

中国物理近况

Physics in China

Recent American visitors to China find a concentration on applied physics, rather than basic research, and an attempt to make the higher-education system more democratic

Gloria B. Lubkin

The People's Republic of China has made remarkable progress in many aspects of applied physics. This was the conclusion drawn by seven physicists from the United States who recently visited China and then discussed their observations with us. They saw the production of integrated circuits, controlled-fusion experiments, a superconducting gravimeter, telescopes, a variety of scientific instruments—all produced in China. The US visitors generally got the impression that China was concentrating very much on applications, rather than basic research. And they found a society-wide attempt to make the higher-education system more democratic.

Most of the physicists visiting China traveled as individuals or members of small groups of scientists. But high-energy theorist Marvin Goldberger (Princeton University) headed a delegation from the Federation of American Scientists. Goldberger (chairman of FAS), Jeremy Stone (director of FAS) and China specialist Jerome A. Cohen were invited by the Scientific and Technical Association of China to be its guests and to talk about scientific exchange and other areas of mutual interest.

Institute of Physics

The Institute of Physics of the Academy of Science, located in the northwest part of Peking, has 600-700

employees. Its director, Shih Ru-wei, received his PhD from Yale in 1934. It has about 150 PhD's or equivalent. The annual budget is 5.50 million yuan, which is about \$2.7 million, Goldberger says. The Institute's research areas include: magnetic films and ferrites and their uses in electronic instruments; argon lasers; semiconductors; widescreen color television; crystallography; structure of insulin; low-temperature physics; earthquake prediction; artificial diamonds; acoustic aspects of linguistics, and plasma physics.

In plasma physics, the Institute is doing theta-pinch experiments with a device built since the Cultural Revolution. The diagnostic equipment was modern, Goldberger says; it uses laser interferometry and so on. One visitor to this lab was C. K. Jen (Johns Hopkins Applied Physics Laboratory). He was told they were observing (D,D) reactions producing neutrons. Goldberger, who saw the same equipment, was told they had not yet measured the neutron spectrum and were aware of the verification problem. Another visitor to this lab, high-energy theorist Rudolph Hwa (University of Oregon) witnessed the demonstration of a loud pinch. His impression was that though the lab appeared to be only at the initial stage of construction, it is nevertheless impressive, considering their lack of experience (as evidenced by the fact that only young physicists were on hand to explain the equipment). Goldberger was told that they

also were studying laser-produced fusion, but because that work was being moved to a new location he could not see it.

Goldberger and Hwa were told of a project to make wide-screen color television using lasers. They did not see it demonstrated, but Goldberger was told that its image is very much brighter and sharper than conventional color television; the screen was about 1.5 meters on a side.

The Institute has a low-temperature laboratory, at which a former student of Jen's, C. S. Hung, is very active. Hung had studied at MIT and in Leiden, the Netherlands, before returning to China. Jen feels that China is now at the point where it can start doing some basic research in low-temperature physics. He, Goldberger and Hwa all saw a superconducting gravimeter that was being used to measure changes in the gravitational constant to one part in 10^7 . A 5-gm tin ball, coated with lead, is floated in a magnetic field and a Josephson junction is used as a detector.

Peking University

Peking University, founded in 1898, has 17 departments, 64 specialities and 4200 students at present. It has 2100 teachers, the same number it had before the Cultural Revolution. On the other hand, the student enrollment before was 11 000 students. By 1974 the enrollment is expected to be raised to 10 000, according to solid-state physicist Raphael Tsu (IBM). Tsu was told

Gloria B. Lubkin is senior editor of PHYSICS TODAY.



Integrated-circuit laboratory at Fudan University in Shanghai. Almost all work in the physics department is on semiconductors. Atmosphere is academic and industrial.

that the faculty remained essentially the same as before the Cultural Revolution. During it, the faculty was busy reorganizing, writing new textbooks, designing new curriculum and doing research.

The vice-chairman of the revolutionary committee at Peking, which is the equivalent of president, is a physicist, Chou Pei-yuan; he is deputy chairman of the Scientific and Technical Association of China. Chou worked at Cal Tech during the latter part of World War II, and received his PhD there in 1928. His dissertation was on general relativity.

The FAS delegation had extended conversations about the revised admission policies and curriculum changes at Peking University. During the Cultural Revolution, students were not trained at the universities. When students were again admitted, only a freshman class was instituted. By now these students are in their third year. Students are no longer taken directly from high school, but must instead spend at least two to three years on a commune, factory or in the army. They are selected by their peers on the basis of intelligence, political consciousness and good health, but the final decision rests with the university.

