search & discovery

France and Germany share their thermal-neutron reactor

Unlike most tools of experimental condensed-matter physics, powerful sources of thermal neutrons demand a high initial investment, and the expense may be too great for a single nation. At the Institut Laue–Langevin, Grenoble, the French and German governments have solved the problem by sharing the costs of their new high-flux research reactor. The project, which will provide the highest external flux of thermal neutrons available, is moving from the construction to the experiment stage, and Rudolf Mössbauer has recently been appointed director of the Institute.

The reactor project was agreed to in 1967 by representatives of France and Germany, and the Laue–Langevin Institute was created to oversee the construction and operation of the reactor. Mössbauer took over as director from Heinz Maier-Leibnitz, and B. Jacrot remains as adjoint director. German and French organizations share the reactor costs equally, the French Commissariat a l'Energie Atomique and Centre National de la Recherche Scientifique each contributing 25%, and the German Gesellschaft für Kernforschung contributing 50%. The total investment was 335 million francs (roughly $70 million), including the reactor, experiments, buildings and personnel. The construction cost for the reactor itself was 138 million francs.

The Grenoble reactor is, like the Brookhaven High Flux Reactor, specially designed for condensed-matter studies, and its principle is similar to that of the Brookhaven reactor. The fissile fuel (an aluminum–uranium alloy enriched with U^{235}) is concentrated in a small core, and the escaping fast neutrons are brought to thermal equilibrium in a surrounding heavy-water moderator or reflector section. Some of the neutrons return to the core to support the chain reaction, and the others are available for experiments.

In three design points the Laue–Langevin reactor differs from the one at Brookhaven: It has a cold-neutron (energy less than 5 meV) source that increases the cold-neutron flux by a factor of 50 or so, a hot-neutron source that increases the flux of 0.5 eV neutrons by a factor of about 20, and a system of neutron guides that greatly reduces the

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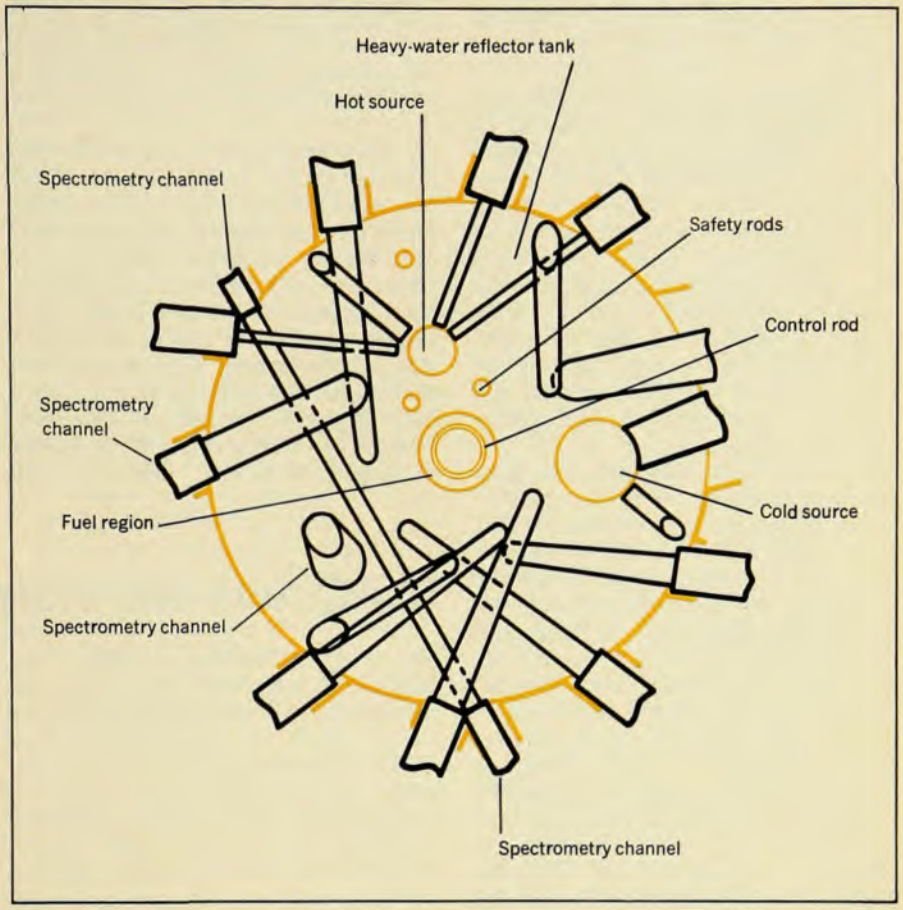


