ENERGY

# Fresh Start for Fusion Project as New Leader Shakes Up Management

Last week, ITER, the €16 billion international effort aiming to prove the viability of fusion as an energy source, shook off nagging worries that soaring costs and management problems, combined with Europe's economic woes, could lead to the downsizing or even killing of the experimental reactor. ITER's governing council finally approved the project's so-called Baseline, an extensive document outlining its cost, schedule, and design, and officially named Osamu Motojima, former director-general of Japan's National Institute for Fusion Science, as ITER's new leader.

The major steps forward brought almost audible sighs of relief from fusion scientists, who can now look forward to 2019, when ITER is supposed to produce its first plasma. "I was beginning to wonder if we were ever going to nail down cost and schedule. Europe had been dragging its feet," says Steven Cowley, director of the Culham Centre for Fusion Energy in Abingdon, U.K. "We're over this nasty hump. Yes, ITER is going to cost a lot of money, but we're going to do it."

That hump included a fierce debate over how the European Union which is responsible for 45% of ITER's budget, would cover a €1.4 billion shortfall in short-term funding for the increasingly expensive project. In June, E.U. member states declined to inject new money into ITER, recommending instead the use of funds already allocated to other research efforts. This outraged nonfusion scientists, and in July the European Commission rejected the advice; current plans are to take just €400 million from existing research budgets and find the rest from money allocated to agricultural subsidies and other uses.

In an attempt to forestall future budget battles, the ITER Council last week placed a cap on the overall budget of the reactor, to be built in Cadarache, France. Building ITER on time and on budget will be a "tough job," Motojima admits.

*"Fusion is not a dream but a real target."*

—OSAMU MOTOJIMA, ITER

He isn't moving slowly, however. The day after his appointment, Motojima announced plans to overhaul ITER's operations. A management review requested by the ITER Council had earlier this year criti-

CREDIT: © ITER ORGANIZATION

PHYSICS

# Diamond Feats Give Quantum Computing a Solid Boost

Quantum computing may finally be ready to grow up. Over the past 3 decades, physicists have learned to use the quantum behavior of atoms to store and process a handful of bits of information. But they've never managed to scale up quantum computers the way the computer industry has integrated millions of transistors on chips.

Now, a pair of new results brings that goal a step closer. Researchers in California report creating a way to vastly scale up the production of quantum bits (or qubits) in a diamond wafer, a leading contender for making a solid-state quantum computer. Meanwhile, researchers in Massachusetts have linked the quantum state of one such qubit in diamond to the quantum state of a photon, the basic particle behind light. The result may open the door to linking large amounts of quantum information in the solid state to photons of light that can carry the information over long distances.

"Both [papers] taken in isolation are extremely important contributions to being able to use diamond as a platform for doing quantum information processing in the solid state," says Ray Beausoleil, a physicist and HP fellow at HP Laboratories in Palo Alto, California. Taken together, Beausoleil adds, the papers could make it possible both to scale up quantum computers and to pass their data over a distributed quantum network.

For decades, researchers have longed to build quantum computers because of the unique way they store and process information. In conventional computers, each bit of data exists in one of two states, either a "1" or a "0." Quantum computers take bits much further. Each qubit can exist as either a 0 or a 1, or as a "superposition" of all its possible states. For example, it might be 19% 0 and 81% 1, or 65% 0 and 35% 1, or countless other in-between combinations. In carrying out its operations, a quantum computer weighs all such values simultaneously. As a result, stringing just 30 qubits together would give a quantum computer the computational power of a conventional computer running at 30 trillion operations per second.

Qubits aren't just theoretical playthings. Researchers have made them out of many different ingredients, including trapped ions and superconductors. They've also entangled multiple quantum states together so that manipulating one bit causes a predictable change in its neighbor. But they've struggled with the scaling step that has defined the success of conventional computers.

That's where diamond may have an edge. In 2006, researchers found that when they inject nitrogen atoms into a wafer of crystalline diamond, nitrogen atoms not only insert themselves in the carbon lattice but also can kick out carbon atoms. If a nitrogen atom winds up next to a vacancy, one of its electrons can form a stable qubit with a property called spin, which researchers can manipulate with radiofrequency (RF) signals, microwaves, or laser light. Nestled inside the diamond lattice, isolated from outside influences, such nitrogen-vacancy (NV) centers





Published by AAAS

cized the project's governance, and several senior managers have recently departed. Motojima intends more changes. "Simplify everything; that is the only possible way to respond to the capping of the project," he says. One casualty of this streamlining will be Norbert Holtkamp, ITER's principal deputy director-general and leader of the project's construction since 2006. An ITER spokesperson confirmed that Holtkamp would soon step down and that the position would be eliminated. "We need to simplify the decision-making process," Motojima says.

