consists of two small conventional mirror cells located at each end of a large central confinement chamber around which is wound a simple solenoidal magnet coil. The hot plasmas in these end cells create positive electric potentials that act to electrostatically 'plug' the end leakage of charged particles from the central cell far more effectively than is possible with a single mirror at each end acting alone. Though invented in the USSR and, independently, in the US about four years ago, the first tandem mirror device to be constructed and operated (Gamma-6; 1978) was built at Tsukuba University, Japan, preceding the larger experiment (TMX; 1979) brought on line at the Lawrence Livermore Laboratory.

The scientific validity of the tandem mirror idea for enhancing mirror confinement was made clear in papers by Kawabe (Tsukuba) and Grubb and Drake (Lawrence Livermore Laboratory) who described experiments in the Tsukuba Gamma-6 and Livermore TMX experiments, respectively. Work in progress (TMX) includes more detailed measurements of particle and energy transport, the role of microinstabilities and their suppression, and the study of plasma pressure limits as determined by MHD effects. Baldwin (Livermore) then described recent developments in tandem mirror theory, including the important new idea (originated by Baldwin and Logan) of the thermal barrier. In a tandem mirror, a thermal barrier is a specially designed cell that, through the generation of a locally-negative potential region, can act to thermally isolate the end plug from the central cell. Thermal isolation then would permit the heating of plug electrons to higher temperatures than those of the central cell, with resultant increased plug potential at lowered plug plasma density — a major economic advantage.

The use of radiofrequency fields to enhance the confinement of open-ended systems has been a major topic in fusion research in Japan for many years. Pioneered at Nagoya under the direction of K. Takayama, this work led to the construction at Nagoya of a large mirror-cusp device, RFC-XX. Itatani (Nagoya) described preliminary results with this machine, in which enhancement of confinement of moderate temperature plasmas by factors of 5 or more (over the confinement observed with r.f. turned off) were seen. Whether good confinement of higher temperature plasmas can be achieved is not yet resolved. RFC-XX however appears to be the most advanced facility for the study of such questions in any fusion laboratory.

An important sub-class of mirror systems are those where the phenomenon of field-reversal is invoked to improve confinement. In a field-reversed mirror — a form of the so-called "compact toroid" configuration — the internal diamagnetic currents of the mirror-trapped plasma are made to be sufficiently intense to reverse the direction of the magnetic field near the axis within the plasma, thus closing the magnetic lines on themselves within the plasma interior and thereby inhibiting plasma losses through the mirrors. Interest in such configurations, which dates back many years to related systems (such as the electron ring ASTRON of Christofilos), comes from their geometric simplicity and, especially, from their extremely efficient use of the external field. The field-reversed mirror shares with the tandem mirror the generic idea that properties of the plasma are used to improve its own confinement. The Symposium provided a forum for the discussion of most of the FRM work now in progress, including, for example, work at the Los Alamos Laboratory on field-reversed configurations produced by a coaxial gun (Sherwood; Los Alamos) and field-reversed electron rings (Fleischmann; Cornell).

Some of the most unusual mirror devices were described in the papers concerning work at Novosibirsk (Ryutov, Koidan). In addition to the AMBAL tandem mirror, now under construction, there are two other mirror devices: PSP-2, a device in which mirror confinement is enhanced by electrically-induced plasma rotation, and GOL-1, a device using multiple mirror cells and operating at very high plasma density. Both of the latter innovative devices owe much in their origin to the former Director of the Novosibirsk fusion group, G. I. Budker, who died July 4, 1977.

Judging from the lively discussion at the conference, and from the enthusiasm of the participants, interest in open-ended systems is increasing not only in Japan but world wide. In the case of the Japanese effort, it seems equally clear that their contributions to research on open-ended magnetic fusion systems will become increasingly important over the next few years. □

100 years ago

PHYSICS WITHOUT APPARATUS

It is almost a proverb in science that some of the greatest discoveries have been made by the most simple means. It is equally true that almost all the more important facts and laws of the physical sciences can be illustrated and explained by the help of experiments made without special or expensive apparatus, and requiring only the familiar objects of common life for their performance. The greatest exponents of popular science — and amongst them notably Faraday — delighted in impromptu devices of this kind. It is indeed surprising how throughout the whole range of natural philosophy the hand of the master can turn to account the very simplest and rudest of apparatus. A silver spoon, a pair of spectacle lenses, a tumbler of water, and a few sheets of paper suffice to illustrate half the laws of geometrical optics. A few pieces of sealing-wax, some flannel, silk, writing paper, pins, and glass tumblers will carry the clever experimenter a long way into the phenomena of electricity. These are things which any person can procure, and which any person can be taught to use. But their right use depends on the possession of

accurate scientific knowledge and a clear understanding of *what* the various experiments are to prove. In fact the art of experiment and the science of inductive reasoning are the essential qualifications necessary to make *Physics without apparatus* profitable.

Amongst the simple mechanical laws with which a beginner in physics must acquaint himself is that commonly referred to as the *law of inertia*, which is, however, very often so imperfectly expressed as to be misapprehended. It requires force to move matter, not because matter is inherently lazy or sluggish, but because it possesses *mass*. The greater the mass of matter in a ball, the harder work is it to send it rolling. Force is also required to stop matter that is moving, the reason again being that a mass moving under the impulse of an impressed force possesses a certain moving energy which cannot be at once reduced to nothing. In either case — either to move a mass or to alter the motion of a mass — force must be employed and energy expended. Of this law of inertia many examples might be given: and there are many curious facts which this law serves to explain. Some of the most striking of these are those in which the effect of sudden forces is different from that which might have been expected. In Fig. 1 we give an illustration of an experiment of this nature. A wooden rod — say a broomstick — has a couple of needles fixed into its ends, and it is then supported upon two wineglasses resting upon two chairs. If a heavy poker is now brought down very violently upon the middle of the stick it will break in two without the needles or the glasses being broken. A feeble or indecisive blow will fail to do this, and will break the glasses or the needles, or both. Here the moving energy of the heavy mass, the poker, is suddenly transferred to the middle of the stick, so suddenly that it is broken asunder before the thrust has *time* to reach the fragile supports. From *Nature* **22** 5 August, 320 & 321, 1880.

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