TECHNOLOGY

Ivars Peterson reports from Gatlinburg, Tenn., at the 25th Conference on Analytical Chemistry in Energy Technology

Where chemists fear to tread

There are places, like the highly radioactive environments in nuclear-fuel reprocessing plants, that are too hostile, hazardous or inaccessible for normal measuring instruments. Tomas B. Hirschfeld, Terrence Deaton and David C. Camp at the Lawrence Livermore National Laboratory are developing remote methods of monitoring actinide concentrations and other properties in such locations.

They use high-quality, long-distance optical fibers, originally developed for telephone networks, to link a laser and conventional spectrometer to the monitoring sites. The tough quartz fibers, less than a millimeter thick, can withstand temperatures as high as 300°C and seem resistant to radiation doses of 10^7 rads or more.

When the system is in place, the analyst sends laser light pulses hundreds of meters through a single fiber to the location of interest. There, the light causes any uranium and other materials present to fluoresce. A tiny sapphire sphere, attached to the end of the fiber in an assembly called an optrode, focuses some of the scattered fluorescent light and sends it back along the fiber to a spectrometer for analysis.

The researchers have found that by modifying the optrode they can measure properties including temperature, pressure, pH and salinity, along with the concentrations of fluorescent materials. Thus, one laser and spectrometer, controlled by a switching center, can monitor a variety of properties at many, distant inspection points.

Simpler investigations of messy samples

"Messy," radioactive samples in unknown chemical form are often difficult to analyze. Warner H. Christie and Raymond E. Eby at the Oak Ridge National Laboratory have shown that a highly sensitive secondary ion mass spectrometer (SIMS) can determine the isotopic ratios for many elements of interest in the nuclear fuel cycle.

One advantage of their method is that the samples required are so small that the materials can be handled in unshielded equipment, and the instrument itself does not become contaminated. Recently, Christie and his group demonstrated that only 20 to 60 femtograms (10^{-15} gram) of uranium left a sample during analysis. This amounts to fewer than a billion atoms.

One application of the method has been quantitative determination of boron and lithium in highly radioactive aqueous solutions of unknown composition generated in the Three Mile Island nuclear reactor accident. The diluted sample used in the spectrometer emitted less radiation than would a wristwatch with a luminous dial. Yet, it was possible to determine the lithium isotope ratio with a precision of 0.5 to 1.0 percent.

In the SIMS method, a source generates a beam of ions, O_2^+, O_2^- or Cs^+, depending on the sensitivity required. The accelerated ions strike a specially prepared surface of the finely ground sample on a carbon substrate. The bombarding particles dislodge material from the surface as ions, neutral atoms and molecular species. After the ions are mass analyzed, detectors monitor the appropriate elemental ions.

Christie and his group believe that SIMS may be useful in the analysis of highly radioactive solutions produced in reprocessing spent reactor fuels. They have already shown how easily the technique measures boron isotope ratios in borosilicate glass. Rings made of this glass are loaded into vessels containing solutions of fissionable uranium to ensure the handling safety of the containers. The glass is sampled regularly to verify that no significant neutron-producing event has altered the boron isotope ratio. The traditional electron impact method was slow, undependable and involved complicated solution chemistry.

PHYSICAL SCIENCES

Dietrick E. Thomsen reports from New York at the annual meeting of the Division of Plasma Physics of the American Physical Society

Reflections on a tandem mirror

The basic problem in the physics of controlled thermonuclear fusion is to confine an ionized gas — that is, a plasma — against its natural tendency to expand and make it dense enough and hot enough to ignite a self-sustaining fusion reaction. A large number of different experimental designs attempt to use magnetic fields to confine the plasma, but plasmas interact in complex ways with magnetic fields, and these approaches have run into one difficulty after another. A fairly new approach, the so-called tandem mirror, is designed to add electric fields to magnetic fields in the attempt at plasma confinement. It has been exhibiting some success in showing that it may work.

The center of a tandem mirror — the one reported on here is the TMX at the Lawrence Livermore National Laboratory in Livermore, Calif. — is a solenoid, a cylinder surrounded by magnet coils. If one tries to keep a plasma in the solenoid, the ions and electrons in the plasma will spiral along the magnetic field lines and out the ends. Strengthening the field at the ends (making a "magnetic mirror") will cause some of the particles to be reflected back into the solenoid, but too many still escape. The TMX design is to plug the ends with dense separate plasmas confined by "fishtail" magnetic fields (so-called from the shape of the field lines).

A fishtail field will hold a fairly dense plasma. The dense plasmas in the ends of the TMX are supposed to generate electrostatic fields (by reason of the electric charges of the particles) and so aid in the confinement of the plasma in the solenoid. The plasmas in the fishtails continually lose material to the outside and so have to be continually replenished. But if that expense can be borne, maybe the solenoid plasma can be confined, increased and heated to the point of ignition. Late last year (SN: 11/22/80, p. 328), the TMX investigators reported that electrostatic plugging worked along the axis of the device.

But the TMX has a certain cross section, and for practical purposes electrostatic confinement ought to work across the whole cross section. At the meeting, D.L. Correll of Livermore reported that the TMX group has achieved electrostatic confinement working from axis to wall (although weaker at the edges than on the axis). The researchers believe that they understand the field configurations across the cross sections well enough to go on toward better confinement and ultimate ignition.

Radio wave heating of plasmas

In a number of experiments thermonuclear plasmas can be heated by resistance to electric currents "naturally" induced in them by the very magnetic fields that confine them. However, even where this "ohmic" heating is present, it seems that some auxiliary means of heating will be necessary.

One such method is to inject energy into the plasma by passing radio waves through it. The principle is similar to that of the microwave oven. It could lead to steady-state fusion reactors, ones that yield energy continuously. These are technically preferable to the pulsed reactors required by rival heating methods.

The available frequency range is divided according to the different aspects of the dynamics of the plasma that the given frequencies couple to when they deliver the energy. As Miklos Porkolab of Massachusetts Institute of Technology reviewed them, the ranges are: Alfven waves (less than 10 megahertz), ion cyclotron resonance (ICRF, 20 to 200 MHz), lower hybrid heating (LHH, 600 to 5,000 MHz) and electron cyclotron resonance (ECRF, above 28,000 gigahertz). According to Porkolab the best results so far have been with ICRF (20 million degrees in the Princeton Large Torus) and LHH. Physicists are encouraged that they may someday reach the 100 million degrees needed for ignition.