreign sources. In our visits to libraries, we found that although such journals as *Chemical Abstracts, Physics Abstracts,* and *Referativnyi Zhurnal* are available in all major institutions, *Science Citation Index,* which many U.S. scientists now find to be the most useful secondary service of all, is almost never available. Foreign title listings, designed to fulfill the current-awareness function, are also practically never available. Perhaps the Chinese feel that their reprocessed version fulfills this function, although it certainly loses the important virtue of timeliness.

LIBRARIES: RECEIPT OF FOREIGN MATERIAL We visited libraries or spoke to librarians in many of the institutions that we visited. They always told us that their libraries were generously funded, and our inspections of their holdings confirmed this. The coverage of foreign books and journals in physics was always impressively inclusive; while no library in any country ever has all the materials that could be considered useful, the coverage of important physics books and journals seemed usually to be as complete as at major institutions in the United States. A few journals, such as *Physical Review Letters,* are received by air mail, hence quite promptly. Many other journals are received directly from the foreign publishers, even though a slightly delayed version could be obtained less expensively through the Chinese reprinting service. (In one case we were told that the journals obtained by direct subscription amounted to about half the total; subscriptions for most of these were handled through a national center.) All libraries in the country are in a mutual-help network, and interlibrary loans are apparently fairly common. Institutions, such as Futan University, that publish journals of their own are apt to have exchange agreements with similar institutions in foreign countries, so they may obtain the journals of the latter without transfer of money.

LIBRARIES: ORGANIZATION AND ADMINISTRATION Most large Chinese universities, like their U.S. counterparts, have separate departmental libraries for physics, for chemistry, and for various other disciplines. Materials used by research workers are housed in these libraries, where they are usually convenient to the place of work; material for large-scale routine use by students is, however, often kept in the central library. Research institutes are more likely to have a single library, as is appropriate considering their more specialized areas of concern and the more compact housing of their staffs. It sometimes happens that even a university has only a central library; as in other countries, this no doubt significantly retards use by research workers. In one such institution we found a very awkward distribution of research-related materials, in that current periodicals, bound periodicals, books, and abstract journals in the same field were stored in a multitude of widely separated locations.

The libraries with which we made contact seemed to be well staffed. The staff members in charge of physics collections have varied backgrounds, most of them with some scientific or technical training, and some, though perhaps a minority, with formal training in librarianship. Decisions on acquisitions and other library policies usually seemed to be reached collectively through discussions involving research and teaching staff and students. This is undoubtedly a manifestation of the greater attention to library users fostered by the Cultural Revolution.

There is a Chinese numerical indexing system for books, analogous to the Dewey and UDC (universal decimal classification) systems, but different from these.

LIBRARIES: USE OF THE SCIENTIFIC LITERATURE Language is a major barrier to use of the foreign literature. True, all Chinese physics students study a foreign language (usually English, but often Japanese, German, Russian, or other), and they are sometimes given explicit instruction and practice in the use of the foreign scientific literature. Most of the libraries with which we made contact did not supply any translation service for their customers, although we were told that the Institute of Physics does supply assistance in Russian and French.

Photoreproduction of journal articles is not yet widely available, although it can be had at some libraries; here it is particularly useful for students and staff who engage in extended work projects at factories and in similar activities. Where full-page reproduction is not available, microfilm copying is sometimes extensively used.

Although some staff members at the universities and research institutes seem to keep fairly well abreast of current developments in the foreign literature, we encountered several indications that the great majority of Chinese physicists do not use this literature as promptly or as effectively as might be expected from its excellent availability in their libraries. In one library many of the most important books and journals had not been checked out for a number of years. In some cases Chinese physicists had not yet become aware of certain developments, published long enough ago to have been received by their libraries, that tied in closely with their own special interests. In other cases, items in the foreign literature were apparently receiving very serious consideration from Chinese physicists, in ignorance of the fact that they had subsequently been discredited. We cannot estimate the relative importance of various possible causes for this inadequate use of the literature, such as language difficulties, ideological antipathy to archival knowledge, or overstrong spirit of national self-reliance, or the mere tendency, often deplorably prevalent in the United States, to disparage work by people or groups with which one has no personal contact.

