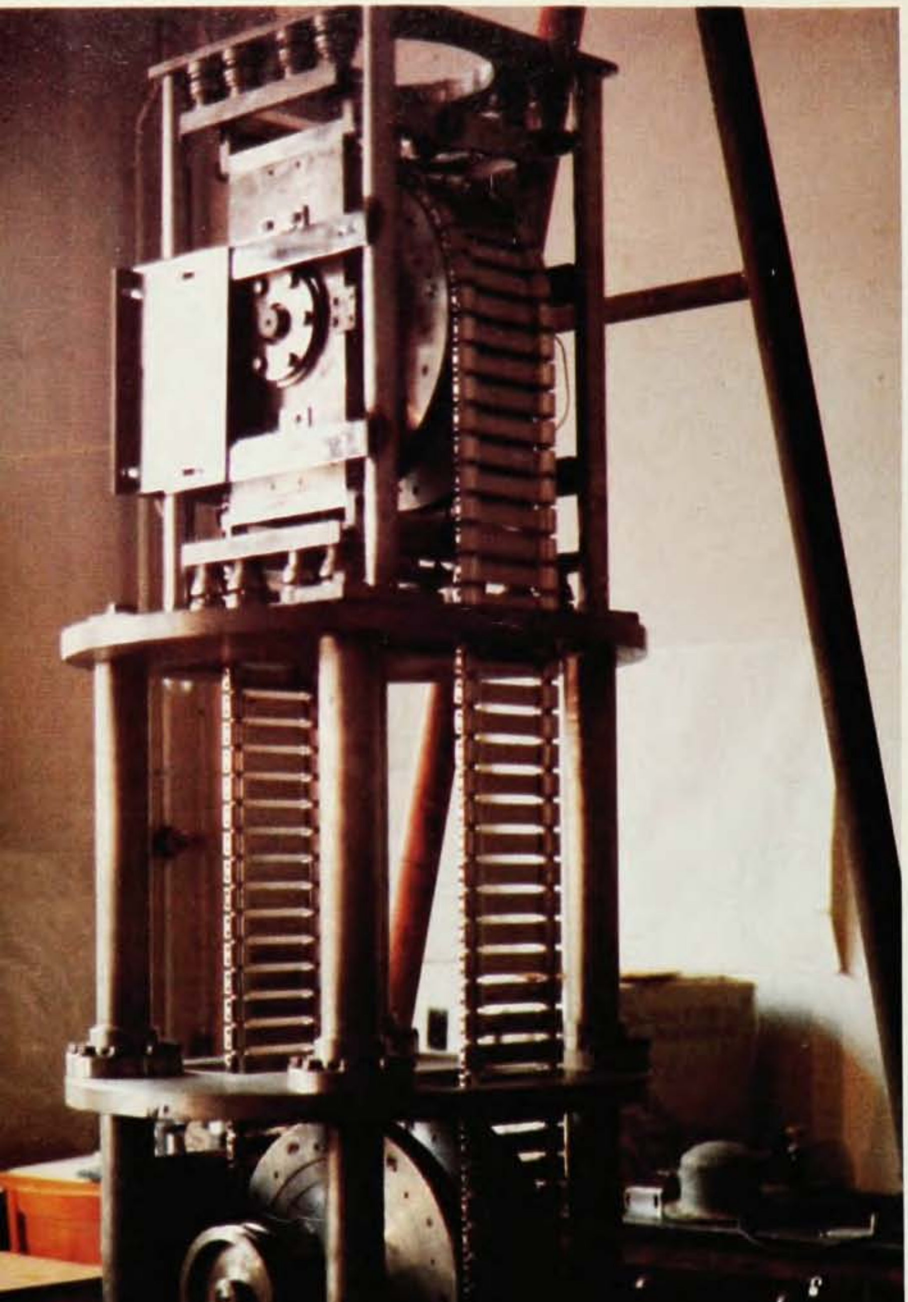

Chinese physics equipment. At the Langchow Institute of Modern Physics (**above**) is a prototype charging system for a future tandem. The ladder, made of stainless steel, tends to wobble because idler wheels are not used. Auger electron spectrometer (**top right**) was designed and built at the Institute of Metallurgy in Shanghai; equipment has an energy resolution of 0.3% and a vacuum of 8×10^{-10} torr. Construction (**middle right**) is underway at the Institute of High-Energy Physics in Peking, which plans to build a 50-GeV proton synchrotron by 1985. Target area (**bottom right**) at Futan University's locally built 3-MeV Van de Graaff. Photos by Gloria B. Lubkin.

Physics Today in China

Gloria B. Lubkin

When I landed in Peking one cold night last November I was warmly greeted by Kuan Wei-yen, a low-temperature physicist who runs Academia Sinica's Institute of Physics. It was the start of a three-week tour of the People's Republic of China as the guest of Academia Sinica, in which I met with Vice-Premier Fang Yi and other leading science officials, visited six physics institutes and five university physics departments.

