stant is about 15 minutes. The UBC magnetic-resonance data indicate that the primary recombination mechanism is $H + H + He^4 \rightarrow H_2 + He^4$, with the helium performing the catalytic function of balancing energy and momentum. The Vancouver group reports[3] that the rate constant for this reaction is about 40% of its room-temperature value. —BMS

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Solid-state physics in China

Materials research and electronic computers are two of the eight fields China has chosen to emphasize during the next several years. So it was not surprising that some of the most advanced research and development that I saw during my recent visit to China (PHYSICS TODAY, March, page 32) was related to solid-state physics and electronic circuitry.

The Institute of Metallurgy in Shanghai specializes in large-scale integrated circuits and related technologies, developing techniques rather than producing commerical items. Of the 1100 on staff, about 600 are scientists and technicians. The bipolar group has produced an emitter-coupled logic circuit that is a 1024-bit random-access memory with an address access time of 28 nanosec. The metal oxide-semiconductor group is developing an 8000-bit memory. Another group is working on a microprocessor that would resemble the Intel 8080, which was introduced by Intel five or six years ago.

Wu Tzu-liang, who heads one of the eight departments in the Institute, told me that the Chinese computer industry has built middle-scale integrated circuits. He said that the fastest computer built in China, which became available in 1978, can do 5 million calculations/sec (putting it in the same range as US computers). The Institute of Metallurgy cooperates with the Institute of Computer Science in Peking and with many semiconductor factories in Shanghai.

The Institute physicists showed me a crystal being grown consisting of GaAs doped with Si, Te, or Cr. Germanium or gallium crystals were grown with a purity of 1 part in 10^6. The experimenters were using vapor-phase epitaxy to produce $AsCl_3$ and Ga. Their gallium source operates at temperatures higher than 800 °C; the substrate temperature is about 750 °C. A single epilayer had a thickness of about 1 micron. Recently, the experimenters have made an epilayer half a micron thick to be used as a far-infrared detector. The detector itself will be built at the Institute of Technical Physics.

The Institute of Physics in Peking was about to start operating a Chinese-built molecular-beam epitaxy system with a vacuum of 10^{-9}–10^{-10} torr. The system also has energy-analyzing apparatus for scanning high-energy electron diffraction and for Auger spectroscopy.

I saw a recently completed Auger electron spectrometer at the Institute of Metallurgy, suitable for analyzing surface layers in the range 5–20 Å. It has an energy resolution of 0.3% and a vacuum of 8×10^{-10} torr. As one of the first experiments with the device, the group recently detected a calcium impurity (0.2%) in the surface layer of stainless steel.

The Institute of Physics in Peking, established in 1950, has a staff of over 1000, and specializes in solid-state physics. It also has a laser lab, a tokamak, a group studying gravitational waves and a small theoretical group. Within the Institute of Physics are four labs established in the 1950's—magnetism, crystallography, low-temperature physics and high-pressure physics.

Deputy director Kuan Wei-yen (who had worked at Kapitza's Institute of Physical Problems in Moscow) told me that in its early days the Institute did mostly applied physics. By the 1960's the Institute was supplying superconducting materials for industry and for large-scale experiments, producing for example, niobium–titanium and niobium–tin. During the same period the Institute also produced synthetic diamonds and made crystals such as ruby rods. Kuan feels that during this period some of the Institute's research was at an international level. But with the onset in 1966 of the Cultural Revolution, research was gravely affected and sometimes stopped entirely.

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Clean room at the Institute of Metallurgy in Shanghai. An American visitor examines a circuit chip under a microscope.

Now that basic research and theory are no longer in disfavor, three new labs were established in the Institute (early in 1979)—surface physics, superconducting materials and solid-state spectroscopy. Construction of superconducting magnets is now being done at the nearby Institute of Electronic Engineering, to be used for high-energy physics, magnetohydrodynamics and plasma physics. They are making a 4-tesla dipole magnet made of multifilament niobium–titanium; the diameter is 10 cm and the total length is 1 meter. Although the magnet is intended for the Institute of High Energy Physics, the 50-GeV synchrotron being developed there will use conventional magnets.

The Institute of Physics has built and is using for solid-state research an 11-tesla superconducting magnet with a 4-cm diameter. It has two concentric coils—one of niobium–titanium and one of niobium–tin. Kuan says the Institute has stopped working on type II superconductors and is trying to find high-transition-temperature superconductors. The Institute is also planning to make quasiparticle junctions for the study of transition-metal phonon spectra.

The Institute of Physics spent two years building a dilution refrigerator, which has now reached 30 mK. Kuan notes that this is not good compared to refrigerators built abroad; for example, Grenoble reaches 1 mK. Now the Institute experimenters are trying to calibrate their low-temperature carbon resistor thermometer. They are also using a rhodium–iron resistance thermometer.

Last year the Institute's magnetism group published some work on low-temperature resistivity anomalies in sputtered Gd–Co alloy films. During a lab tour I saw their equipment. Another group is working on magnetic bubbles, but they are still a long way from being usable as computer memories.

Although the theory group at the Institute of Physics was disbanded during the Cultural Revolution, it has been revived. Recently a new Institute for Theoretical Physics has been established in Peking, with some of its 29 theorists temporarily housed in the Institute of Physics.

The University of Nanking is doing research in crystal defects, is building a mixer using the Josephson effect and is doing basic measurements on superconductors at liquid-helium temperature. Lower temperatures are not yet available; however a dilution refrigerator is being built. I saw a crystal-growing furnace, being used to make $KNbO_3$ (pulled at 0.33 mm/hour) and yttrium–aluminum garnet (pulled at 0.1–0.15 cm/hour). It takes the group two days to grow $KNbO_3$, five or six for YAG. But while I toured the physics labs at the University, no electricity was available. When a power outage occurs, the crystals are frequently ruined.