When questioned about how students compared with those selected the old way, the FAS group was told they have not had enough chance to evaluate the system because they have not yet graduated a class. During the Cultural Revolution classes had been suspended; so they are now just admitting their third class of students. The

curriculum has been shortened from five to six years before the Cultural Revolution to three years now (except for theoretical physics, which takes four), at which time they receive the equivalent of a bachelor's degree. Within the university there are small factories, one of which manufactures oscilloscopes, and students spend significant time working in these factories.

The elementary-physics lab Goldberger saw at Peking seemed comparable in equipment to that in the US.

High-energy theorist Chen Ning Yang (State University of New York at Stony Brook), who last year became the first American physicist to visit China in many years (PHYSICS TODAY, November 1971, page 61), returned for another visit this summer. He chatted with a group of forty or fifty students in the physics department at Peking University and found them very dedicated, hard working and highly motivated. Compared with the average Chinese students he knew when he lived in China, he found them very articulate, which he attributes to the present attitude of encouraging people to speak up. "The students are very much concerned about their own contribution to society and about the progress of China as a whole. They regard their studies as an instrument through which they can contribute to society."

Yang spoke to a student of about 25, a freshman, who had previously been a mechanic in a factory for seven years. When asked how he came to the university, he said that everybody of the

right age group has the chance to go. They had discussion groups to decide which among them would be recommended. Then the universities send people out to screen the candidates. The former factory worker felt that although he had forgotten a lot, his seven years of work had given him some experiences a student fresh from high school would not have.

All the beginning students go through four months of remedial classroom work to make up for what they have forgotten and to provide a more uniform level of preparation. This was true not only in Peking, but also in Sian and Nanking, where Yang also visited. During the four-month refresher course the more advanced students help the less advanced.

Several hundred students are enrolled in the physics department at Peking, which is divided into about ten different specialties. Last year no new students were admitted either to the theoretical-physics or low-temperature physics specialties, but this year both took in students, Yang was told. It is not clear how this came about. "It is clear that by establishing these specialties and assigning these students to these specialties in the freshman year, China is making a scientific training that's more specialized than the usual one, say in the United States." He feels that China has taken this course because it urgently needs people in various applied-physics fields, and it feels that this approach will train people quickly to handle practical problems.

In the College of Science, Tsu was



Shanghai Industrial Exhibit. In foreground is 300-kW generator. The sign above statue of Mao Tse-tung says, "Build a Socialist society with great effort, speed and economy."

told, are mathematics, physics, biology, geophysics, chemistry, electronics and radar, nuclear energy and physiology. Tsu discussed the physics curriculum with Huang Kun, a leading semiconductor theorist, who is now on leave from Peking to run a pilot integrated-circuits factory. Students take the following courses as undergraduates: calculus, vectors, complex variables, differential equations, electricity and magnetism, atomic physics, modern physics, mechanics, thermodynamics, solid state, quantum mechanics, theoretical physics and statistical mechanics.

Tsinghua University

Tsinghua University of Engineering and Technology, also in Peking, is sometimes called the MIT of China. There are 2000 teachers, of whom 200 are professors. Tsu was told there are 11 departments: science, electrical power, electronics and antennas, mechanical engineering, water conservation, applied mathematics, chemical engineering, automation, architecture, industrial materials (probably metallurgical engineering), and precision instrumentation. There are no humanities or liberal arts any more in the university. Physics, which is part of the science department, is emphasized, and the physics building is very big.

Tsu was told that they don't have exams any more, but on the other hand they do have take-home assignments that resemble exams. The students are now given a chance to air their grievances, unlike the previous system.

The physics department looks like a

combination of a small-size factory and a research institute, Tsu told us. He found that the equipment being made there was almost as sophisticated as something built by Hewlett-Packard. He saw girls at Tsinghua doing ultrasonic bonding, for example, an essential technique for integrated circuits.

He found, too, that the students were using sophisticated equipment, rather than the simple apparatus typically used by American undergraduates. Thus when they start a regular job, they already would have industrial experience.

At Tsinghua he saw them doing integrated-circuit photoreduction work. In this procedure you draw a pattern, which is then microscopically reduced to a very small size onto a photosensitive emulsion on top of a chip of silicon or germanium. By a process known in the US as "photoresist," the unexposed part is etched away. Then the chip is placed in an evaporator and you deposit, say, aluminum on top. Such a process is continued, until finally the copper contacts are applied. The optical system used for all of this comes from the Chinese Institute of Optics, which uses a computer to help in the design. One might find such sophisticated integrated-circuit techniques in the US at IBM, Bell Labs, Texas Instruments, or a few of the larger universities, but certainly not in the smaller ones, Tsu notes. But he found this assembly going on in Tsinghua and elsewhere.

