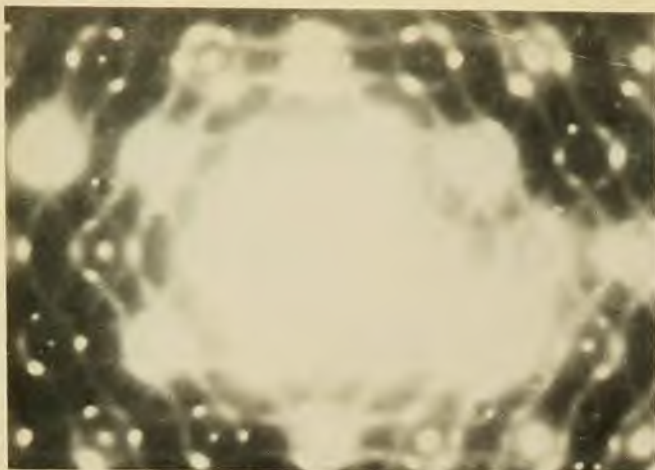
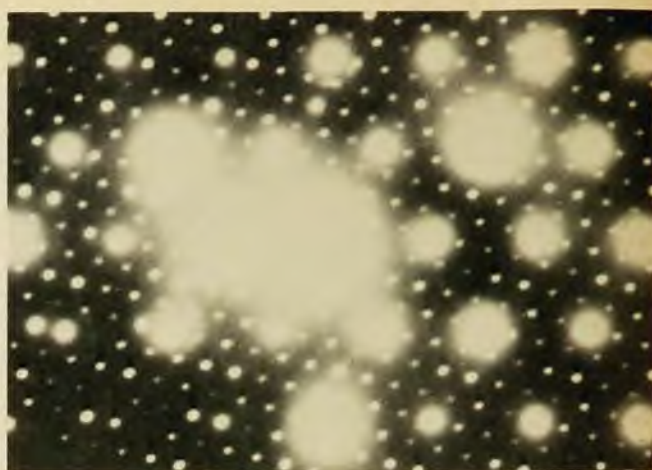




Satellite Bragg spots surrounding brighter reciprocal lattice spots result from charge density waves. Below a first-order transition, the period of the charge density waves changes from being incommensurate



(left) to being commensurate (right) with the lattice. The material is tantalum diselenide in octahedral coordination with one layer per unit cell. These electron diffraction photographs are from reference 1.

of the charge density wave depends on the temperature. At a sufficiently high temperature, the distortions are not seen at all. As the crystal is cooled through a transition temperature T_0 , the incommensurate distortions manifest themselves as satellite Bragg points with wave vector $\mathbf{G} \pm \mathbf{q}_0$, where $\mathbf{G}$ is a reciprocal lattice vector of the undistorted lattice. At a lower temperature still, the wave vector may become a rational fraction of a reciprocal lattice vector: the crystal then forms a commensurate superlattice. At this point, the position of the peaks changes, and their intensity may greatly increase (see figure).

Wilson, DiSalvo and Mahajan first showed that weak superlattice Bragg spots develop at the same temperature as that which characterizes electronic anomalies in resistivity and magnetic susceptibility in several materials. Their technique of electron diffraction located the positions of the Bragg spots well enough that Moncton, Axe and DiSalvo could use neutron scattering to study in detail the intensity and position of such peaks as a function of temperature. In particular they studied the behavior of one polytype of tantalum diselenide and niobium diselenide. The former had $T_0 = 122.3$ deg K and locked into a commensurate superlattice at 90 K while the latter had $T_0 = 33.5$ K and remained incommensurate down to 5 K. The Bell Labs group has also investigated the effects of doping on the formation of periodic structural distortions and has found strong dependence on doping levels—further evidence that the behavior is caused by charge-density wave instabilities because doping produces a systematic change in Fermi-surface dimensions.

The materials under study were metals such as niobium and tantalum sandwiched between two layers of material such as sulfur or selenium. They can

be made in various polytypes because the metal atom can be found in either octahedral or trigonal prismatic coordination and because the layers can be stacked in various ways. Overhauser has been working with colleagues at Purdue to find superlattice formation in pure elemental metals, where he believes they may also appear.