High-flux neutron reactor at the Laue–Langevin Institute, Grenoble. Horizontal cross section of the 2.5-meter (diameter) reflector tank shows the spectrometry channels for extracting neutron beams; these channels are oriented with axes that do not reach the reactor core, so that the transmission of the unwanted fast-neutron background is minimized.

Vibrational lifetimes in liquids

For the first time the vibrational population lifetime of simple normal modes of polyatomic molecules in liquids has been directly measured, according to the experimenters, Alfred Laubereau, Dietrich von der Linde and Wolfgang Kaiser[1] (Munich Technical University). Earlier the vibrational dephasing lifetime in both liquids and solids had been measured by the Munich group,[2] who studied polyatomic molecules in liquids and lattice vibrations in diamond, and by Robert Alfano and Stanley Shapiro[3] (General Telephone and Electronics), who measured lattice vibration lifetimes in calcite and molecular vibrational lifetimes in liquid nitrogen. Some observers believe that the technique opens a new field for the study of molecular relaxations in liquids and optical phonon relaxations in solids.

In their most recent paper the Munich group has actually measured two lifetimes. One is the lifetime of the excited vibrational state of the molecules; in nuclear magnetic resonance studies this time is known as T_1, the

relaxation time (or population lifetime), the time it takes for the energy in the system to make a transition to the ground state. The second lifetime, the dephasing time of the vibrations, corresponds in nmr studies to T_2, the phase memory time.

The first measurement of population lifetime in a fluid, hydrogen gas, was done by F. DeMartini and Jacques Ducuing[4] (then at MIT). In the measurements of DeMartini and Ducuing the times were in the microsecond range, whereas the Munich measurements are done in the picosecond range. The technique, however, is similar.

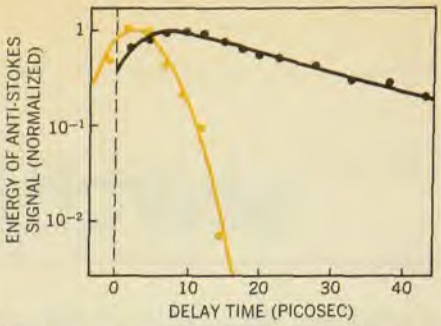
To measure the ultrashort lifetimes the experimenters excite vibrations by stimulated Raman scattering generated by applying a powerful picosecond optical pump pulse. This causes an increase in the population of the excited vibrational state. Under normal circumstances the population of the molecules in the excited vibrational state is small; so all that are there have been produced by the pump laster pulse. The number of excited vibrations that are created is proportional to the stimulated Raman light.

You then apply a second probe pulse and look at the probe Raman scattering as a function of time after the first pulse. By varying the delay time between pump pulse and probe pulse and measuring the intensity of the probe Raman scattering you can determine the rise and decay of the excess density of excited molecules, thus directly measuring the vibrational decay time.

When you apply the probe beam at an angle such that the probe beam, the probe Raman light and the created vibrations are phase matched together, then the lifetime that is measured is called the "dephasing time" (since the probe scattering intensity is sensitive to both the phase and population of the molecular vibrations). If the probe scattering is detected in a direction in which phase matching to the created vibrations is unimportant, the time that is measured is called the "population time." This scattering in a non-phase-matched direction is very weak.

