letters

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interesting question by suggesting that the cold-fusion results may be explained by cosmic-ray muons. I have investigated cold fusion for many years and find that the Fleischmann–Pons effect is strongly dependent on the palladium material. Palladium–boron alloys made by the US Naval Research Laboratory have worked especially well in my experiments (see US Patent 6,764,561, 20 July 2004, and US Patent 7,381,368, 3 June 2008). That seems to me to suggest the importance of impurities (boron is an oxygen getter) rather than cosmic-ray muons.

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In his letter about cold fusion involving muonic atoms, Jacques Read discussed the 1989 experiment by Stanley Pons and Martin Fleischmann that "has been repeated over and over." Like most nuclear physicists of my generation, I was very excited by the idea of cold fusion of hydrogen nuclei. I had accepted the prevailing conclusion that what was reported by Pons and Fleischmann was not fusion. In 2002, however, after a coincidental encounter, I started participating in research in condensed-matter nuclear science (CMNS)—the term practitioners now use instead of cold fusion. I was looking for at least one reproducible-on-demand demonstration of a strong nuclear reaction due to a chemical process. I have not been successful thus far. But I have met many CMNS scientists, read their reports, and participated in their international conferences.

The excess energy Read mentions is no longer the only claim made by CMNS researchers. Others are emission of nuclear particles, transmutation of elements, and changes in isotopic composition of elements. A recently published book by Edmund Storms,[1] a retired materials scientist from Los Alamos National Laboratory, summarizes what has been discovered since 1989. I believe that reports made by recognized scientists should be taken seriously, even when their results conflict with what is expected. According to CMNS researchers, a new kind of nuclear phenomenon in condensed matter has been discovered. But conditions under which the new phenomenon would be reproducible remain to be identified.

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Practical, near-term fusion power

The fusion–fission hybrids report (PHYSICS TODAY, July 2009, page 24) reflects the commonly accepted view that fusion power is a long way off. Not necessarily. Abundant clean energy can be generated from pure fusion power plants on a timeline consistent with the urgency of the world's energy, economic, and environmental problems. Heavy-ion fusion (HIF)—inertially confined fusion (ICF) ignited by beams of high-energy heavy ions—is the solution. In July 1976, 50 senior scientists, including Nobel laureates, from the major US ICF and accelerator laboratories assembled for an ad hoc two-week summer study.[1] Capturing the positive consensus of that meeting, the director of the Office of Inertial Fusion, now in the Department of Energy (DOE), stated at its conclusion that HIF's first step should be a $100 million facility (1976 dollars).

Multiple international design studies, annual workshops, and key experimental demonstrations rapidly confirmed that outlook. In May 1979 John Foster, chair of a DOE review of ICF, told the Energy Research Advisory Board that HIF would be the way to fusion power "if you wanted to make a conservative approach."[2] But the facility project that would have brought together a critical mass of talent was not funded. Yet, repeated assessment of the concept's prospects, propelled by the mountainous record of accomplishments of high-energy accelerators, has sustained HIF's progress worldwide.

In short, accelerator systems using technology established before 1976 can deposit tens of megajoules in fusion fuel pellets in nanoseconds via classical deposition physics. Also crucial, the repetition rate, efficiency, durability, and reliability needed for economical energy production are standard with high-energy accelerators. The road from achieving fusion burn to economic power production is clear, because

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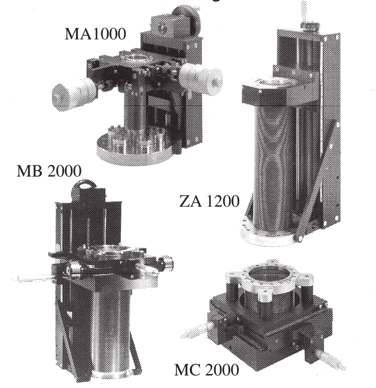

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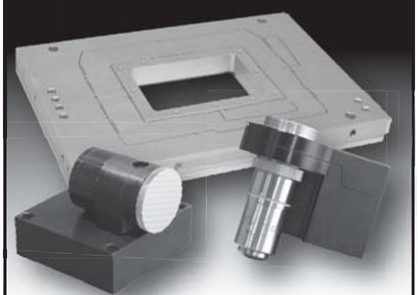
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development of extraordinary materials is not needed—a result of using thick liquid walls of lithium to protect HIF chamber materials from neutron damage.