Futan University

In Shanghai is Futan University, which some say is the most outstand-

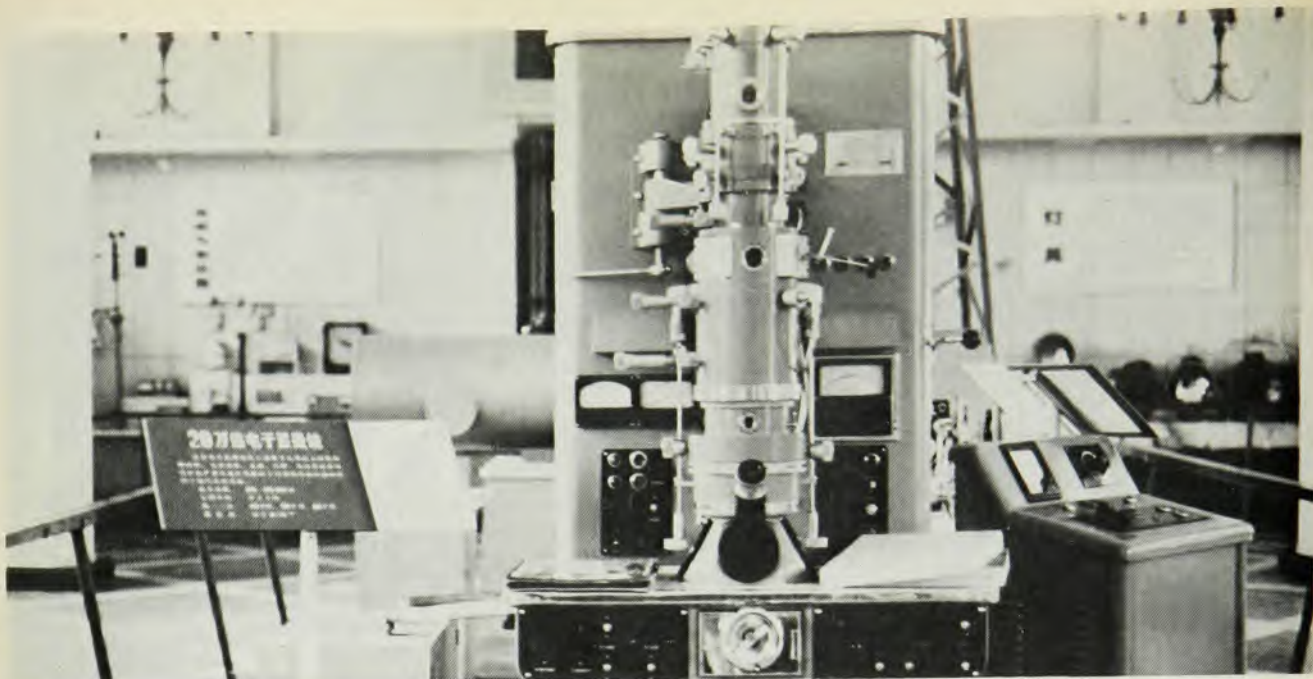
ing in physics in China. Before the Cultural Revolution, the university had 6500 students and 2500 teachers and staff. Now the university has 150 professors, 304 lecturers and 1060 teaching and research assistants, according to the FAS. There are 1800 students, Tsu was told.

Apparently there are no graduate students in China. Goldberger asked how graduate education and the training of future professors will be conducted. He was told that they haven't solved the problem yet. Goldberger feels that they are still seriously rethinking their whole educational philosophy and that it is still very much in a transitional stage.

Tsu was told that PhD's would no longer be given because they are bourgeois. Instead a person will include in his resume that he has gone to graduate school and taken certain courses, but he will not have the degree itself.

Futan has six science departments: chemistry, mathematics, physics, optics, atomic physics and biology. In the college of arts the departments are Chinese literature, foreign languages, political science, philosophy, economics, journalism and history. Tsu found that almost all of the work in the physics department was on semiconductors, including a fair amount of integrated-circuit work. Again he found a combination of an academic and industrial atmosphere. He said a substantial amount of industrial research is being done on things such as vacuum ionization gauges, nuclear counters, gas tubes and flash lamps.

He and several visitors saw the con-



Electron microscope displayed at Shanghai Industrial Exhibit has a magnification of 200 000 and a resolution of 7 Å; the best German microscope has 50 per cent better resolution.

struction of halogen-tungsten lamps, which are very high-intensity sources. Tsu saw one lamp that was 16 feet long and produced 500 000 watts. They were being built under the direction of a man named Tsai, who had no formal training.