Even though the approval of ITER's Baseline is supposed to signify an end to major changes, Motojima will also request that the project's scientists and engineers seek new ways to simplify the fusion reactor's design and the integration of its many components, which are being built by the project's seven international partners—China, the European Union, India, Japan, the Republic of Korea, the Russian Federation, and the United States. Motojima says the ITER Council wants him to present cost-saving plans at a meeting in November. Any such changes won't mean that ITER will produce significantly less science, Motojima emphasizes: "I'm keeping the [original] scope of ITER."

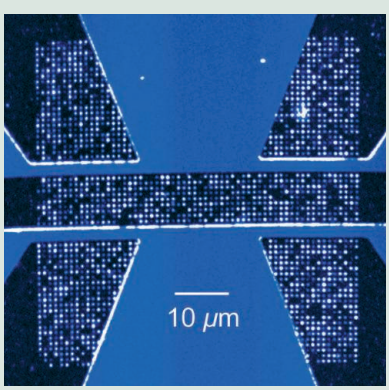
If anyone can pull that off, it may be Motojima, who is widely praised for his oversight of the construction of another fusion experiment, Japan's Large Helical Device. "He's a real machine-builder" and "also has a real directorial presence," says Cowley. Indeed, fusion scientists say that Motojima's appointment and the departure of former ITER Director-General Kaname Ikeda, a career diplomat with an engineering background, represent an acknowledgement that the project has moved on from securing funding to a phase dominated by construction. ITER's key components are now being built, Cowley notes. Even more promising, he says, industrial bids for other components are in line with cost predictions.

Although some European politicians called for killing ITER in favor of promoting more immediate renewable-energy projects, Motojima argues that fusion science has rapidly matured over the past half-century. "Some say fusion is always a dream. This is not true. … Fusion is not a dream but a real target," Motojima says.

**–JOHN TRAVIS**

can maintain their quantum states much longer than qubits in rival solid-state quantum-computing setups can.

Creating NV centers in diamond has been slow going, as researchers typically make them by firing nitrogen atoms through a tiny aperture one at a time. In a paper published online in *Nano Letters* on 23 July, however, researchers led by David Awschalom, a physicist at the University of California (UC), Santa Barbara, report that they created a 60 × 60 array of NV centers in diamond by shining a beam of nitrogen atoms through a thin mask containing 3600 apertures. The mask, made with a conventional high-resolution technique known as electron-beam lithography, can be scaled to any size. The UC researchers also showed that they could use RF electronics to control the quantum state of individual and neighboring NV centers, a development that sets the stage for using those neighbors to carry out complex quantum computations. "This brings the ability to do nearest-neighbor information processing much closer to realization," Beausoleil says.




**Upscale.** Array of NV centers in diamond.

This week in *Nature*, meanwhile, researchers led by Harvard University physicist Mikhail Lukin report that they can reliably link quantum information in an NV center to the polarization state of photons. The feat marks the first time solid-state qubits have been linked to light, Lukin says, and it opens the way for using diamond-based qubits for long-distance quantum communication, cryptography, and distributed computing. Beausoleil cautions that it's still far too early to know whether diamond-based quantum computers will beat out their rivals. Even so, it looks as if the field is finally set to stop crawling and to start walking.

**–ROBERT F. SERVICE**



## *Science*Insider

### From the *Science* Policy Blog

The U.S. Environmental Protection Agency (EPA) has rejected petitions asking it to halt the planned **regulation of greenhouse gases**. Some cited e-mails made public as part of the "Climategate" affair to question scientific aspects of the issue. But EPA says there's "no evidence" to suggest climate data were suspect. http://bit.ly/petition_epa

Mirroring its House of Representatives counterpart and the president's request, a Senate spending panel has proposed a $1 billion boost for the **budget of the National Institutes of Health**. The bill contains $50 million for the Cures Acceleration Network, a drug-development program that some scientific groups worry could come at the expense of funding proposals from scientists. http://bit.ly/NIH_boost

A House committee hearing explored **open access** in scientific publishing. Advocates of making papers freely available say informing the public is a noble goal, while publishers worry that expanding a 2-year-old NIH policy to more agencies will hurt the scientific enterprise. http://bit.ly/hearing_access

A Spanish National Research Council panel has recommended the **retraction of a paper** published last year in *Science* that described an enzyme-monitoring chip called the reactome array (*Science*, 9 October 2009, p. 252). But some scientists, including a Nobel laureate who conducted a blind test of the technology, maintain that the array works. http://bit.ly/reactome_debate

Senate Majority Leader Harry Reid (D–NV) has dropped a legislative mandate on the use of **alternative energy** from an energy package he introduced. The announcement came a week after Reid said that limiting carbon emissions via Senate legislation was impossible because he could not muster 60 votes. http://bit.ly/mandate_out

**Dispersed oil droplets** could have unknown and dangerous effects in the Gulf of Mexico, say scientists. Issues include their small size and the makeup of the dispersant molecules used by BP. http://bit.ly/drops_deadly

For more science policy news, visit **news.sciencemag.org/scienceinsider**.





Published by AAAS