This account of my impressions is well characterized by the old story about the elephant as interpreted by a group of blind men. In this case the elephant should probably be a Chinese dragon, but never mind. One man touches the leg and describes the elephant as resembling a tree. A second feels the tail and says the elephant must be like a rope. A third encounters the elephant's flank and says it is like a great wall.

Not only are my views colored by the particular physics labs and universities I visited, my picture only shows the way they looked in November 1979. The situation is changing rapidly. In many ways it hardly resembles the China I described seven years ago in PHYSICS TODAY. With the deaths of Chairman Mao Tse-tung and Premier Chou En-lai, a new leadership is stressing the need to modernize China. Science and technology are being emphasized and basic research is again respectable.

In fields of physics China has concentrated on, I saw signs of remarkable progress in lasers and large-scale integrated circuits. In other fields, I saw ambitious efforts to build a heavy-ion accelerator, a 50-GeV synchrotron and a belt pinch device for magnetic fusion.

Cultural revolution

In the period 1966–76, the Cultural Revolution in China appears to have af-

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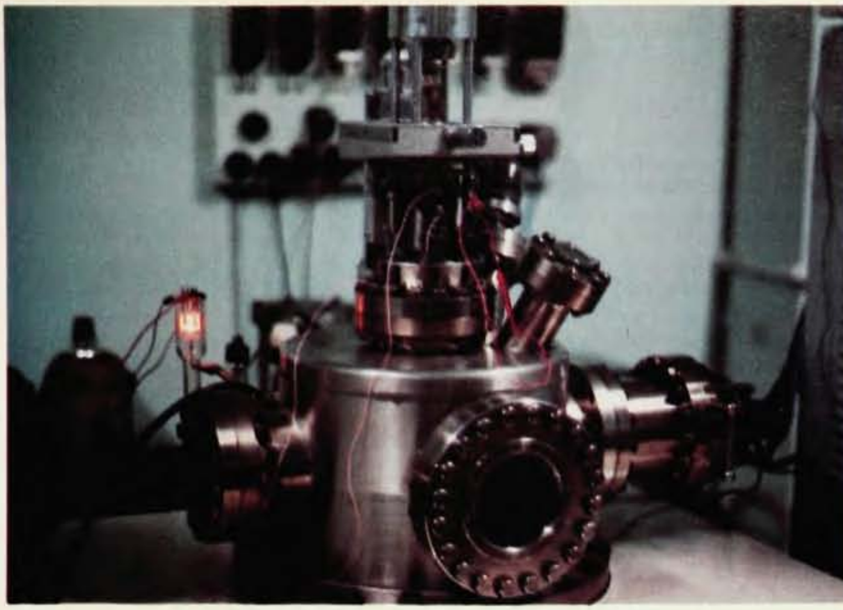
As China rebuilds, it shows signs of remarkable progress in such fields as lasers and large-scale integrated circuits.



fected the life of every physicist there. Basic research was practically nonexistent. The university physics departments were turned into factories and places for political discussion.

Wherever I went, the physicists I met would at one time or another bring up the destructive influence of the so-called Gang of Four during the Cultural Revolution. At Northwestern University in Sian, Y. S. Chiong, an elderly physicist who earned his PhD under E. N. da C. Andrade at University College London, described his own suffering: "I spent about a year in the country and a half a year in a factory to serve as practice. Some would call this valuable," he went on, "I call it cruelty."

At Tsinghua University in Peking, known as the MIT of China, Hsu Yi-chuang (who studied at the University of Chicago with Clarence Zener in the late 1940's) recalled, "This university was completely under the control of the Gang of Four. I was sent to a farm 'to reform' me for two years—from 1969 to 1971." Nearly all the teaching faculty who were not followers of the Gang of Four were sent to farms.

As I sat in a lounge at the University of Nanking with Chan Hou-ling, Pao Chia-shan and Ou-yang Yung-pei, Chan (a university administrator) said that all three of them had been attacked as bourgeois intellectuals, and that most of the leaders in the university had been similarly assaulted. Half of the teachers were labeled "reactionary or counter-revolutionary. We had 27 people die abnormally, in some cases suicide."

The roof of the Tsinghua University physics building was burnt, and some laboratories were completely destroyed,

Gloria B. Lubkin is senior editor of PHYSICS TODAY.

along with equipment and samples. Some of the remaining equipment was sold and the rest was converted to manufacture lasers. Northwestern University physicists described a similar experience: The labs were converted into workshops; most of the research equipment was either destroyed or else it was converted for factory use.

Applied research did continue at some universities. Physicists at Futan University in Shanghai did work on semiconductor devices, detectors and electronics, for example. Futan's locally built Van de Graaff accelerator (completed in 1958 and rebuilt in 1964) was essentially not operated during the early years of the Cultural Revolution and in the later years was used for applied research only.

