and both those photons were then zipped to a third location. There, the two photons were entangled with each other — and this caused both their partner electrons to become entangled, too.

This did not work every time. In total, the team managed to generate 245 entangled pairs of electrons over the course of nine days. The team's measurements exceeded Bell's bound, once again supporting the standard quantum view. Moreover, the experiment closed both loopholes at once: because the electrons were easy to monitor, the detection loophole was not an issue, and they were separated by enough distance to also close the communication loophole.

"It is a truly ingenious and beautiful experiment," says Anton Zeilinger, a physicist at the Vienna Centre for Quantum Science and Technology.

Matthew Leifer, a quantum physicist at the Perimeter Institute for Theoretical Physics in Waterloo, Canada, says that he would not be surprised to see one of the authors of the paper share a Nobel prize in the next few years. "It's that exciting."

A loophole-free Bell test also has implications for quantum cryptography, says Leifer. Companies already sell systems that use quantum mechanics to block eavesdroppers. The systems produce entangled pairs of photons, sending one photon in each pair to one user and the other photon to a second user. The two users then turn these photons into a cryptographic key that only they know.

But loopholes — and the detection loophole in particular — mean that malicious companies could sell devices that fool users into thinking that they are getting quantum-entangled particles, when they are instead being given keys that the company can use to spy on them. In 1991, quantum physicist Artur Ekert observed[4] that integrating a Bell test into the system would ensure a genuine quantum process. For this to be valid, however, the Bell test must be free of any loopholes. The Delft experiment "is the final proof that quantum cryptography can be unconditionally secure", says Zeilinger.

In practice, the technique will be hard to implement, because so far it has generated entangled electrons at a very slow pace.

Zeilinger also notes that there remains a last, somewhat philosophical, loophole, first identified by Bell himself: the possibility that hidden variables could somehow manipulate the experimenters' choices of what properties to measure, tricking them into thinking quantum theory is correct. ■

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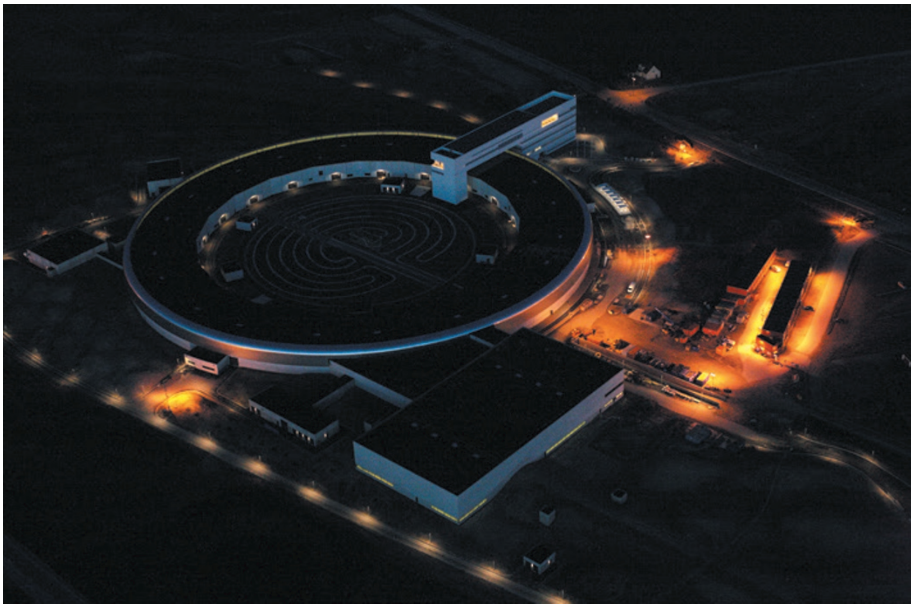

PERRY NORDENG/LUND UNIV.

The next-generation synchrotron at Lund in Sweden has passed its first test.

TECHNOLOGY

X-ray science gets an upgrade

Swedish synchrotron promises super-bright beams and will open up new avenues for researchers.

BY DAVIDE CASTELVECCHI

In what researchers hope marks the start of a new era for X-ray science, electrons have begun circulating in a next-generation synchrotron in Lund, Sweden. This machine promises to lower the costs of X-ray-light sources around the world, while improving their performance and enabling experiments that were not possible before.

Synchrotrons are particle accelerators that produce X-rays that are used in research ranging from structural biology to materials science. At 10 p.m. local time on 25 August, the first bunches of electrons began circulating inside a new 528-metre-long, 3-gigaelectronvolt (GeV) machine at the MAX IV facility in Lund, project director Christoph Quitmann told *Nature*. MAX IV is the first 'fourth-generation' synchrotron in the world.