Actually, the information-gathering habits of Chinese physicists may well be very similar to those that Western physicists would have if faced with the same problems. For example, one group, whom we queried about their sources of awareness of papers in the literature, replied that references in other papers were the principal source, with journal browsing and word of mouth next. This is very similar to the known pattern for U.S. and British physicists, as described, for example, in the recent NAS study, *Physics in Perspective*. Abstract journals and title listings, which are somewhat less used by British physicists than the other sources mentioned, were used even less by these Chinese physicists.

Chinese universities often exert themselves to make their libraries useful to the general public and in particular to factory workers. The latter are encouraged to visit the libraries; materials for which duplicates are available can be checked out to them, and other materials may be copied. At Futan University, we were told that the library had begun providing to factory people materials they have not requested but that the university thinks may be of value to them.

C. TECHNOLOGY TRANSFER

A major topic of interest to us was the transfer of technology from the research laboratory to production. We saw a number of examples of successful transfer. We probably were able to get a fairly complete picture of the methods used, but, of course, we have difficulty judging whether or not the system works as smoothly, efficiently, and effectively in practice as in theory. We could not judge, either, which institutions that we visited were best solving the problems of transferring technology.

Technology transfer within China occurs through a number of channels which should, in principle, be relatively effective. Mainly it involves personal contacts rather than reports or publications. The Chinese have adopted a number of measures to stimulate personal exchanges, such as student-faculty groups at factories. There is obvious difficulty in adopting Western technology to China's needs because of China's present relative isolation. The main centers of advanced technical knowledge are the research institutes (many under the Chinese Academy of Sciences) and the universities. Since the universities reopened after the Cultural Revolution, most work in solid state physics has been applied, with much of it directly oriented toward factory production. The universities have concentrated on advanced technology, generally not available or in short supply in the factories. The main areas are semiconductors, electronics, lasers, magnetism (ferrites, magnetic bubbles), and superconductivity.

UNIVERSITY TO FACTORY

As discussed in the chapter on education, most students spend extensive periods of time in factories, where they learn production methods from the workers. Faculty members accompany the students so that they can continue their course work. In this way, both students and faculty come in direct contact with practical problems. In turn, student-faculty groups may help solve problems that arise from needs of society. This usually occurs with more advanced students doing thesis or "graduate practice" work in the last 6 months of their studies.

Examples at Tsinghua University are the design of a machine for making gloves, now in production at a factory, and a process-control computer that is in the final interfacing stage. The latter, if finally judged to meet the standard, will go into production either at the university or in a factory. Other examples are given in Chapter Four, Section C.

The faculty, we were told, often gives short courses designed for a particular group of workers; this occurs, for example, when the university has developed a product of potential interest to the workers. Such a course was given at Futan University on a new light source for photographic printing designed and developed at the University. This project is in the process of being transferred to a factory for manufacture. On a mcre practical level, many correspondence courses are given in various fields of technology. An example, also from Futan University, is the teaching about and implementing of electrical machinery for commune mechanization. Faculty learn about needs when they go to the countryside as part of this program.

Products developed by university staff and students may be built in factories directly under university supervision. The university factories make a wide range of products: components such as Si-chip integrated circuits (made by almost all universities), instruments such as dual-trace oscilloscopes (Peking University), devices such as Si-control-rectifiers (Peking University), and equipment such as step-and-repeat cameras (Tsinghua University). Peking University developed the GaAs range finder contracted by the railroad company.

When large-scale production is required, production may be transferred from the university to a factory chosen by the local bureau in charge of factories. One example is the transfer of the task of making diffusion furnaces designed by staff at Tsinghua University to the Number One Semiconductor Equipment Factory in Peking, which formerly made and repaired measuring scales of the sort used in stores. Another is the transfer of production of the computer designed by the mathematics department at Futan University to a factory in the neighborhood that formerly made doorknobs.