At the Institute of Physics, Kuan Wei-yen told me, the influence of the Gang of Four was comparatively low, but research stopped entirely some of the time. "Although there was no fighting here, people were divided into two factions," and political arguments had a great deal of influence. The Gang of Four faction was vigorously opposed to any theoretical study. Although in 1972 Chou En-lai had encouraged scientists to emphasize basic theory, the Gang of Four attacked his policy, calling it an "ill wind." Intellectuals were attacked—"the more knowledge you have, the more reactionary you will be." Einstein was called a "bourgeois intellectual," and a campaign was organized to criticize the theory of relativity. The attack on Einstein reminded me of a similar attack by Hitler, who described relativity as "Jewish physics." Kuan recalls that the relativity critics in fact understood little of the theory. Among the defenders of relativity was Chou Pei-yuan, whose PhD in general relativity was from Caltech. Chou is now president of the Chinese Physical Society, a vice-president of Academia Sinica and head of Peking University.

At every lab I visited in China I was struck by the absence of young physicists. At the Institute of High-Energy Physics in Peking, for example, the youngest scientist is 38. At least half a generation of physicists has been lost. In the first three years of the Cultural Revolution, the universities essentially shut down entirely. When the universities reopened, students were admitted on the basis of recommendation by their production unit. No entrance exams were required; instead, a prospective student had to have the right kind of political attitude.

Although Tsinghua University did enroll graduate students in 1972 at the suggestion of Chou En-lai, the influence of the Gang of Four prevailed and the students were unable to do graduate work. In general, graduate education essentially ceased for ten years.

Academic achievement was downgraded as elitist. A popular figure during the Cultural Revolution was a student, known as "a hero who goes against the tide" because he handed in a blank examination paper. No academic degrees were awarded during the ten-year period.

Because secondary education also suffered during the Cultural Revolution almost all the university students were ill-prepared.

Although the Cultural Revolution has ended, new university graduates are not yet available. Those who graduated right before the Cultural Revolution were sent to farms, generally for two years. Some remain there; others are working in factories or teaching in secondary schools. A few managed to continue studying or doing physics. The rest have probably forgotten a good bit of what they learned. One physicist remarked to me, "That was the most serious effect produced by the Gang of Four—the damage to people." Even those who were not working on farms had stopped doing research for ten years and will need time to catch up.

In the early years of the Cultural Revolution, apparently scientific publishing essentially ceased. Although, for example, the Institute of Optics and Fine Mechanics in Shanghai continued to do applied research involving lasers during that period, very little if at all was published about it. I saw an international quality six-beam laser for thermonuclear fusion and other noteworthy laser activities. But, as Chi Ying-shih, who was demonstrating a 10-GW carbon-dioxide laser said, he published a paper about it only in 1978. During the Cultural Revolution "we weren't free to exchange papers," even within China. Scientists had so many restrictions on publishing their results that they weren't enthusiastic about doing so. And, I suspect, the government may very well have classified work at the Institute because of potential military applications.

From 1962 to 1978 no annual meeting of the Physical Society of China was held. During that period, the society appears to have been inactive.

After the Cultural Revolution

The overthrow of the Gang of Four in October 1976 was marked in Peking by a three-day celebration attended by almost everyone from the Institute of Physics. Their enthusiasm was echoed by scientist colleagues all over China. Over the next year or so, a series of discussions were held to identify priorities for science and technology, and in March 1978, a National Science Conference took place in Peking. At the meeting Vice-Premier Fang Yi, who is responsible for Chinese

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Students at the University of Peking. Of the 8200 students attending this year, 700 are majoring in physics.

science and technology and serves as president of Academia Sinica, outlined the official plan for modernizing China through science and technology. He pointed out that China now lags 15 to 20 years (and sometimes more) behind the most advanced world levels. In the next eight years China plans to increase the number of professional research workers to 800 000.

"We must build a vast army of working-class scientists and technicians who are both Red and expert, and we must have our own experts in science and technology who are first rate by world standards. We must also acquire the most sophisticated equipment for scientific experimentation so that we can approach advanced world levels [by the end of the century] in most branches of science and technology, catch up with them in some other branches and take the lead in certain branches." Over the next eight years emphasis will be placed on eight fields: agriculture, energy resources, materials, electronic computers, lasers, space science and technology, high-energy physics and genetic engineering.

When I met with Vice-Premier Fang in the Great Hall of the People in Peking, I asked how these priorities were established. He replied, "The decisions were made in accordance with the international situation in science and specific conditions in our country. For example, computers have been developed all over the world. So we must develop them also."

As for energy priorities, he noted that China has plentiful hydroelectric capacity—almost 600 million kilowatts, of which only 1–2% have been exploited. In addition, China has lots of coal and petroleum. So the emphasis at this time should be on hydroelectricity, coal and oil as energy sources. China intends to develop nuclear power, too, and, "we're studying fusion power, but it must be done slowly. We can't do everything. It's also a very expensive business."

One priority that surprised many Western scientists was the decision to build a 30–50-GeV proton synchrotron for high-energy physics research at a time when China has relatively little experience in the field and is still a developing nation. Most of those American particle physicists who were asked for their opinion apparently counseled the Chinese against building one.

