

LETTERS

Magnetic Fields Are Getting Higher on Research Lab Agendas

I greatly enjoyed Greg Boebinger's article on "Correlated Electrons in a Million Gauss" (June, page 36), but I was disappointed by the accompanying box entitled "Generating High Magnetic Fields." The discussion of DC or nearly DC magnetic field generation was accurate, but the description of (and references for) the generation of short-pulse magnetic fields in the last two paragraphs of the box was incomplete.

It was back in the early 1950s that Andrei Sakharov proposed the explosively driven Magneto-Cumulative Generator (MCG). Subsequently, Soviet (now Russian) researchers used the MCG to generate magnetic fields in the range of 200–1000 tesla. Similar work was carried out at the Los Alamos National Laboratory and other institutions worldwide. The more recent development of high-power pulsed electrical generators in the US, UK and Russia has provided another route for generating large, pulsed magnetic fields. For example, existing generators are capable of delivering more than 10 MA in 100 ns to low-inductance loads. Indeed, experiments carried out at Sandia National Laboratories in both coaxial and solenoidal field geometries have generated magnetic fields in the 1–2 kT range over volumes of cubic millimeters and for time scales of 10 ns.

In his accompanying box, Boebinger could have argued (correctly) that the small spatial extent, very short time scales and lack of survivability of the samples make these other generating techniques undesirable or inappropriate for a wide range of experiments. But he failed to do so. Consequently, he leaves the casual reader with a mistaken impression concerning the magnitudes of magnetic fields that have been achieved.

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We have read with great delight Greg Boebinger's lucid article in which he discusses experiments with nondestructive magnets in the 100-tesla regime, and mentions the proposed "pulsed hybrid" at the National High Magnetic Field Laboratory (NHMFL) in Los Alamos—a design that should reach 100 T without damage to the magnet or the sample.

At Los Alamos National Laboratory, we have a long history of experimenting with explosively driven implosion devices reaching the 1000 T regime. As early as 1958, Los Alamos scientists obtained fields as high as 1400 T.¹ Los Alamos research in this area has resulted in a series of continually improving devices, which can now generate fields with great reliability and reproducibility, although emphasis has been placed on nonimplosion devices of large volume but lower peak field (≤ 250 T).

Since the end of the cold war, we have been experimenting with the elegant devices designed and built by our Russian colleagues at the All-Russian Institute of Experimental Physics (Arzamas-16). These devices, called MC-1 generators, can produce 1000 T fields with excellent homogeneity.² This collaboration's first experiments were performed in December 1993 at Los Alamos, with Arzamas-16 colleagues using both lower-field Los Alamos and high-field Russian generators driven with US high-explosive charges. In this campaign the critical field of yttrium barium copper oxide (YBCO) was measured (340 T at 30 K), as was its complex microwave conductivity,³ and the nonlinear Faraday effect in cadmium sulfide was measured at fields up to 750 T.⁴

In late April of this year, scientists from seven laboratories in four countries gathered at Los Alamos to launch a campaign of pioneering experiments in physics and chemistry at ultrahigh magnetic fields. The Dirac campaign (named in honor of P. A. M. Dirac) is a collaboration among Americans, Australians, Japanese and Russians that is without precedent at Los Alamos.

Six main experiments are under way: (1) a search for the quantum limit phenomena in a two-dimen-

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sional organic metal and a search for new phenomena beyond that limit; (2) an attempt to observe high-magnetic-field-induced superconductivity, a theoretically predicted phenomena, yet to be validated by experiment; (3) several experiments to observe a field-induced transition to conductivity in several Kondo insulators; (4) use of the Zeeman effect to break one bond of a quadruply bonded transition metal complex, a novel use of magnetism in chemistry; (5) exploration of the Faraday rotation in samples containing the ions Eu^{3+} and Sm^{3+} , which should provide level-crossing benchmarks for calibrating ultrahigh-magnetic-field probes, independent of the media in which the ions are embedded; and (6) an exploration of non-linear Faraday rotation in cadmium manganese tellurium at low temperatures and ultrahigh fields.

The Dirac campaign will also include several experiments using the MC-1 and several 150 T experiments using Los Alamos generators. The 150 T device, called a strip generator, uses strips of high explosive to compress a seed field in a triangular current amplifier, which feeds into a single-turn coil. Because the coil explodes, rather than implodes (as with the MC-1), the samples can sometimes be preserved. Modifications of this design can reach 250 T.

We are also planning to bring ultrahigh magnetic fields into the laboratory. We propose to use a pulsed-power facility called Atlas, currently being designed for science-based stockpile stewardship and likely to be in operation in about four years. Atlas will be capable of delivering about 36 MJ of electrical energy to implode a cylindrical metallic liner. Initial calculations are encouraging; with an appropriate seed field, we should be able to reach fields in excess of 1000 T.

The NHMFL facilities here at Los Alamos constitute an invaluable asset in conducting this series of experiments. Besides furnishing lower-field data, the 50 T pulsed magnet has enabled the experimenters to test and retest their samples and apparatus before committing them to explosive experiments.

We invite interested scientists in the broader academic and basic research communities to join us in exploiting the full scientific potential of the NHMFL Los Alamos facilities.

References

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BOEBINGER REPLIES: I welcome the remarks by Spielman, Ekdahl, Fowler and Solem, for they discuss in accurate detail the destructive magnet technologies that are capable of achieving the very highest magnetic fields. They also accomplish something that I could not in my article: getting into print a few more column-inches about the generation of intense magnetic fields (space limitations prevented my covering destructive technologies in any useful detail).

Spielman makes quite explicit the criteria that I used to focus my article primarily on physics in a million gauss—the magnetic field range that can be, or soon will be, achieved by nondestructive magnets. In mentioning the destructive magnet technologies in both the opening paragraph of the main article and in the closing paragraph of the box, I suggested that experiments are seriously limited by the microsecond time scales and near-certain sample destruction with each magnet pulse. Of course, one can apply similar criticism to nondestructive pulsed magnets: only a small subset of experiments that can be performed in DC magnets are appropriate for nondestructive pulsed magnets, which provide peak fields for only milliseconds but do make it possible to perform hundreds of pulses on the same sample.

I take heart that half of the experiments that Ekdahl, Fowler and Solem describe in their letter fall within the scope of the physics I discussed in the article. I wholeheartedly second their invitation for scientists to explore the full range of possibilities offered by the pulsed magnets at the National High Magnetic Field Laboratory (NHMFL) in Los Alamos. I extend that invitation to include the DC magnets at the other two NHMFL sites, in Tallahassee and Gainesville, Florida. And while I am at it, wherever you are in the world, should you have an idea for a high-magnetic-field experiment, quite likely there's an excellent high-magnetic-field laboratory near you.

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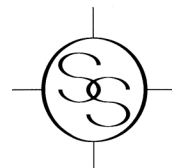
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