In their new experiments, the Munich group studied trichloroethane and ethyl alcohol. For trichloroethane they found a population time, for the CH_3 valence-bond vibration, of $(5 \pm 1) \times 10^{-12}$ sec and a dephasing time four times shorter. For ethyl alcohol they found a population lifetime of $(20 \pm 5) \times 10^{-12}$ sec and a dephasing time 80 times shorter. They remark that their values for the two kinds of lifetimes show clearly that phase relations between excited molecules relax more rapidly than does the vibrational energy.

At the moment there is practically no understanding of what value these lifetimes should have in liquids, of how fast vibrational energy can be transferred to other degrees of freedom such as rotation, vibration, libration and translation, or transferred among molecules; in fact the energy-transfer mechanisms themselves are little understood. One leading experimenter feels that the technique is opening up a new field in physical chemistry—the study of rates of transfer of vibrational energy among molecules. He also feels that these experiments may turn out to be even more interesting in solids, where one would concentrate on energy transfer involving optical phonons, rather than the much-studied acoustic phonons.



Lifetimes for ethyl alcohol. Colored points show the decay of the coherent scattering, from which the dephasing time can be calculated. Black points show the decay of the incoherent scattering, from which it is possible to calculate the vibration time.

Alfano and Shapiro feel that the next stage will be to measure what the phonons decay into. They feel that many solid-state physicists will be interested in these measurements because optical phonons play a fundamental role in various processes in solid-state physics such as infrared absorption, hot-carrier effects and luminescence, and because phonon decay rates give a measure of the lattice anharmonicities. —GBL

References

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SLAC runs one storage ring, plans one

The electron-positron storage ring, SPEAR, is now running at SLAC as scheduled, and performance attained so far meets all expectations. Now SLAC, in collaboration with the Lawrence Berkeley Laboratory (LBL), is looking ahead to a still more powerful colliding-beam device called "PEP", a device that would involve collisions between protons, electrons and positrons.

SPEAR is a single storage ring in which counter-rotating beams of electrons and positrons collide in two interaction regions that allow high luminosities without exceeding the limit for beam–beam instabilities. The interaction regions have specially tailored beam-optical properties, called "low-beta insertions" to facilitate collisions of high-intensity, high-density beams without seriously affecting the orbit dynamics. The energy is variable and will go to a maximum of 2.8 GeV in each beam. The design maximum luminosity (the number by which the cross section is multiplied to get the interaction rate) is 10^{32} cm^{-2} sec^{-1} at an energy slightly above 2 GeV in each beam with circulating currents of 0.25 amp each.

SLAC began building SPEAR in August 1970, financing it as a multiyear equipment project out of the regular laboratory budget. Its total estimated cost was $5.3 million, and SLAC stayed within its budget.

On 22 April, six days after tests began, SPEAR stored its first positron beam. Two days later the first electron beam was stored and two days after that the first beam–beam collision occurred. Since then the experimenters straightened out their closed-orbit deviations, raised the single-beam circulating current to 50 milliamps in each beam and achieved luminosities of 1.2×10^{30} cm^{-2} sec^{-1} per interaction region with about 20 milliamps of electrons colliding with 20 milliamps of positrons. This luminosity now makes SPEAR the world's highest-luminosity colliding-beam device for electrons and positrons, said Burton Richter. He believes that the peak circulating current, which is 39 amps, is the highest peak current ever circulated in such a machine. At present the highest energy electron–positron colliding-beam device is at the Cambridge Electron Accelerator (PHYSICS TODAY, June, page 20).

Richter says that the correcting and control elements have so far been able to control most of the suicidal urges of the circulating beams. However, they do find one beam instability at 50 milliamp that causes a coherent growth of radial amplitude and loss of about