"Why is China building a 50-GeV accelerator?" I asked. Fang said, "We're a large country of 960 million people, but we're poorer than the United States. Accelerators are useful for studying many things: medicine, physics and so on. We can't build a 400-GeV accelerator like you have in the US, but we must look ahead to the future."

While Fang and I spoke, the meeting was being filmed by television cameras and still photographers. It took a while for me to get used to this Chinese press coverage of the American physics press. I find it difficult to imagine similar coverage of an interview with a high-level American official by a Chinese science reporter.

Will China expand financial support for basic research? "We want to but we're not as rich as the US is. So we have to do things gradually, step by step."

What can US physicists do to help China? "There are many possible ways. For example, in the building of our accelerator, we have already received much assistance, for which we're very grateful. Some American physicists have come to China and others in the States have helped us by advice." Former Fermilab director Robert Wilson "took off his coat and helped us in the labs [to build a prototype magnet for the main ring]." Fang feels very moved by Wilson's involvement. "We have great possibilities of cooperation in the future in other fields of science."

Fang expressed the hope that PHYSICS TODAY would continue to flourish and that in the future China can obtain more copies. In all the physics libraries I visited, PHYSICS TODAY was on display but usually in photocopied form rather than the original.

As I took my leave, Fang said, "Although we are backward, we have 6000 years of civilization behind us. So we have much to show you." He urged me to visit the archeological excavations in Sian. And if I want to go as far as Sinkiang, I'd need a week just for the trip. So I ought to visit China again.

Highlights in physics research

It seems clear to me that Chinese physicists are extremely capable and can catch up with the rest of the world in almost any field China decides to emphasize. In some aspects of marine embryology, for instance, Chinese work is more advanced than anywhere else, according to an eminent American embryologist I met in Nanking.

In several physics labs I saw Chinese-built equipment that closely resembles apparatus found in the US and Europe. But the most modern-looking instrument is often on an antique wooden table in a dusty, unheated lab. The physicists, who have often developed and built the equipment themselves are justifiably proud as they describe its capabilities.

As we sat talking at the Institute of Physics in Peking, Kuan explained that because the Gang of Four had sabotaged Chinese industry, modern experimental equipment is in short supply. "So scientists in the Institute have to spend a lot of their time building the equipment themselves. But basic research usually requires sophisticated equipment. For example, experiments in surface physics require ultrahigh vacuum and one must have equipment for preparing a pure

Meeting in the Great Hall of the People. From left: Vice-Premier Fang Yi (president of Academia Sinica), Wu Ling-an (Institute of Physics), Li Ming-de (Foreign Affairs Bureau, Academia Sinica), Chien San-chiang (vice-president, Academia Sinica), Gloria B. Lubkin (PHYSICS TODAY).

surface film and equipment for detection." The Institute was about to take possession of a molecular-beam epitaxy system built with the cooperation of Academia Sinica's Science and Technology Equipment Factory in Shenyang. The system does indeed have an ultrahigh vacuum—10^{-9}–10^{-10} torr—and is essentially at a state-of-the-art level for such equipment. Energy analyzing apparatus has also been built for scanning high-energy electron diffraction and for Auger spectroscopy, and a quadrupole mass spectrometer has been constructed. Because the equipment has only recently been finished, it will be some time before it can be put into routine operation. One US expert on molecular-beam epitaxy who had seen the Chinese MBE equipment said he was very impressed by it but noted that the integrity of the system can only be judged ultimately by the quality of the film it produces.

During a tour of labs at the Institute of Physics, I saw work on optical processing with coherent light, holographic recording on thermoplastic and low temperature resistivity anomalies in sputtered gadolinium-cobalt alloy films. Kuan told me the Institute has built its own helium dilution refrigerator.

The Institute of Optics and Fine Mechanics in Shanghai had an impressive assortment of laser experiments to show me. In 1973 with a single 10-GW laser hitting frozen deuterium they detected 1000 neutrons. By boosting the laser power by a factor of ten they measured 2×10^4 neutrons from lithium deuteride. Since 1977 they've been using a six-beam neodymium-glass laser; each beam produces 10 J in 100 picosec. Six aspheric lenses and a cw yttrium aluminum garnet laser focus the beams to a point on the target with an accuracy of 10 microns. A variety of plasma diagnostic equipment is on hand. Teng Hsi-ming, vice director of the Institute, told me that although their electronic technique is somewhat backward, he fells that their optics technique and technology are quite advanced. His Institute would be eager to swap Chinese knowhow in advanced optics for American electronic techniques.

I also saw an experiment at the Institute of Optics and Fine Mechanics involving four-wave mixing of two-phase conjugation. Wu Tsun-kai explained that the experiment changes a weak infrared signal to a strong visible signal. The Institute's results were so new that no article had been submitted for publication yet.

