New Alloy Shows Promise as High-Field Superconducting Magnet

An alloy of niobium, germanium and aluminum, $Nb_{0.8}(Al_{0.75}Ge_{0.25})_{0.2}$, has remained superconducting in a 410-kG field at a temperature of 4.2 K. The alloy has the highest known transition temperature, 20.7 K. If the alloy can be made into a wire or tape that can maintain a high current density, it could be used to build a high-field superconducting dc magnet (provided one could make a structure that would hold together under the enormous forces produced by the fields). The best material previously tested, Nb_3Sn, has a critical field of about 220 kG at 4.2 K and has been used in commercial magnets for several years.

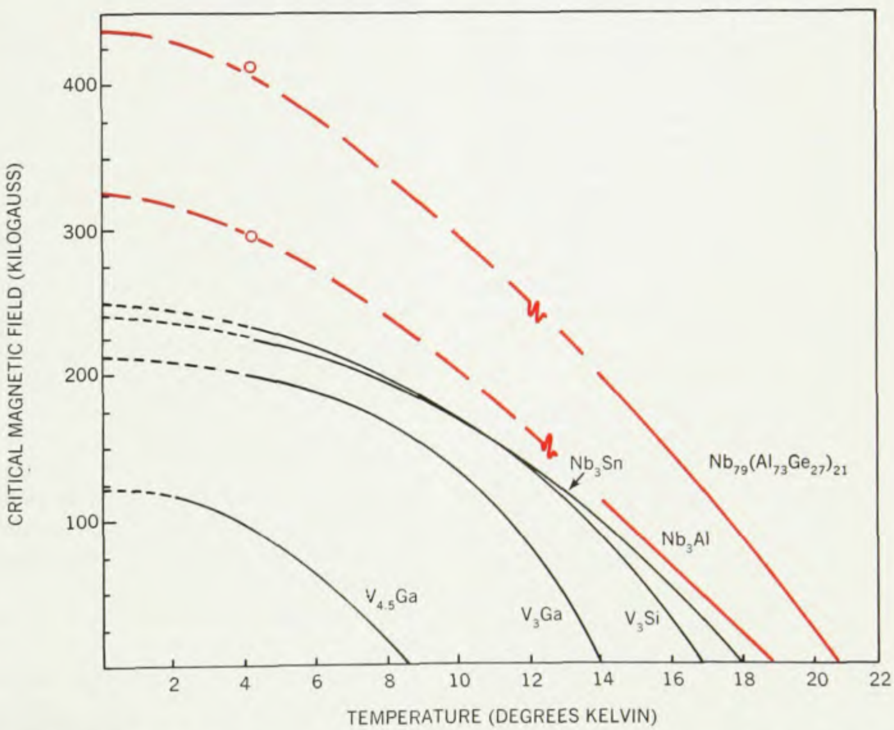
The experimenters, Bernd Matthias (University of California at La Jolla and Bell Labs), Simon Foner and Edward McNiff (MIT), Theodore Geballe (Stanford and Bell Labs) and Ronald Willens and Ernest Corenzwit (Bell Labs), also tested a Nb_3Al sample, whose transition temperature is 18.7 K, and found a critical field of 320 kG at 4.2 K. They reported their results at the March APS meeting in Dallas and in the 6 April issue of *Physics Letters.*

The highest field at which a type-2 superconductor is expected to go normal, known as the Clogston–Chandrasekhar limit (after Albert Clogston of Bell Labs and B. S. Chandrasekhar of Case Western Reserve), is proportional to the transition temperature; it is the field at which normal-state Pauli paramagnetism becomes competitive with superconductivity. The limit is only approximate, however; spin-orbit coupling effects can raise the limit. The paramagnetic limit predicts a critical field for the niobium–aluminum–germanium alloy of 380 kG, rather than the observed 410 kG.