Getting the first beam is an absolutely crucial first step" in demonstrating fourth-generation technology, says Chris Jacobsen, an X-ray physicist at the Argonne National Laboratory in Lemont, Illinois. MAX IV, he says, is "leading the world towards a new path in synchrotron light sources".

In synchrotrons, bunches of electrons circulate at nearly the speed of light inside a ring-shaped vacuum tube. Powerful 'bending' magnets steer the electrons around the rings, and 'focusing' magnets push them together against their mutual repulsion. The electrons then pass through special magnets that shake them sideways to produce pulses of X-rays, known as synchrotron radiation.

Fourth-generation light sources promise to squeeze the electrons into tighter bunches, leading to X-ray pulses that concentrate more photons into a tighter, brighter beam. This means that it will take just minutes for researchers to do experiments that could take days on a third-generation machine, Jacobsen says.

FOURTH GENERATION

Eventually, beams from fourth-generation machines could enable materials scientists to observe chemical reactions inside a battery as they happen, or structural biologists to reveal the structure of proteins from smaller protein crystals than those needed at existing light sources.

The crucial innovation in the fourth-generation machines is to employ a narrower ▶

vacuum pipe in which to circulate the electrons. In MAX IV's case, the pipe is 22 millimetres across, about half as wide as in a typical existing synchrotron. This makes it possible to get stronger magnetic fields using more-compact bending and focusing magnets, which are also less expensive and can consume ten times less electricity than third-generation systems because of their smaller size.

But keeping such a narrow pipe free of air would not have been possible using conventional high-vacuum pumps alone. MAX IV borrowed a technology from the Large Hadron Collider (LHC) at CERN, Europe's particle-physics facility near Geneva, Switzerland, which circulates protons rather than electrons. The LHC's trick — now adopted by MAX IV — is to coat the inner surface of the pipes with a special alloy that absorbs any gas molecules that happen to bounce around inside the tubes.

"The Swedes should be very proud of their innovative fabrication techniques, which lower the cost of making these machines," says physicist Herman Winick, a veteran synchrotron builder at the SLAC National Accelerator Laboratory in Menlo Park, California.

In the next few weeks, the MAX IV team will have to test whether they can circulate the large number of electrons that will be necessary to produce high-quality beams of X-rays, says Robert Hettel, an accelerator physicist at SLAC. And in subsequent months, they will build eight experimental stations, or beamlines, around the synchrotron, which they plan to open on 21 June 2016, a date chosen for the symbolism of the summer solstice.

The synchrotron that fired up on 25 August is the larger of two that the MAX IV team is building; the smaller fourth-generation machine will produce electrons of 1.5 GeV for making 'softer', or less energetic, X-rays. The combined cost of the machines and of the first eight beamlines will be 4.5 billion Swedish kronor (US$530 million), Quitmann says, which is being paid for by the Swedish government.

Quitmann says that his team reached "a major milestone last night". But, he adds, "We have still a long way to go". ■

The US Precision Medicine Initiative aims to collect health and genetic data from 1 million people.

ANDY KROPA/REDUX/EYEVINE

PERSONALIZED MEDICINE

Health study set to decide data policy

Specialists are split over whether participants should have free access to their genetic information.

BY SARA REARDON

After dozens of unsuccessful treatments, Eric Dishman started to suspect that his illness was due to something other than the rare kidney cancer he was diagnosed with in 1989. Five years ago, he had his whole genome sequenced, then gave the data to oncologists — and learned that he had a different type of cancer altogether.

He was treated successfully, and remains cancer-free. "I was an early prototype for precision medicine," he says.

Dishman now leads the health and life-sciences division of microprocessor giant Intel in Banks, Oregon. He is also a member of a working group run by the US National Institutes of Health (NIH) for the Precision Medicine Initiative (PMI) — a US$215-million project to collect data on genomes, health records and physiological measurements from 1 million participants, to learn how genetics, environment and lifestyle influence disease risk and the effectiveness of treatments.

Next month, the group is expected to release a project plan. Observers are eager to learn its answer to a key question: how much information about disease risk, especially genetic data, will the project share with participants?

That issue is the subject of much debate. Dishman and others say that participants should at least have the option to see all their personal data so that they can investigate their own health, just as he did. But some specialists in the field say that showing participants their data is irresponsible, because the information is challenging for people to interpret and its significance is often uncertain.

Most genetic variants linked to disease increase risk only slightly, yet people who discover that their genome holds such a variant might worry excessively or seek unnecessary

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