The Institute of Metallurgy in Shanghai has a misleading name; it really specializes in large-scale integrated circuits and related technologies. Wu Tzu-hang (who took his PhD under Roman Smoluchowski at Carnegie Tech in the late 1940's) explained that the Institute simply develops new techniques; it doesn't produce circuits in commercial quantities although it does make small amounts for the research institutes of Academia Sinica. Once the Institute of Metallurgy develops the optimum process, industry takes over.

Wu believes US industry is at least five or six years ahead of Chinese circuits, which still rely on outdated equipment. As Chian Pei-chen showed me around the metal oxide semiconductor lab, he remarked that the Institute would like to buy the most advanced US equipment for making large-scale integrated circuits but that such sales are restricted.

The Institute's bipolar group (headed by Chang Ming) last year developed a circuit called ECL 1024, a 1024-bit random access memory with an address access time of 28 nanosec, power dissipation of 500 milliwatts and a chip size of 2.8×3.1 mm. The metal–oxide–semiconductor group is now developing an 8000-bit memory. For comparison, US firms are putting 32 000 or 64 000 bits on a chip. Typical wafer sizes in the US are larger (three or four inches rather than one or two inches) and have more layers of isolation than those I saw at the Institute of Metallurgy. But the Institute's sophisticated technology was impressive.

The Institute of High-Energy Physics campus in Peking is bustling with activity as it prepares to build a 50-GeV proton synchrotron. Six lab buildings are under construction on the campus—one for the linac, one for magnet fabrication testing and four for the experimental physics division. But the site of the actual accelerator, outside the city near the Ming Tombs, is still being surveyed geologically for the best machine orientation. The National Science Conference in 1978 had set 1983 as the target date for completing the synchrotron but since then the Chinese government decided some economic adjustments were in order. Now the target date is 1985.

Last June a Department of Energy

delegation of particle physicists met in Peking with the Institute of High Energy Physics designers and most of them agreed that the Institute's earlier design ought to be modified. As Hsieh Chia-lin told me, one strong advocate of such a modification had been Robert Wilson, who had just spent a month at the Institute helping staff members build a prototype dipole bending magnet with a small gap (suitable for training purposes only because it is not full size). As a result of the joint meeting, the Institute has indeed altered the design, shortening the linear accelerator from 200 MeV to 93 MeV. A booster synchrotron, not in the earlier design, will accelerate the protons to 2 GeV, and then they will be injected into the main ring. Such a redesign allows the magnets in the main ring to have a narrower gap (5.6 cm instead of 8.6 cm), reducing the overall size of the magnet. The detailed magnet design is not yet ready.

During a lab tour I saw a 3-MeV cavity built for training staff members to make magnetic field and rf measurements. In the next phase, the Institute will build on this experience to produce a 10-MeV cavity that will be a prototype for the 90-MeV linac. The 3-MeV cavity is made of electroplated copper rather than the usual copper-clad steel. I saw a Cerenkov counter for detecting pions, kaons and protons in the 5–10 GeV/c momentum range. A streamer chamber has also been operating but was down when I visited.

The Institute of Modern Physics is in Langchow, a smoggy petrochemical complex (said to include a gaseous diffusion plant for uranium) a bit east of Lop Nor. Until six years ago the Institute was closed to foreigners (shades of Los Alamos?), and the Institute's director, Yang Cheng-chung (whose PhD is from the University of Liverpool), told me I was the first foreign woman scientist to visit. The Institute has been doing heavy-ion research since 1973 and is now converting its fixed-field cyclotron to a 1.7-meter sector-focusing cyclotron. It will be used as an injector for a separated sector cyclotron. This first phase, Yang hopes, will operate in 1985. He expects it to produce heavy ions from carbon to xenon (with 50 MeV/nucleon for low Z and 5 MeV/nucleon for high Z).

A parallel effort is underway to build a tandem electrostatic accelerator that would inject into the separated sector cyclotron. This second phase, which Yang termed "ambitious," would allow uranium to be accelerated to 10 MeV/nucleon. In a lab tour I saw a Langchow version of a charging device that strongly resembles the Laddertron (being built at Daresbury, England) or the Pelletron (built by the National Electrostatics Corp., in Middleton, Wisconsin). Yang told me that James A. Ferry of National Electrostatics, who visited Langchow, offered assistance in building its tandem.

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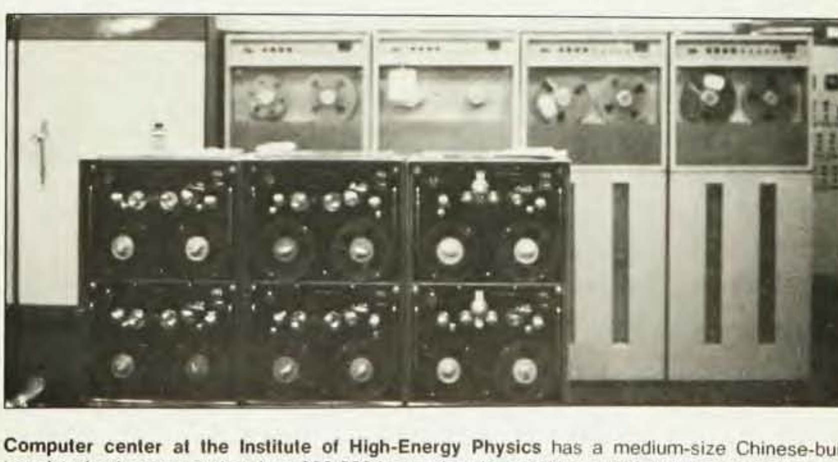
X-ray appearance potential spectroscopy (APS) equipment at Futan University. Hua Chung-yi recently spoke at the American Vacuum Society meeting on experiments with the equipment.

