Superconducting gems

THE compositions and structures of the two high-temperature superconductors $La_{2-x}(Ba,Sr)_xCuO_4$ and $YBa_2Cu_3O_7$ are now well established; that their physical properties are less well known results largely from the fact that they are most easily synthesized as powders or ceramics. One therefore measures the properties of a collection of randomly oriented grains, which is unsatisfactory because the grain surfaces may behave differently from the bulk material, and because any anisotropy will be hidden by a measurement that averages over many different grain orientations. The successful growth of single crystals of $YBa_2Cu_3O_7$ as large as 4 mm, reported by Schneemeyer *et al.* on page 601 of this issue[1], is thus an important step.

Although several groups (see, for example, ref. 2) have succeeded in growing partially oriented thin films of $YBa_2Cu_3O_7$ (now familiarly termed YBCO), growth of macroscopic crystals from a melt has proved difficult. Because YBCO melts incongruently, the first crystals to form from a liquid of YBCO composition are not YBCO; liquids richer in copper and barium are needed to get YBCO to crystallize first. Schneemeyer *et al.* found that crystal size, morphology and superconducting properties depend strongly on the melt composition used.

Although the structures of the lanthanum- and yttrium-based superconductors differ, they are both layered materials containing planes of Cu–O. This structural anisotropy is reflected in the electronic properties of both compounds, as revealed by oriented measurements of critical current density and upper critical field. In $La_{2-x}Ba_xCuO_4$, the upper critical field is five times higher when the field is applied perpendicular to the Cu–O planes[3]; in YBCO, the critical current density is more than ten times higher parallel to the planes[4]. It is therefore expected that other properties of these materials will show similar degrees of anisotropy, which is why oriented measurements on single crystals will be so important. Although the critical current and critical field measurements can be carried out on crystals only 0.5 mm in size, many other types of measurement will be made easier (or even possible) by crystals of the size grown by Schneemeyer *et al.* Neutron scattering measurements, for example, require a large sample because neutrons interact so weakly with matter. And any surface measurement, such as optical reflectivity or X-ray photoelectron spectroscopy, requires careful preparation of the sample surface to remove impurities or oxidation; this will be easier with larger crystals. Laura Garwin

1. Schneemeyer, L.F. *et al. Nature* 328, 601–603 (1987).
2. Chaudhari, P., *et al. Phys. Rev. Lett.* 58, 2684–2686 (1987).
3. Hidaka, Y. *et al. Jap. J. appl. Phys.* 26, L377–L378 (1987).
4. Dinger, T.R. *et al. Phys. Rev. Lett* 58, 2687–2690 (1987).

Fundamental forces

In pursuit of the fifth force

E. Iacopini

NEWTON's theory of gravity assumes that the source of the gravitational force is the inertial mass. As a consequence of this hypothesis and of Newton's second law, the acceleration of a body in the presence of only a gravitational field is independent of its mass (*g*-universality). The equivalence of inertial and gravitational mass is a principle in Einstein's theory of general relativity and in several other alternative theories of gravitation. It is for all these reasons that the *g*-universality has been tested many times with increasing precision. Using the results obtained with these tests, one can set limits also on the existence of new long-range forces, that will manifest themselves as an apparent *g*-universality violation, provided their source is not the inertial mass. The recent hypothesis of E. Fischbach *et al.* (*Phys. Rev. Lett.* **56**, 3–6; 1986) on the existence of a fifth force, popularly but misleadingly called antigravity, has given a new impulse to the field. Since then two experiments (Thieberger, P. *Phys. Rev. Lett.* **58**, 1066–1069; 1987 and Stubbs, C.W. *et al. Phys. Rev. Lett.* **58**, 1070–1073; 1987) have been completed that test the hypothesis, but come to contradictory conclusions.

The historical experiments by Eötvös in 1922 and Renner in 1935 set limits for $\Delta g/g$ at 3×10^{-9} and 7×10^{-10}, respectively. More recently, Dicke's and Braginskii's experiments pushed the accuracy to 10^{-11} and 10^{-12}, respectively. These latter experiments, however, actually compare the accelerations of bodies in free-fall towards the Sun, that is, on a very different scale of distance. In 1986, Fischbach *et al.*, reanalysing the Eötvös data, claimed there was evidence of a fifth force, different from the four known fundamental interactions, repelling all bodies from the Earth in proportion to their baryonic charge or nuclear content. The result would be that samples with the same (inertial) mass, but different chemical composition would arrive at the ground at slightly different times in a Galileo-type experiment. According to Fischbach, the potential energy of two point-like masses m_1 and m_2 placed at a distance r is

$$V = -(Gm_1 m_2/r)\times(1 - \alpha_{12}\exp(-r/\lambda))$$

where G is Newton's universal constant of gravitation; the first bracket is the usual form of Newton's law of gravity; and the second represents the short-range departure caused by the fifth force, with λ the range of the fifth force, and α_{12} is material dependent, proportional to the product of the two baryonic charges β_1 and β_2, normalized to their respective masses.

Geophysical gravity determinations in mineshafts (Stacey, F.D. & Tuck, G.J. *Nature* **292**, 230–232; 1981) support the idea of a short-range departure from newtonian gravity with $\alpha_{12} \sim 10^{-2}$ and $\lambda \sim 1$ km. Fischbach's suggestion is that the

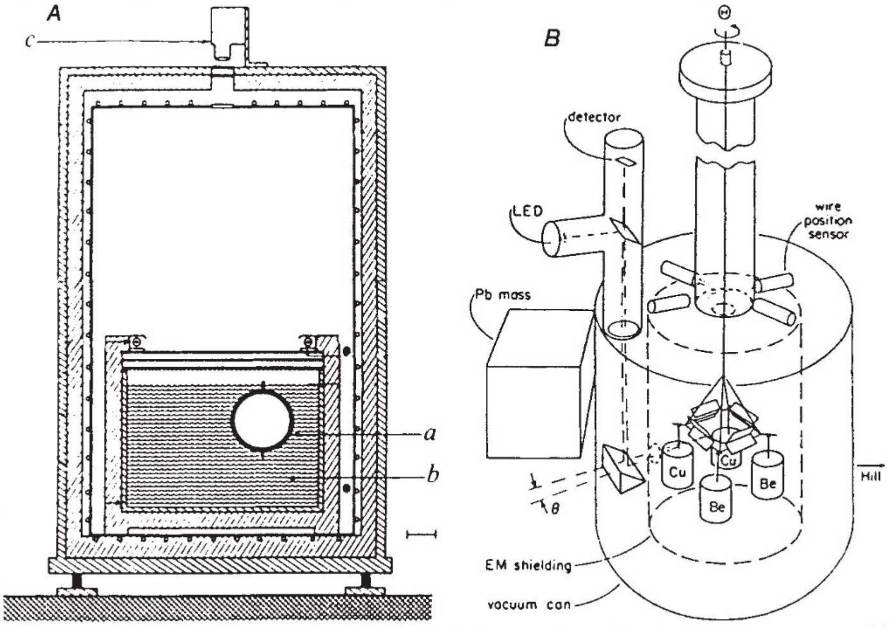

Fig. 1 *A*, Thieberger's accelerometer, in which the position of the hollow copper sphere (*a*) floating in distilled water (*b*) is viewed by the camera (*c*) once every hour. The whole apparatus is screened from electromagnetic effects and kept at constant temperature (scale bar, 10 cm). *B*, The torsional pendulum of Stubbs *et al.*, in which the differential force acting on the beryllium and copper cylinders is detected by the light-emitting diode (LED)–detector system as the pendulum rotates. The lead mass is to compensate for local gravity gradients.