Not only experimental studies, but theoretical work should be done, asserts the Bell Labs group, in order to clarify the expected physical properties of charge-density wave systems. Their call is certain to be answered: Because of the recent experiments, interest in both charge and spin density wave instabilities has soared. Axe feels that an important area to be studied may be the extent to which the formation of charge density waves influences superconductivity, which is a better known and closely related example of a Fermi-surface instability.

—BGL

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Alcator team reports good plasma parameters

Alcator—the high-field toroidal plasma experiment at MIT—has achieved very successful operating conditions since last summer. Its plasma density is the highest of any Tokamak-like plasma-containment device, and its Lawson number (product of density and containment time) is competitive for the

high ion temperatures at which it runs (see box). Several unique features of this device are its high current density and the wide ranges of such parameters as density and plasma current. Alcator's staff is all the more pleased because the project had initially been making a slow start.

Bruno Coppi and Bruce Montgomery have led the design and construction of the machine. Ronald Parker and Robert Taylor participated in the final construction and have directed the experiments. Parker is the project manager. Collaborating with the MIT group throughout the construction was a team from the Institute for Plasma Physics from Jutphaas in the Netherlands. A team from Frascati, Italy conducted the Thomson-scattering measurements of the electron distributions, and a number of other overseas universities have collaborated in several experiments.

Alcator's name signifies "high-field torus," although, at 65 kG, the machine is far from its design field of 120 kG. Coppi told us that the field coils have been tested up to 100 kG but that they presently plan to increase the magnetic field in steps, doing all the plasma physics possible at each level. They hope to run at 75 kG within three months.

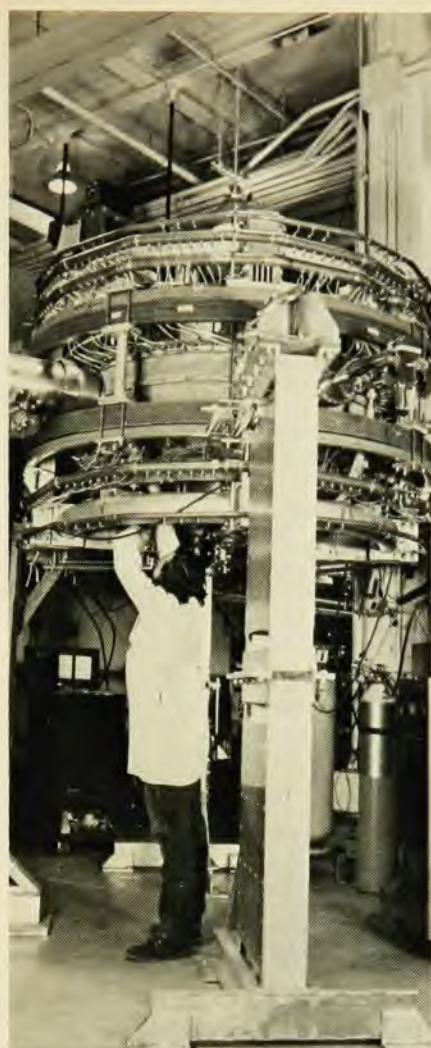
The original goal of this device, and one reason for its high field, was to reach high ion temperatures by producing plasmas with relatively large particle densities and vigorous ohmic heating of the electrons. Both of these features require high current densities whose maximum value depends on that of the magnetic field. In the absence of collective modes the ohmic heating of the electrons and the energy transferred from them to the ions results from elastic collisions between electrons and ions. Thus collisional ion heating is weak at low densities and relatively high temperatures. On the other hand,

"turbulent heating" of the ions can be achieved by stimulation of microinstabilities, which can have much stronger effects than collisions.

Recent experiments on the Alcator machine point to the identification of high ion temperatures (up to 1.2 keV) with just such a new and turbulent regime in the plasma. This so-called "slide-away" regime¹ seems to set in when the plasma density is low and the ratio of electron toroidal velocity to the thermal velocity is about 0.2 to 0.3. The strong ion heating that occurs under these conditions seems to correlate with the excitation of an ion plasma frequency mode.