INSTITUTE TO FACTORY

The research institutes in China were originally designed to be similar to those in the USSR, that is, primarily for basic research and having little contact with industry. Considerable changes were made after the Cultural Revolution to make the work more practical.

The way products developed at research institutes are transferred is less clear, although there appear to be close connections between institutes, universities, and factories. In the laser area, there is an institution known as the "experimental laser station" in Shanghai that develops products and their applications from ideas and designs originating from research institutes including the Institute of Optics and Fine Mechanics. At the Institute of Optics and Fine Mechanics, ideas for products are developed further toward the production stage by a design institute (one being the Laser Equipment Station). It is not clear that workers in research institutes have as direct access to factory problems as do the faculty-student groups that go to factories as part of the teaching programs. Nevertheless, a number of examples have been given of problems transferred from institute to factory, such as quartz, ruby, and diamond production from the Institute of Physics. At the Institute of Semiconductors, one of the main activities is to improve reliability of semiconductor products. The Institute is conducting testing and failure analysis in close coordination with a number of semiconductor factories.

The institutes, in general, are working on relatively exploratory projects, such as lasers and semiconductor microwave devices, which will be transferred to factories someday if successful. When they are, we were told, personnel may go with the project to help transfer the knowledge.

FACULTY-STUDENT TEAMS IN FACTORIES

Less sophisticated products may be developed at the factory by student-faculty teams in residence. Examples are the design of simple agricultural machinery, such as a rice transplanter for a small factory at Wuhsi, and help in design at the Shanghai Machine Tools Factory. The groups are said to be welcomed by the factories, even when their contributions cannot be very great (as at the Shanghai Machine Tools Factory, where there are many engineers). Factories such as those in communes that are short of technical personnel probably welcome the visiting groups.

FACTORY TO UNIVERSITY OR INSTITUTE

Factories are urged to be self-reliant. However, if a technician (or engineer) needed help in solving a problem, he would, if necessary, go to an expert in a university or institute. An example was given us of a design problem which was solved by staff members at Futan University with the use of their computer. Other examples are given in Chapter Four, Section C.

There appears to be little red tape involved in these informal arrangements. However, a university would not volunteer its help to a factory; it would have to be asked. This may be a handicap if the factory is backward but determined to "go it alone." It was stated that teachers at the universities may come from the factories, if their expertise is called for.

TECHNICAL MEETINGS

As we discussed earlier in this chapter, there are many meetings on special topics (such as semiconductor reliability) that help provide information exchange for people within a specialty. However, there is little opportunity for someone in a different field to learn of these problems and perhaps help solve them by another approach. Since unifying background principles are neither stressed nor considered important, technical meetings are confined to rather narrowly defined engineering topics.

EXCHANGE BY TRANSFER OF PERSONNEL

An important method for transfer of technology in China is to send people (factory workers and technicians) to a place where the technology is being used, in order to learn on the job for a period of some months. Thus, the housewives in the Number One Semiconductor Equipment Factory in Peking learned to read circuit diagrams and wire circuit boards at Tsinghua University, and the university staff gave them considerable help in getting started in the early years. Some 30-40 staff members of Futan University spent several months at the former doorknob factory, and the factory came to be used by student-faculty teams as part of their training. The textile factory at Tsun Hua got started by sending a group of workers to another textile factory in production to learn the various skills required. They were given some old machines by a factory that was buying new equipment. In agriculture it is also common to send people from one commune to another for temporary periods to learn new methods. Communes appreciate the technical skills brought by student-faculty teams sent out to learn for a few months.

The strong dependence on person-to-person contacts for technology exchange within China probably works reasonably well because the scientific and technical establishment is relatively small and because there is little transfer between specialties. As the establishment grows, it may be necessary to rely more on publications to initiate contacts and to otherwise enhance technology transfer. Studies in the developed countries have shown that person-to-person contact is by far the most common form of technology transfer, although publications play an essential role. This very effective method unfortunately cannot be used to transfer technology from the developed countries to China, where, except for the occasional visitor, publications from those countries must be relied upon.