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.

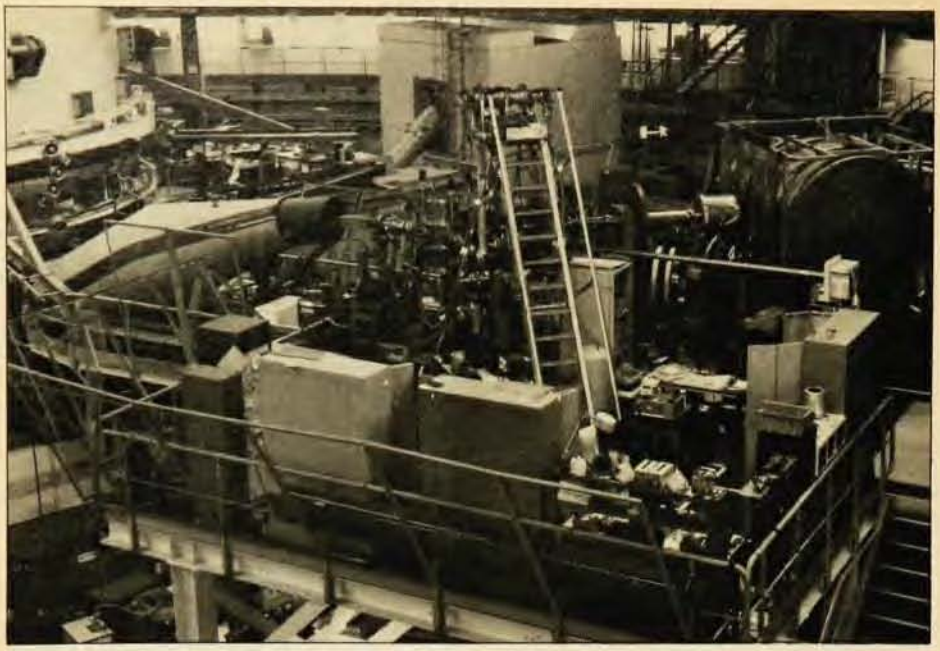
Ultra-cold neutrons are so slow (a few meters per second, comparable to a jogger) that they are totally reflected at the surfaces of most solids (PHYSICS TODAY, June 1977, page 42). Whereas the wavelength of thermal neutrons is of the order of crystal lattice spacings (making them useful probes for solid-state 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



Laue–Langevin Institute high-flux reactor is behind the cylindrical shielding wall at the far left. Ultra-cold neutrons emerge after being slowed by gravity in the thickly shielded, inclined neutron guide at the left. A horizontal guide tube brings them to the large cylindrical magnetic shield at the right rear, which houses the apparatus of the Harvard, Oak Ridge, Sussex, Rutherford, Grenoble group for measuring the electric dipole moment of the neutron.

for a non-zero neutron electric dipole moment.

Time-reversal invariance forbids the neutron to have an electric dipole moment, but the behavior of the neutral kaon system strongly implies that time-reversal symmetry is not inviolate. Various theoretical estimates of the dipole moment (divided by the charge of the electron) range from 10^{-20} to 10^{-32} cm. Steven Weinberg's gauge-theoretic estimate of a few times 10^{-25} cm is not far from the present experimental upper limit. Pendlebury and his Sussex colleagues, together with Norman Ramsey's Harvard group and physicists from Oak Ridge, the Rutherford Lab and Grenoble, have been looking for a neutron electric dipole moment at the ILL since its inception. Using cold neutrons from the liquid-deuterium moderator they have determined an upper limit of 3×10^{-24} cm for the dipole moment. V. M. Lobashov and his coworkers at the Leningrad Institute of Nuclear Physics have more recently used ultracold neutrons to bring the upper limit down to 1.6×10^{-24} cm. With the new ultracold source, the ILL collaboration hopes to be able to reduce this limit by perhaps two orders of magnitude, providing a strong test of the gauge-theoretic prediction, and shedding light on the mechanism of CP symmetry violation in the neutral kaon system.

Ramsey's graduate student, Blayne Heckel, reported at the Washington APS meeting in April that their collaboration (Harvard, Oak Ridge, Sussex, Rutherford, Ispra) has observed parity-violating rotation of the polarization of cold neutrons passing through 5 cm of tin at the ILL. This precession is attributed to the parity-violating component of the weak interaction between the neutrons and the electrons and nucleons of the tin.

The neutron is inconveniently long-lived, as elementary particles go, for an accurate determination of its mean life. The lifetime of the ephemeral lamda hyperon is known with better fractional precision. Reducing the present 14-second uncertainty on the 918-second neutron lifetime should contribute to our understanding of the weak interactions. Because one can store ultra-cold neutrons in a confined space for long period, they can be used to measure the mean decay time with great accuracy. But the confinement of ultra-cold neutrons by reflection off containment walls is less than perfect; the record to date is a few hundred seconds. Wolfgang Paul and Uwe Trinks (University of Bonn) have therefore been investigating magnetic confinement. They have succeeded in trapping ultra-cold neutrons for 45 minutes at the ILL in a small storage ring with a 50-kilogauss hexapole field produced by toroidal superconducting coils. They are now building a "magnetic bottle," which will be filled with liquid He^4 to render neutrons ultra-cold before trapping them.

The continuous neutron-beam currents produced by even such high-flux reactors as that at the Laue–Langevin Institute are still at least an order of magnitude lower than those available to experimenters using electron, proton, or photon beams, and inadequate for what is required by some of the new experimental techniques. To provide higher neutron currents and the timing capabilities possible with pulsed (as distinguished from continuous) beams, the US, Japan and several European countries are building new spallation sources. In these facilities, intense short bursts of neutrons are generated by GeV protons hitting a metal spallation target. (See PHYSICS TODAY, December 1979, page 42.)

The Deuxieme Souffle seeks to develop new capabilities at ILL that will complement the spallation sources and other national facilities. John White, the director of the Institute for the past three years, argues that continuous high-flux neutron beams such as those at Grenoble are likely to retain their superiority over pulsed spallation beams for polarized neutron diffraction and polarization analysis, high-resolution inelastic scattering and spin-echo spectrometry, and nuclear and elementary-particle physics.

The renewal program will emphasize the development and installation of new instrumentation and techniques in these areas of neutron experimentation. The Institute plans to build magnetic supermirrors for the production of intense beams of highly polarized neutrons. Whereas the supermirrors used in cold-neutron guides have alternating layers of different (nuclear) scattering length, the alternating layers of a *magnetic* supermirror achieve polarization by having different magnetic scattering properties. A neutron experiences two major classes of scattering in materials: nuclear collisions, and magnetic-dipole interactions with electron spins and orbits.

Polarized neutron beams make it possible to distinguish between nuclear and electronic scattering, permitting detailed study of magnetic spin densities and disorders in materials. With polarized beams, one can also achieve very good energy resolution in neutron scattering experiments, by employing spin-echo techniques that use the precession of scattered neutrons in the magnetic field of a spectrometer as a sensitive measure of velocity. The application of spin-echo techniques to a three-axis spectrometer, and a diffractometer for separating the thermal diffuse scattering are currently being tested. Nuclear physics will be served by an improved polarized beam and a new fission-product spectrometer.

A new biology/chemistry laboratory to be built at the Institute in collaboration with the European Molecular Biology Laboratory will exploit neutron scattering for the study of viruses, biological tissues, DNA structure, polymer structure and dynamics, and for high-resolution molecular spectroscopy of solid and liquid crystals. —BMS □