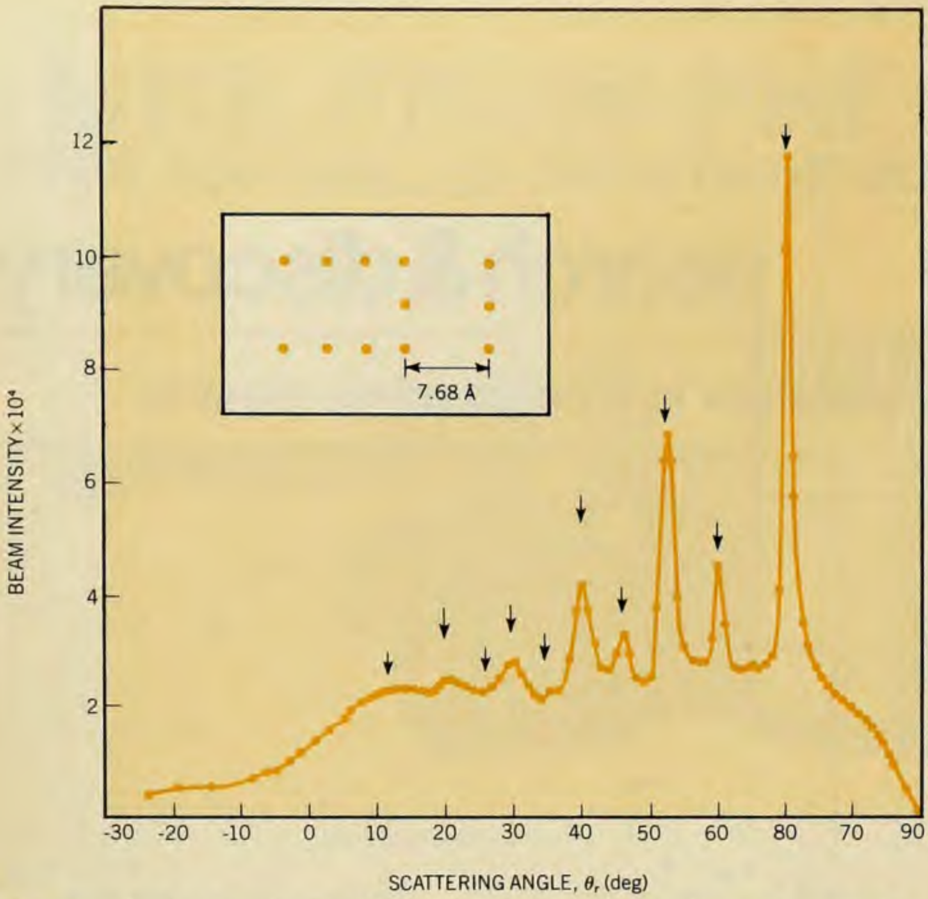

Diffraction of helium atoms from the (100) surface of silicon as observed by Cardillo and Becker. The intensity of the scattered helium beam is plotted as a function of the scattering angle, θ_r. The incident angle is 70° and the wavelength of the helium atoms is 0.57 Å. The inset shows the arrangement of the crystal unit cells for a two-domain 2 × 1 net for the (100) surface of silicon.

Genoa under Giovanni Boato, for example, has used helium atoms and hydrogen molecules to probe surfaces of graphite and silver. Robert P. Merrill and his coworkers at Cornell have examined tungsten and other metals. A group at the University of California at San Diego under David R. Miller has used the inelastic scattering of atoms to examine the behavior of phonons at the crystal surface. And a group at Penn State headed by Daniel R. Frankl is now investigating the two-dimensional band structure of alkali-halide surfaces using atomic helium. There is a concomitant interest in theoretical work related to these problems as well, and groups at Case–Western Reserve, San Diego, State University of New York at Stony Brook, Madrid, and the University of Virginia, among others, are investigating the theoretical aspects of the scattering.

To obtain their beam, the Bell Labs experimenters used a high-pressure expansion nozzle that produces a supersonic, collision-free beam with a relatively narrow, adjustable velocity range. In their experiments, helium speeds ranged from about 1 km/s to about three times that, with a spread (full width at half maximum) of 12%. The corresponding wavelengths are 1.06 Å to 0.32 Å. The scattered beams are in general extremely weak (10^{-3} or 10^{-4} times the incident intensity in Cardillo and Becker's experiments, for example) and require very sensitive, but by now standard, detection techniques. The atomic beam was chopped at the source and then detected with a quadrupole mass spectrometer and a lock-in amplifier.