Earlier experiments reported for the niobium–aluminum–germanium with dc fields showed a critical field of 200 kG at 14.0 K. To extend their measurements to 4.2 K, the experimenters used a long-pulse (10-millisec) multilayer copper wire coil, capable of producing 450 kG, and 0.2-mm-thick samples. They remark that, although pulsed fields yield a lower limit for the critical field, the independence of the critical field with sample thickness indicates that their observed values should be very close to that expected for a dc field. The measurements were made with small rf currents; no attempt was made to test high critical current-carrying capacity.

Matthias told PHYSICS TODAY that nobody really knows what the limit on critical temperature, and therefore critical field, will be.

"How does one get still higher transition temperatures?" we asked Matthias. "Purely metallurgically," he said. "The way we have done it in the past. It's not an elegant method; it's not an attractive method either. But it's the only method that has worked so far. I think it's very bad to promise people in technology, who want to use these wires: 'Ah, we may get still higher transition temperatures by new and entirely different methods.' This has been going on for 12 years or longer; there was no result, and now the reaction has set in." Matthias thinks that the highest transition temperature one can hope to achieve is 25–30 K. —GBL



BEHAVIOR OF HIGH-CRITICAL-FIELD MATERIALS. Solid curves in color are dc measurements. Points at 4.2 K are new measurements made with pulsed field. Dashed colored curves are extrapolations assuming no Pauli paramagnetic limiting. Nb_3Sn is available commercially and V_3Ga is being developed for commercial application. $Nb_{79}(Al_{73}Ge_{27})_{21}$ has highest known transition temperature, 20.7 K.

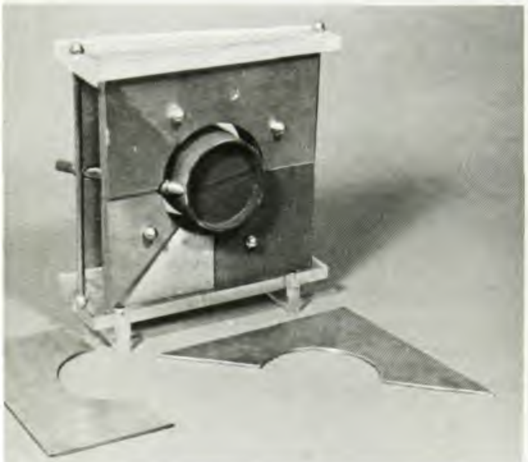
MIT Tokomak Has Anomalous-Resistivity Heating and 130 kG

MIT has started design and construction of a high-field Tokomak-like device called "Alcator." By extrapolation of experimental results, the experiment could achieve confinement times considerably longer than previous Tokomaks, electron temperatures of roughly 5 keV, and electron and ion densities of 10^{14} particles/cm^3. These parameters are of thermonuclear interest and, if achieved would allow the study of plasmas with reactor-like characteristics.

The name "Alcator" is short for "alto campus torus," which means high-field torus. The project is a collaboration between the Francis Bitter National Magnet Laboratory and the MIT interdepartmental plasma-physics group; the project is led by Bruno Coppi and D. Bruce Montgomery.

Alcator will use the existing motor-generator sets at the Magnet Laboratory to produce a very high confining magnetic field—130 kG. The Tokomak T-3 at the Kurchatov Institute in Moscow has 25 kG and the proposed Tokomak T-10 would have a 50-kG field.

One of the key ideas of Alcator is to take advantage of anomalous plasma resistivity, to reach a high temperature



PART OF COIL ASSEMBLY for MIT Tokomak. Model shows two turns separated by 15 deg; each is made of two conducting plates of copper sandwiched between two reinforcing plates of high-strength stainless steel and one insulator. Inside the bore is the plasma chamber, which has a thick-walled copper shell to help stabilize the plasma column. At left is 2-cm viewing port. Conductor plates can each be made of two 180-deg half-plates (shown) to facilitate assembly about plasma chamber.

in a time shorter than the confinement time. Coppi explained that plasma resistivity is determined not only by electron-proton collisions, but to a great extent by interaction between particle and collective effects. By having a sufficiently large current density flowing inside the plasma, one excites plasma collective modes; so a greatly enhanced plasma heating occurs. The same high magnetic field that permits the attainment of an enhanced resistivity and the proper choice of geometrical parameters are expected to allow very good plasma containment.