The Institute of Modern Physics might buy some of the components for its tandem from NEC, according to Yang.

Foreign interactions

From the founding of the People's Republic of China until the recent reopening of official contacts between the US and China, few American physicists were able to visit China. Those who did were mostly of Chinese ancestry or members of scientific or educational delegations. After the Sino–Soviet split and under the influence of the Gang of Four, foreign contacts were frowned upon and Chinese scientists were expected to be completely self-reliant, although some foreign technology was imported from Germany, England and France, for example. The leadership in Chinese science, on the other hand, was largely trained abroad—the older ones in the US or Europe, the younger in the Soviet Union. For instance, Chien San-chiang, who was my host at a delightful dinner in Peking, is one of three physicists who are vice-presidents of Academia Sinica (out of a total of seven). Chien worked with Joliot-Curie in Paris during the 1930's. The second, Chou Pei-yuan, has a Caltech PhD. The third, Yen Chi-tzu, was a student of Paul Langevin in Paris.

Now China is opening its doors wide, welcoming scientists willing to spend some time lecturing there. T. D. Lee of Columbia University and C. N. Yang of



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Computer center at the Institute of High-Energy Physics has a medium-size Chinese-built transistorized computer that does 300 000 instructions/sec and has a 500 000-byte core memory. The computer is being used to design the synchrotron; the software is Fortran and Algol. The peripheral equipment was all built in China except for a disk unit (which was made in Bulgaria).

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Chang Ming is in charge of the bipolar group at the Institute of Metallurgy. The estimated percentage of women physicists in China ranged from 10% to 25%, depending on which physicists were asked, compared with 5% in US.

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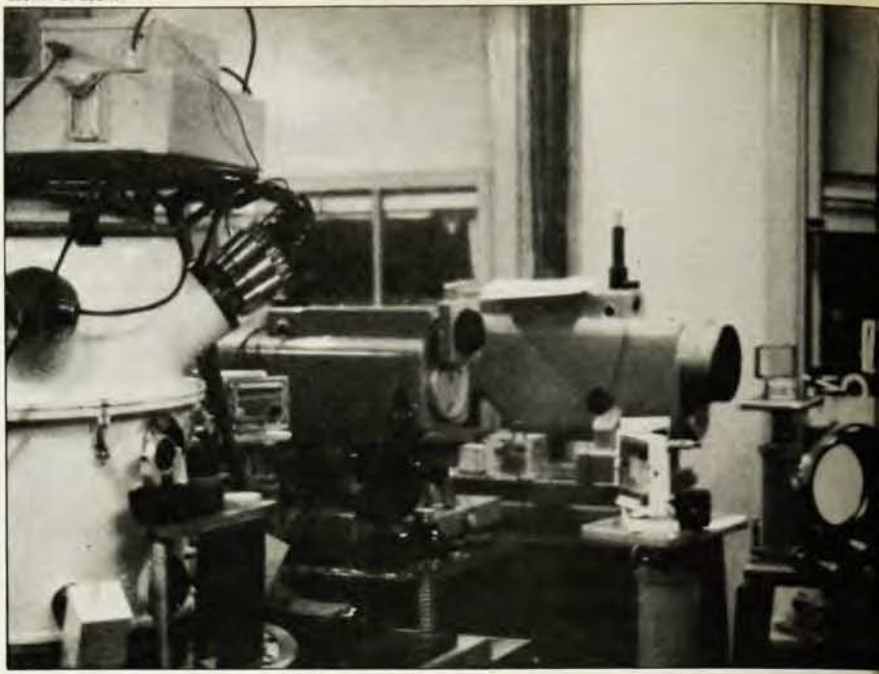

Stony Brook had already visited several times since 1972. But last spring Lee spent three months giving lectures in Peking, attended by 1000 students from all over China. Yang lectured in China for a month this January.

At dinner in the Peking Friendship Hotel I unexpectedly sat next to Kerson Huang of MIT. He and his wife Rosemary were spending six months at the Institute of High Energy Physics—Kerson teaching particle theory and Rosemary teaching English. In Hangchow, at the famous Dragon Well, I saw Arthur and Aurelia Schawlow. He was spending a month at the Shanghai Normal University, lecturing to a group of 120 students from 56 institutes on laser spectroscopy. Visiting archeological sites in Sian I saw Pierre Grand of Brookhaven and his wife. He was spending three weeks at the Institute of High-Energy Physics helping with the linac design.