The major difficulty in observing the diffraction is in obtaining a clean, regular surface. In these experiments, the crystal was cut and polished outside the vacuum chamber, but cleaned and annealed *in vacuo*. The scattering, and presumably therefore the crystal surface, degrades within minutes, due to adsorption of residual gases even at ultra-high vacuum (about 6×10^{-10} Torr). Cardillo and Becker therefore heated the crystal frequently to drive off adsorbed gases. The brief heating completely restored the intensity of the specular reflection, and, by implication, the crystal surface.

Results. From their data, Cardillo and Becker have confirmed the 2 × 1 two-domain structure of the Si(100) surface obtained with LEED. The basic structure has a fourth-order periodicity as well, a periodicity that is often difficult to see with LEED. More recently they have obtained data to demonstrate a 7 × 7 reconstruction of the Si(111) surface consistent with that obtained from electron-diffraction measurements. As in the diffraction of light, the intensity of the interference maxima is modulated by an envelope due to the internal structure of the unit cell; in this context the peaks in the envelope are often called "rainbow maxima." The atom diffraction data can thus give information not only about the regularities of the crystal surface, but also about the details of the contours within the unit mesh. Structural calculations for the (100) and (111) reconstructed surfaces of silicon are now underway at Bell Labs.

Atom diffraction is clearly a powerful tool for the examination of crystal surfaces. Needless to say, the application of this technique to semiconductors can be expected to have implications for technology, because as integrated circuits take up smaller and smaller volumes, the surface effects become more and more important. Furthermore, the geometry of the surface clearly plays a role in the formation of any junction, and therefore in the function of junction devices. As yet, the information about semiconductor surfaces is far from complete, and the new results can be expected to have a considerable impact. —TVF

Reference

1. M. J. Cardillo, G. E. Becker, Phys. Rev. Lett. 40, 1148 (1978).

Brookhaven light source invites user interest

To plan for the use of the National Synchrotron Light Source facility at Brookhaven National Laboratory, the lab is asking for expressions of interest or intent from potential users. The facility is now under construction; groundbreaking ceremonies were held 28 September. It is to consist of two electron storage rings, a 0.7-GeV ring to provide radiation between the infrared and about 10 Å, and a 2.5-GeV ring whose spectrum will extend down to about 0.1 Å (see PHYSICS TODAY, March 1977, page 17). The smaller ring is scheduled to be available for users by mid-1981; the larger is expected to be ready in late 1981 or early 1982.

The facility will provide a number of equipped beam lines for general users from universities, government and industrial laboratories, as well as Brookhaven staff scientists. In addition, some beam lines will be available for dedication to specialized uses by a Participating Research Team. Such a team can take a primary role in designing, constructing and maintaining a specialized beam line and will, in turn, for an agreed-upon time period have exclusive use of the beam for a fraction of the scheduled beam time.

Expressions of interest or intent both from potential general users and from potential members of Participating Research Teams should be sent to Martin Blume, Department of Physics, Brookhaven National Laboratory, Upton, N.Y. 11973, by 31 December 1978. A description of the facility, a statement of policy and outline specifications of the beam lines now being planned are available from the project secretary, C. Albert, NSIS project, Building 911C, Brookhaven National Laboratory.

PLT reaches high temperature

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year—3×10^{13} cm^{-3} sec when the density was 10^{15} cm^{-3} but the ion temperature was only 0.7 keV. These two experiments together suggest that tokamaks can achieve both good confinement and high temperature in more powerful experiments such as the Tokamak Fusion Test Reactor now under construction at Princeton.

This month at the APS Plasma Physics Division meeting in Colorado Springs, Eubank of Princeton is scheduled to report even higher ion temperature—6.5 keV—obtained by raising the neutral-beam power to 2.5 MW. Although previous tokamak experiments at lower temperatures indicate that confinement improves with density, higher neutral-beam-heating powers will be required to extend the high-temperature regime to higher densities and $n\tau_E$-values.