One of the vice-presidents of Futan University is Hsieh Hsi-teh, who also heads the modern-physics research effort there. After she received her PhD from MIT in the 1950's, she returned to China and helped to start semiconductor research there. Futan is doing semiconductor, surface and laser physics. On the lab tour, I saw an experiment on soft x-ray spectroscopy looking at the surfaces of stainless steel and silicon.

Futan also has a laboratory for electric-light research. My hosts showed me a large diplay of unconventional light sources. For example, the lab had built metal-halide lamps for plant growth, to produce photochemical reactions and to attract insects or fish. There was a pulsed high-luminosity lamp for high-speed photography or optical pumping, xenon lamps with either a short or long arc, and another lamp for simulating a solar source. A fluorescent lamp without an electrode was shown; the mercury discharge is produced by high-frequency induction. I also saw a high-pressure sodium lamp, cadmium, zinc, hydrogen arc and blackbody lamps. —GBL

Laue–Langevin Institute expands

The von Laue–Langevin Institute, at Grenoble in the French Alps, is getting its second wind. This much we are told by the appellation *Deuxieme Souffle*, the name given to the 104-million-franc renewal program recently approved by the steering committee of this joint French–German–British neutron-beam laboratory. The planned expansion of neutron sources and instrumentation should add significantly to the experimental capabilities of what is already the most powerful source of continuous neutron beams in Europe—and the leading source of cold and ultra-cold neutrons in the world.

The high-flux research reactor at the Laue–Langevin Institute has been serving experimenters with a prodigious array of neutron-beam facilities and instrumentation since it first went critical in 1972. Neutron beams ranging from hot to ultra-cold have been used for studies in solid-state, nuclear and elementary-particle physics, chemistry and biology.

Running at 57 megawatts, the ILL reactor provides a flux of thermal neutrons comparable with the high-flux reactors at Brookhaven and Oak Ridge, but it has considerably more neutron-beam ports and auxiliary facilities than any of its American rivals. The Oak Ridge reactor has no cold-neutron source, and the Brookhaven cold source is just now coming on the air for the first time.

The Deuxieme Souffle envisions an expenditure of FF 104 million (about $25 million) over the next five years, over and above the Institute's normal operating budget of FF 140 million a year. The operating budget of this one Institute is half again as large as the total budget for comparable research at all US neutron sources. It is not considered economically feasible to augment the basic reactor flux appreciably. Therefore the major plans of the renewal program are for the development of improved neutron-beam sources in the heavy-water reflector surrounding the reactor core.

The reactor core is immersed in D_2O, which serves as a moderator to bring the MeV fission neutrons quickly to thermal equilibrium at room temperature, with a mean energy of about 1/40 of an electron volt. For experiments requiring cold and ultra-cold neutrons, a liquid-deuterium moderator near the core cools neutrons to a temperature of about 25 K (0.0002 eV). The renewal program calls for the replacement of this cold source by an improved design with a factor-of-two increase of cold-neutron flux.

A second cold source is planned for one of the present thermal-neutron ports. Using liquid hydrogen as a moderator, this source will provide optimum flux in the wavelength region 2–5 Å, which lies between the thermal and liquid-deuterium source spectra. De Broglie wavelengths of this order are particularly suitable for the investigation of biological, polymeric and metallurgical structures by small-angle neutron diffraction scattering. This second cold source will also permit the installation of novel instruments for such experiments, as well as intense polarized beams for solid-state and elementary-particle physics.

Ultra-cold neutrons are so slow (a few meters per second, comparable to a jogger) that they are totally reflected at the surfaces of most solids (PHYSICS TODAY, June 1977, page 42). Whereas the wavelength of thermal neutrons is of the order of crystal lattice spacings (making them useful probes for solid-state studies), ultra-cold neutrons, at a temperature of about a millikelvin, have wavelengths of the order of a thousand angstroms, and therefore see most condensed matter as an impenetrable barrier. This permits them to be confined for periods of a few minutes, making possible extremely accurate measurements of the electric dipole moment and (with additional magnetic confinement) the lifetime of the neutron—roughly 15 minutes.

The new liquid-deuterium cold source is designed to permit the extraction of an ultra-cold beam with an intensity greater by one or two orders of magnitude than any ultra-cold beam in existence at present. These neutrons will be slowed down from liquid-deuterium temperature by being made to work against gravity in a vertical guide and against the blades of a cold-neutron turbine.

The liquid-hydrogen cold source may eventually be used to feed a system of neutron guide tubes with "supermirror" surfaces. Guide tubes steer neutrons around gentle bends by taking advantage of the fact that they will be totally reflected even at speeds above the critical ultra-cold velocity—as long as they hit all surfaces at a sufficiently small grazing angle, so that the velocity component normal to the surface is subcritical. Supermirrors are devices that extend the critical grazing angle for total reflection by about a factor of three. This is accomplished by depositing alternating layers of increasing thickness of two materials with different neutron scattering lengths.

Devices such as vertical guides and turbines, which do not actually remove heat from the neutron gas, cannot increase the density of ultra-cold neutrons beyond their concentration in the reactor itself. To achieve high densities of stored ultra-cold neutrons, Robert Golub and Michael Pendlebury of the University of Sussex have proposed that a beam of cold neutrons (10 Å) be cooled and trapped in a container of superfluid helium-4 at 0.7 K. The neutrons would give up heat by quantum excitation of the superfluid.

Golub and two ILL physicists, Paul Ageron and Walter Mampe, have recently demonstrated the production of ultra-cold neutrons by this technique, and a 3-meter-long moderator vessel of superfluid He^4 will be built during the renewal program as an external ultra-cold source. The first experiment intended for this facility will be a search