"Sister-university" relationships are being established between Chinese and American universities. Many US physics departments already have a number of Chinese physicists, some doing graduate work, others even more advanced. The son of Vice-Premier Teng Hsiao-ping will be doing graduate work in physics at the University of Rochester.

Many nations are helping China learn experimental particle physics and accelerator design—all the US high-energy labs, CERN in Switzerland, DESY in Germany and KEK in Japan. The Mark-J collaboration at DESY, which recently reported evidence of the gluon (PHYSICS TODAY, February, page 17), has 30 Chinese scientists, who have done a good job on the experiment, according to their colleague Samuel C. C. Ting of MIT.

The Institute of Modern Physics in Langchow has been helped by the group in Caen, France building the GANIL heavy-ion accelerator. At this writing the DOE is now formalizing US–China cooperation in nuclear physics.

Chinese physicists are turning up at all manner of physics meetings in the US, Europe and Japan. At the American Vacuum Society meetings in New York last October two Chinese physicists gave papers of current interest. Hua Chung-yi of Futan University in Shanghai described an experiment in soft x-ray spectroscopy. Chang Kai-ming of Futan described a calculation of bond lengths and bond angles from LEED data on the gallium arsenide (110) surface.

In Chinese physics labs I saw many foreign instruments. The older varieties are often of Russian or French manufacture. Among the newer devices I saw equipment from Spectra-Physics, Canberra, Schlumberger and Teletype.

Self-help

In January an international conference on theoretical physics was held in Canton. This May an international laser conference is being held in both Shanghai and Peking, sponsored by the Electro-optics Association of China. Charles Wang at the University of California at San Diego is the US program chairman.

Chinese physics journals are being revived and new ones established. Before the Cultural Revolution, the Chinese Physical Society had two: *Acta Physica Sinica* (Chinese Journal of Physics) and *Wuli* (Physics) *Bulletin*. Both stopped publishing in 1966. In 1972 a single publication, *Wuli*, began as a combination of both journals. Two years later *Acta Physica Sinica* resumed publication, and *Wuli* was transformed into a Chinese version of PHYSICS TODAY, intended for physicists, engineers and science teachers. *Wuli* has a circulation of 80 000.

Two new publications are starting up: *Physics in Education* has a circulation of 100 000; a journal called *Progress in Physics* is being planned.

Laser Journal (*Jiguang*) has been published since 1974 by the Institute of Optics and Fine Mechanics and covers laser research throughout China. It has a circulation of 30 000 (of which 300 go abroad). A journal of low-temperature physics with Kuan Wei-yen serving as editor has just started publishing. *Physica Energiae Fortis et Physica Nuclearis* has been published for a couple of years, and the Chinese Nuclear-Physics Society has just started the *Chinese Journal of Nuclear Physics*.

Meanwhile Western physics journals are still being photocopied because China does not yet adhere to the international copyright agreement.

The university physics departments I visited were obviously still suffering greatly from the effects of their ten-year ordeal. All had plans for returning to genuine basic research, rather than applied physics, but as Hsu Yi-chuang of Tsinghua University told me, they must first spend time recovering from the damage of the Cultural Revolution, rather than obtaining new physical ideas. "We're laying the foundation now. You'll find that in nearly all physics departments and institutes we're following the work of other countries. We want to change the situation, but that will take time."

This refreshing candor shown by Hsu is typical of the physicists I met. But coupled with their openness about today's

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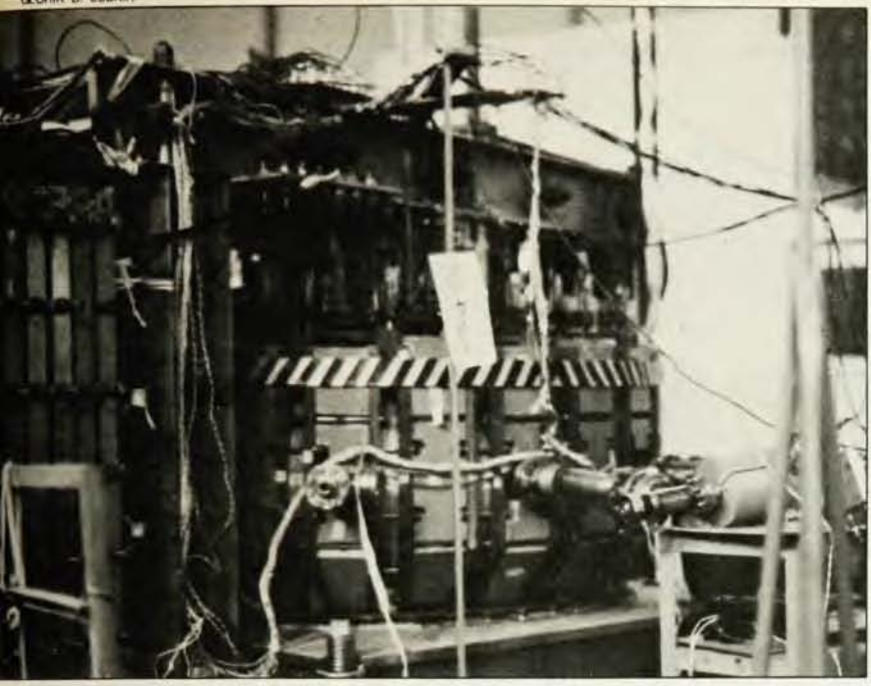