In a summary lecture at the Innsbruck Conference, C. M. Braams, who heads fusion research in the Netherlands, assessed progress in magnetic-confinement experiments. He started his talk with a quote from Lev Artsimovich (who pioneered the tokamak approach) in his summary lecture at the 1961 International Conference on Fusion in Salzburg: "It is now clear to all that our original belief that the doors into the desired region of ultra-high temperatures would open smoothly at the first powerful pressure exerted by the creative energy of physicists, have proved as unfounded as the sinner's hope of entering Paradise without passing through Purgatory. And yet there can be scarcely any doubt that the problem of controlled fusion will eventually be solved. We just do not know how long we shall have to remain in Purgatory. We shall have to leave it with an ideal vacuum technology, with thoroughly elaborated magnetic-field configurations, with accurately prescribed geometry of the lines of force, and with programmed cycles for the electrical circuits, bearing in our hands the high-temperature plasma, stable and quiescent, pure as a concept in theoretical physics when it is still uncontaminated by contact with experimental fact."

Bringing the audience up to date on the passage through Purgatory, Braams noted that "the most striking single result [in magnetic-confinement experiments]" is that "passing the milestone marked 'D–T ignition temperature' was achieved [in a tokamak]. It is true that very energetic ion populations have been produced before; it is also true that we are still some distance away from actual ignition conditions. The reason why, nevertheless, we attach so much weight to the results from the Princeton Large Tokamak is that we now have proof that one confinement method can satisfy both the temperature requirement and the requirements of plasma purity and isolation that are necessary for plasma energy break-even in a beam-plasma system, or—if one wishes to call it so—for the scientific proof of the feasibility of deuterium–tritium fusion-energy production."

The Princeton Large Torus, when it first started running in November 1975, was briefly called by some the "Princeton Large Turkey," Goldston told us. But the negative connotations of a turkey have surely been overcome in recent operation of the device. The Princeton Large Torus has a 32-kG magnetic field in the toroidal direction. As in a huge air-core transformer, current in the primary induces a toroidal current of about 0.5 MA in the plasma (the secondary). With the ohmic heating power of 600–700 kW, due to this current, PLT has obtained ion and electron temperatures of about 1 keV and 2 keV respectively. A maximum $n\tau_E$-value of about 10^{13}cm^{-3}sec was reached at a density of 1.5×10^{14}cm^{-3}.

Even when no powerful auxiliary heating is introduced, the plasma bombards the wall of the vacuum chamber, and impurities enter the plasma. In early experiments with ohmic heating in PLT, experiments used a tungsten limiter, wrapped around the plasma doughnut like a wedding ring. Goldston explained that tungsten was considered desirable because it has a minimal sputtering coefficient. However, even a very small admixture of partly stripped ions in the plasma turned out to be capable of radiating enough energy to the walls to short circuit the magnetic confinement of the plasma energy.

Neutral beams. Last Fall the experimenters turned on the 40-keV neutral-beam squrces. At first, results were very discouraging, Goldston said. Metallic impurity radiation increased by a factor of three or four, and electron heating was poor: $\Delta T_e = \pm 400$ eV.

Two changes in the apparatus helped alter the picture dramatically. One was to use a water-cooled graphite limiter. Graphite also has a fairly low sputtering coefficient. Furthermore, if one does get carbon atoms in the plasma, they are completely ionized in the core; so the carbon atoms cannot radiate energy from the plasma.

The second change was to use titanium gettering on the vacuum vessel, depositing a fresh layer of titanium on the stainless-steel surface (because it has become contaminated during each 2–5-minute rest period between shots. The rest is needed to cool the coils. The plasma discharge itself lasts for about 1 second.) During the experiment the titanium holds onto the light impurities such as oxygen and also prevents iron from getting into the plasma.

The $13-million Large Coil Test Facility (shown in a scale model) to be built at Oak Ridge will be used to test six 40-ton superconducting magnets, each about 15 feet × 12 feet, roughly half the size of magnets expected to be appropriate for early fusion reactors. The photo shows the 40-foot-high vacuum tank, in which the magnets will be mounted for testing, with its cover removed. In the foreground, a magnet coil is being moved with a lifting device. The facility is to operate in 1981. The design is flexible enough to allow testing later of full-size coils.