Shanghai Industrial Exhibit

A remarkable selection of scientific instruments was on display at the Shanghai Industrial Exhibit; all of the equipment was Chinese-made. Tsu saw a 44-picosecond rise-time sampling oscilloscope. (The US, Tsu says, has one with 28-picosecond rise time.) He saw a 100-MHz digital counter, which resembled one advertised in the US. A 200 000 $\times$ electron microscope, which had a resolution of 7Å, was on display. (He has been told that the best German microscope can beat that by about 50% in resolution.) There was a 2-meter grating spectrometer with a range of 2000–10 000 Å. He saw a mass spectrograph with mass resolution of $M/\Delta M$ of 1000; it had a sensitivity of 10^{-9} . Tsu saw an ion pump that resembles the US Vac-Ion pump; it operated at 14 000 liter/sec. There was a crystal-pulling furnace, 1500 deg C, capable of automatic temperature control. It can pull a 3-kilogram crystal; this furnace is about as big as the largest available in the United States, he says.

Tsu learned about neighborhood factories, which are primarily operated by housewives. He was told that a neighborhood factory can produce 200 diffusion ovens each year; these are used to grow epitaxial silicon layers. Wherever

he went in China he found the epitaxial-growth technique was being employed.

Institute for Computer Research

At the Institute for Computer Research in Peking Tsu saw a second-generation computer with an access time of 2 microsec, and a memory of 32 000 words (with 48-bit words). The machine had both a core memory and a drum memory. In China, he was told, they don't have a disc technology, so they transfer the drum contents onto external magnetic tape. Input is paper tape; they apparently do not use punched cards. Tsu opened the computer and found that it does not use integrated circuits.

But in Shanghai he saw a machine known as the TQ-11, which has some integrated circuits, but not all. It has a drum memory that contained 8192 words.

Institute of Semiconductors

The Institute of Semiconductors of the Academy of Science is located in Peking. It is directed by Wang Shouwu, who received his PhD in 1949 from Purdue University. The institute is one of the largest in the Academy of Science and consists of four departments: materials science, lasers, integrated circuits and microwave devices. There are four buildings, one of which housed the entire Academy of Science prior to 1949.

Tsu found that the materials-science lab closely resembles such a lab in the US: One sees gas or liquid-phase epitaxial growing in ovens, people making

measurements of carrier concentration, uniformities and mobilities. Half of the effort is on silicon technology. The other half is on the technology of gallium arsenide and the other III-V compounds. Most of the equipment is Chinese-made, although Tsu occasionally saw a fast-sampling oscilloscope that was Japanese-made. The whole building is air-conditioned and has double-thick windows, a feature that is unusual in China.

Tsu was very impressed with the progress in integrated circuits all over China. Although they do not yet have large-scale integrated circuits in production, he feels that within a couple of years they will, and that these will then be incorporated into computers. Before he went to China he had heard people say that although the Chinese could build the atomic bomb, because that technology is well known, they could not do complicated things like integrated circuits—that this must be learned by observation and cannot be learned from the literature. But the Chinese were not able to visit our institutes to learn the procedures. So they just went ahead and did it, even if they had to make mistakes in the process, Tsu observed. And of course this is not too different from the way the industry began in the US.

Institute of Electronics

The Institute of Electronics of the Academy of Science is in Peking. Jen, who is an expert in microwaves and millimeter waves, found that although the institute works in lasers, it concentrates mainly on his own field.



Chang Yu-che (left) and Chen-Ning Yang stand in front of an ancient astronomical instrument at the Purple Mountain Observatory, which Chang directs. Yang is from Stony Brook.

The work is very advanced in both science and technology. He saw them manufacturing and using the generators of these waves—klystrons, traveling-wave tubes and carcinotrons (a crossed-field forward-wave amplifier that operates at 1000 watts) reaching to the millimeter ranges. The equipment, all made in China, was well made, some of it at the institute itself. He feels that the quality compares quite favorably with the US but that it does not exceed our quality.

Astronomy and fluid mechanics

C. C. Lin (MIT) works in astrophysics, fluid mechanics and applied mathematics. He visited a radio-astronomy observatory in Miyun, about 70 km northeast of Peking. He saw a system of 16 dishes in a row, each dish about 2 meters in diameter, and spaced 72 meters apart. The interferometer has a resolution at 2 meters of about 6 minutes of arc. It is being used to observe the activity of the solar corona, which he saw was being automatically recorded. The radio telescope was built with the help of W. N. Christenson of the University of Sydney, who periodically visited China to assist in its design.