Fusion experiments. Target chamber for laser fusion (left) at the Institute of Optics and Fine Mechanics in Shanghai. The six beams from a neodymium-glass laser are focused on the microballoon target to 10-micron accuracy. Small tokamak (right) at the Institute of Physics in Peking has an outer diameter of 90 cm and a magnetic field designed for 2 tesla, currently operating at 1.2. Diagnostics include a neutron spectrometer, optical spectrometer, residual gas analyzer and a 100–200-MW pulsed laser.

shortcomings is a strong drive to improve physics in China.

In university physics departments I saw physicists modifying or building new instruments, readying for experiments but not yet turning out publishable results, although some groups were very much in the thick of experiments. Typically the university equipment was more primitive than in the Academia Sinica institutes.

Even during the Cultural Revolution, some theoretical physics continued, I learned during a discussion at Northwestern University in Sian. Hu Po-yu told me that he had stopped working on the straton model of elementary particles in 1966. But he was encouraged to return to theoretical physics by conversations with C. N. Yang during his visit to China in 1972. Yang is said to have urged Chou En-lai to encourage basic research, and when the latter did so, Chou Pei-yuan was criticized by Gang of Four followers (an indirect slap at the Premier). As soon as Hu learned about gauge theories from Yang, he became involved in them himself and is now working on problems involving a background field of instantons.

University faculty appear delighted that once more entrance exams are required. Although the entering students are still handicapped by inadequate secondary-school training, each year they improve. Hsu told me that some of the entering students at Tsinghua are very good because they learned by themselves during the Cultural Revolution, "but others just crammed to pass the exams."

When the universities started up in earnest again, entering classes had many older students. Those who did not enter then and are now roughly 30 years old are presumably considered too old for college and can expect to remain in a nonintellectual occupation the rest of their lives.

At Northwestern University, Chien Ching-sun, chairman of the physics department, told me that students have limited experimental skills because much of the lab equipment in secondary schools was destroyed during the Cultural Revolution. Similarly the teachers have limited experimental experience because labs were converted to workshops and research equipment either destroyed or converted to manufacturing use.

At a few physics departments faculty members were concerned that the present curriculum for physics majors is too difficult, in part because it is still modeled after the Soviet system. Pao Chia-shan, vice-chairman of the physics department at Nanking University, contrasts the present situation with his own student days in Peking. At that time, the emphasis was on making the fundamentals strong. "Now students learn too much and forget the fundamentals. You can't assign enough problems to the students because the time is limited."

At present the faculty to student ratio in the universities I visited is astonishingly high. At Futan University the physics department has 450 teachers, about 500 undergraduate physics majors and 45 graduate students. Nanking University has more than 200 teachers in the physics department, 800 undergraduate physics majors and 40 graduate students. Northwestern University has 93 physics faculty and about 300 physics majors. The faculty are aware that the universities are top-heavy and plan to increase student enrollments drastically.

In general, no degrees are being awarded as yet, either at the undergraduate or graduate level, although Nanking University's physics department told me that this year some foreign students will receive degrees. The Ministry of Education has asked Nanking for comments on the degree system.

Problems

Throughout my three-week stay in China I was struck by anomalies: At a construction site at the Institute of High-Energy Physics, I saw a modern crane operating next to a laborer bent almost double as he pulled a cart loaded with rubble. I saw the crystal-growing laboratory at the University of Nanking by flashlight because the electrical power had been shut off for the day; such power cuts often cause the crystal to crack. I narrowly escaped a broken leg or worse while viewing the acoustics lab in Nanking by flashlight. In the dim environment I failed to see that the room I was entering had no solid floor—it was an anechoic chamber.

Lights were out intermittently during my visit to Northwestern University. My guide, Han Chien-kuo from the Institute of Physics, said that his institute, too, often copes with power outages in Peking. The Institute's tokamak, crystal growing and nmr experiments continue operating with the help of an auxiliary generator.

Most labs I visited last November were, like most buildings I visited, chilly at best, with apparently no heat supplied (except for an occasional space heater in the lounge for visitors). Physicists typically dress in layers of clothing to help keep them warm.

Like the universities, the institutes I visited have surprisingly large staffs. Of course many of the physicists are busy building instruments because they are unavailable commercially in China. And others on the staff are essentially learning on the job to be research physicists because their university physics education was incomplete or too long ago.

Yes, China has a lot of catching up to do. But I carry away the feeling that the dragon is fully awake and is fiercely striving to be at the frontier as soon as possible.

* * *

More detail on certain aspects of physics in China will appear on the news pages of PHYSICS TODAY in the next few months. □