The major plasma diameter will be 108 cm and the minor plasma diameter 26 cm. The coil will be cooled with liquid nitrogen and pulsed for 1 sec from the existing 32-MW power supply at the Bitter Laboratory. Total cost of the experiment is expected to be \$750 000, of which \$525 000 comes from the AEC. Construction is expected to take 18 months.

We asked Coppi to compare Alcator with the proposed T-10. He feels that MIT has a much better chance to be able to heat its plasma. The Kurchatov device would increase its energy content by choosing a better aspect ratio and larger dimensions (3-meter major diameter and 1-meter minor diameter) and somewhat higher field than T-3. So T-10 will probably have a substantially longer confinement time than Alcator. The MIT device, Coppi says, can achieve high specific energy content by optimizing the magnetic field and the aspect ratio at the same time.

What are the limitations on Alcator? Coppi says that trapped-particle modes might give difficulty, and since temperatures will be higher, radiation losses are uncertain. But in any case the experiments should be interesting because they open a new plasma regime for study. —GBL

No Sign Found in Search For Neutral Tachyons

While theorists debate whether tachyons are forbidden or compulsory (PHYSICS TODAY, December 1969, page 47), the search continues for these faster-than-light particles. Last year Torsten Alväger, Michael N. Kreisler and Michael B. Davis[1] failed to find evidence for charged tachyons. Now Charles Baltay, Gerald Feinberg and Noel K. Yeh of Columbia, and Ralph Linsker of the Goddard Space Flight Center, have set an upper limit on the production of neutral tachyons.[2]

The Columbia–Goddard group looked for tachyons among the neutral particles produced by K^- and $\bar{p}$ beams stopped in the 30-inch Columbia-BNL hydrogen bubble chamber. The reactions studied were

$$\bar{p} + p \to \pi^+ + \pi^- + X^0$$

and

$$K^- + p \to \Lambda^0 + X^0, \quad \Lambda^0 \to \pi^- + p$$

Once all the charged-particle tracks are measured, kinematics allows one to calculate the energy E and the momentum p of the missing neutral(s). Thus each event is tagged by a value of its missing mass squared, $MM^2 = E^2 - p^2$. For tardyons (that is, ordinary particles) MM^2 must be positive. However, if X^0 is a tachyon with imaginary mass, MM^2 must be negative. In the more likely case that X^0 is a pair of neutral tachyons, the value of the missing mass squared can be either positive or negative and the phase space for obtaining a value of MM^2 within the range of the experiment is large for all possible values of the tachyon mass. Thus by studying the distributions in missing mass squared, the experimenters hoped to see the signature of neutral tachyons if they exist. One advantage of this method is that it does not depend on any assumptions about the interaction of tachyons with other matter, after the tachyons are produced.

The film used in the experiment consisted of 20 000 pictures with an average of 8 stopped K^- events per picture and 10 000 pictures with an average of about 1 1/2 stopped $\bar{p}$ events per picture. The resulting missing-mass plots gave evidence only for production of gammas and known tardyons such as neutral pions. The researchers estimated the upper limit for tachyon production to be at least a thousand times smaller than a typical strong-interaction process. —BGL

References

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Low-Field Room Built at High-Field Magnet Lab

A magnetically shielded walk-in room whose residual field is about 100 nanogauss is now operating at MIT's Francis Bitter National Magnet Laboratory. The room's designer, David Cohen, has recently reported[1] using a point-contact "SQUID" (superconducting quantum interference device) inside the room to record the magnetic field of the human heart without noise averaging. Cohen also plans to use the room for ac and dc measurements of the magnetic field from the human brain; roughly the brain's field is 1 nanogauss and the heart's peak field is 1 microgauss.

The room is also suitable for testing cryogenic magnetometers, measurements of geophysical samples and other physics experiments requiring less than 1 microgauss. It is a national