The classical deposition of ion beams in fusion targets contrasts sharply with the complex plasma physics of laser–matter interaction. The greater effectiveness per beam megajoule amplifies HIF's crucial ability to deliver to fuel targets 10 times the goal of the National Ignition Facility's (NIF's) laser. More, and more effective, driver energy reduces the needed degree of fuel compression substantially. Reduced compression is accompanied by reduced growth of hydrodynamic instabilities, which in turn relaxes tolerances for pellet fabrication.

The compression requirement is reduced to the realm already demonstrated in ICF research by HIF's ability to use the fast-ignition method. Only a small fraction of the pre-compressed fuel is heated to ignition temperature to start propagating fusion burn. If fast ignition could be accomplished with laser beams, NIF's energy gain could be 10 times higher than its official goal. But fast ignition via laser driver holds exquisite challenges. In contrast, 10 years ago in Russia, Boris Sharkov and associates began designing fusion pellets and HIF driver layouts to exploit HIF's ability to achieve fast ignition with classical energy deposition, in fuel pre-compressed to a density already experienced in the lab, with a relatively long-duration ion pulse, in geometries simple to fabricate.[3]

Why has the US not taken advantage of HIF? The oil "shocks" of 1973 and 1979 were not taken seriously enough, nor were warnings of oil's approaching limits. The issue has been leadership. Elements of HIF are spread among the offices of DOE's three undersecretaries. Tellingly, all fusion work to date has been outside the office responsible for civilian energy systems. The National Academy of Sciences, in reviewing military ICF programs in 1985, noted HIF's advantages but averred that HIF was "supported primarily by other programs."[4] But there are no other programs. HIF has been an orphan—as Burton Richter put it, "starved and virtually ignored." While energy production is the sole purpose of HIF, its homelessness is shared by all inertial fusion energy work in the US.[5]

We could be much closer to ICF power than we are, but the situation is good overall. While the US has veered from HIF's founders' use of mainstream accelerator technology, European and Russian HIF programs steadily resolve details and use new facilities. Decades of ICF progress, using the laser driver and various other technologies, have built a formidable technical basis and community. The fast-ignition concept that benefits HIF enormously only came to light in the 1990s. And HIF enjoys the continuous advance of accelerator technology.

Heavy-ion fusion was discovered at DOE labs. DOE now has requested that the National Academy of Sciences assess the need for an office charged to develop civilian power from ICF. The NAS study is expected to take a year, beginning this summer. An unbiased examination will show, again, that through HIF, fusion power is much closer than it appears. Establishing a home for inertial fusion energy would accomplish a lot.

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Of wetting and osmotic transport

In his article "The First Wetting Layer on a Solid," Peter Feibelman (Physics Today, February 2010, page 34) points out that the first layer of water molecules on a solid surface embodies the boundary condition for water transport, pollution, corrosion, and other molecular transport phenomena. That observation and the revealing high-resolution images presented bring to mind a fundamental problem of osmotic water transport.

In 1827 René Dutrochet pointed out that osmosis actually involves binary transport,[1] in which water moves one way and solute moves the other way. In 1855 Adolf Fick took the idea much further,[2] expanding on the work of other experimentalists. He considered a cylindrical pore in a hydrophilic membrane separating either water or a dilute salt solution on one side and a concentrated one on the other.[3] He reasoned that water will preferentially flow along the walls and salt will tend to migrate along the axis of the pore. As a consequence, he expected concentration gradients in the plane of the pore. Under certain conditions, he suggested, salt migration could be completely inhibited even though the pore might be large enough to allow migration of salt molecules. Subsequent contributions by Jacobus van't Hoff[4] and Walther Nernst[5] established that molecular diffusion in aqueous solutions involves the migration of a solute in one direction driven by the gradient of osmotic pressure, and the flow of water in the opposite direction.

Binary transport in aqueous solutions is widely recognized, but the actual mechanisms are not clear. Solute diffusion involves the random migration of free molecules or ions. However, because water is a condensed phase, its migration cannot be visualized in terms of random motion of molecules. It is not clear if such a flow of water can be considered viscous, because viscosity typically involves wall effects and external forces. If it is viscous, what is the nature of that flow?

Work along the lines described in Feibelman's article may throw more light on the nature of binary transport in osmosis and on molecular diffusion in which random motion of unattached molecules in one direction is accompanied by the migration of a condensed phase in the opposite direction.

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A two-color twist on test taking

Test taking is a humiliating experience for many students, with no perceived direct educational benefit. That need not be