The experimenters at Alcator have proposed a theoretical explanation for the behavior they observe in this region. The Thomson-scattering measurements² of the electron distributions in the slide-away regime suggests a combination of two distributions—one of non-current-carrying electrons, and the other of current-carrying electrons that circle around the toroid. The circulating electrons are held from running away collectively, under the influence of the applied electric field, by the same microinstability that heats the ions as well as by other microinstabilities that only affect the electrons and have been well identified experimentally. These slide-away electrons might be distinguished from the "run-away" electrons that are usually associated with unfavorable instabilities by the fact that they keep together in a large group and do not attain the high speed of run-aways. The ion temperatures are measured by charge-exchange reactions and by emission of neutrons from fusion reactions.

Other, indirect experiments at Alcator indicate that it has an exceptionally clean plasma—an exceedingly important property for future Tokamak scaling. Coppi confesses that they do not yet know the exact reason for this pu-



Alcator, the Tokamak-like device at MIT, features high values of current densities. Its magnetic field of 65 kG is being increased in steps; the coils have been tested to 100 kG.

rity but plan to determine its cause and measure the impurity concentrations. They also have deduced that, because the energy confinement time varies directly with density in Alcator, the product of density and containment time goes as the square of the density.

The MIT device is a university experiment, as distinguished from more heavily funded projects such as those at national laboratories. But its work lies midway between the exploratory area of pure research, typical of university projects, and its "national-laboratory" role of determining parameters in a new and interesting region. Thus it will be especially useful as a research tool to explore plasma physics relevant to thermonuclear reactors; its wide range of parameters and high magnetic field enhance this role for it. However, it was not designed strictly as a research reactor—it has neither the flexibility nor the space for multiple diagnostic experiments—and at least one observer commented to us that Alcator should not be

overlooked as a potential source of a set of plasma containment parameters that work. —BGL

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Superconductivity in SN_x

continued from page 17

idence of a metal-insulator (Peierls) transition; other pseudo-one-dimensional conductors, such as TTF-TCNQ, undergo such transitions. In other words, the metallic properties of this inorganic polymer appeared to persist down to much lower temperatures than the metallic properties of the organic conductors.

At IBM, San Jose, Richard Greene, Paul Grant and Bryan Street prepared their own crystals of $(\text{SN})_x$ and reported low-temperature (10 K–1.5 K) specific-heat measurements.² The results below 3.2 K, taken together with their measurements of other transport properties, indicated that the metallic properties persisted down as far as 1.0 K, with a conduction band width of at least 0.9 eV. A few months later, Greene and Street, along with Laurance Suter (Stanford University) saw superconductivity at 0.26 K in single crystals of $(\text{SN})_x$.³ (See figure, page 17.)

Any question of "dimensionality" of the system is of course largely semantic rather than basic: If the material were completely one-dimensional, fluctuations would prevent any three-dimensional superconducting transition. The considerable degree of anisotropy, however, has been clearly established. Labes and his coworkers had reported on the anisotropy of the electrical conductivity, finding a factor of 500 to 1 at 20 K.⁴ They also showed that thin films could be prepared. The Pennsylvania group (Arthur Bright, Marshall Cohen, Anthony Garito, Alan Heeger, Alan MacDiarmid, Chester Mikulski and Peter Russo) measured the optical reflectivity of $(\text{SN})_x$ films from the near ultraviolet to the far infrared (from $30\,000\text{ cm}^{-1}$ through 500 cm^{-1}).⁵ They found metallic reflectivity that they attributed to the component of light polarized parallel to the principal conducting axis.

This work, as well as similar optical studies on single crystals, was described by the Penn group at the Denver meeting. Both sets of data were analyzed according to the Drude model, appropriate for a metal.⁶ An interesting result from the Penn experiments is the achievement of fully oriented epitaxial

Machine operating conditions

Major radius = 54 cm
Minor radius = 9.5 cm
Toroidal field = 65 kG
Pressure = 3×10^{-9} Torr

Plasma operating conditions

Average density:
 2×10^{12} to $2 \times 10^{14}\text{ cm}^{-3}$
Peak density:
up to $3.5 \times 10^{14}\text{ cm}^{-3}$
Plasma current: 20 to 200 kA
Electron temperature:
0.1 to 1.8 keV
Ion temperature: up to 1.2 keV
Confinement time: 0.5 to 15 msec
Plasma current pulse: ≤ 400 msec
Beta (poloidal): 0.05 to 1.0