In Nanking at the Purple Mountain Observatory Lin saw a Schmidt telescope with a spherical reflector whose diameter is 60 cm and a glass corrector whose diameter is 43 cm. It was built in China in 1964 to track their artificial satellite. At another observatory there is a larger Schmidt telescope whose spherical reflector is 90 cm in diameter and glass corrector is 60 cm in diameter. This telescope is being used

for stellar spectra. The Purple Mountain Observatory also has a solar spectrograph with a resolution of $1 \text{ \AA}/\text{mm}$.

At the University of Nanking Lin spoke to an astronomy professor named Tai, who had taken his PhD from Cambridge University. He learned that they have 30 new students, either in astrophysics and geophysics or just astrophysics. (This was not clear.)

Lin also visited the Mechanics Research Institute of the Academy of Sciences, which is in Peking. He remarked that he did not necessarily see their best equipment in applied mechanics, because presumably that is kept secret. But the equipment he did see was of first-rate quality. He saw supersonic wind tunnels and a laser device being developed for measuring fluid velocity.

The institute workers were concerned with problems of compressible flow. On another occasion, this time in Shanghai, Lin was asked how to solve by numerical methods certain partial differential equations that they were meeting in the design of gas turbines. These problems, he notes, are not easily solved either in China or in the United States.

Nuclear physics

Chang-Yun Fan (University of Arizona) is an experimenter in space physics, but he did not see anything directly related to his speciality. He did, however, visit the Institute of Nuclear Physics of the Academy of Science in Peking, where he saw their 2.5-MeV Van de Graaff accelerator, and a research reactor, which had a flux of 10^{14}

slow neutrons/cm² sec. He saw all kinds of detectors that were Chinese-made: sodium-iodide and cesium-iodide detectors, solid-state detectors, lithium-drifted silicon detectors and plastic detectors. And at Peking University he saw these detectors being assembled.

High-energy physics

When Yang visited China last year he was told that they were considering the possibility of constructing a high-energy accelerator. This year he was surprised at the very large number (more than last year) of relatively young (30-35-year-old) physicists who appear to be pushing China towards this commitment. Although the precise design was not fixed, they were talking about an accelerator in the range of \$100 million.

Yang feels that after the Cultural Revolution, there was a period of great emphasis on the practical side of research work. He now believes that the interpretation of what is practical has been liberalized. For example, he was told by T.H. Ho about work related to field theory and axiomatic field theory. Many people are interested in the phenomenology of high-energy physics; a number of physicists are getting into the field. Others are very interested in the possibility of gauge fields materializing into intermediate bosons and photons, such as the work of Steven Weinberg (MIT); he did not, however, hear of any new work in this field. Yang also gave a seminar on his work in statistical mechanics, but this subject is not a particularly active one



Marvin Goldberger (left) is greeted by Kuo Mo-jo, president of the Chinese Academy of Science, who is a poet, scholar and calligrapher. Princeton physicist Goldberger is president of the Federation of American Scientists. FAS director Jeremy Stone is behind Goldberger.



At the Institute of Physics of the Academy of Science in Peking. From left: Wang Cheng-shu (Mrs Chang Wen-yu), Chang Wen-yu, C. N. Yang, Teng Chia-hsien and Chou Kuang-chao. Chang was scheduled to visit the US last month with a delegation of scientists.

in China, according to Yang.

When Hwa was lecturing on high-energy inclusive reactions in Shanghai, he had a long philosophical discussion with some of the physicists there. Although some of them did not appear to be high-energy physicists, they were very much opposed to the bootstrap idea of Geoffrey Chew (Berkeley). They felt that there must be constituents inside a particle. Hwa feels that this belief is based on dialectical materialism, which holds that things are made of substance and are not abstract. The argument given was that we must be able to split the particles

further, because history has proven it. Even if the bootstrap succeeds in predicting all the particle masses and so on, they felt one should go on asking what are the constituents of the particles. In Peking, after he gave another lecture, the physicists with whom he met also were in favor of a constituent picture, but gave more cogent arguments involving the consideration of form factors.

Hwa met some of the physicists who worked on stratonons. They told him they were trying to do the same thing as Murray Gell-Mann (Cal Tech) had done with quarks. They feel that

quarks have met better success than stratonons.

Future

The future looks bright for more American physicists to visit China. At this writing, for example, T. D. Lee (Columbia) is there. And last month a delegation of Chinese scientists that includes Chang Wen-yu was scheduled to visit the US. Chang, who was formerly at Princeton and Purdue, is well known for his discovery of mu-mesic atoms in cosmic-ray experiments. We all have much to learn from each other. □