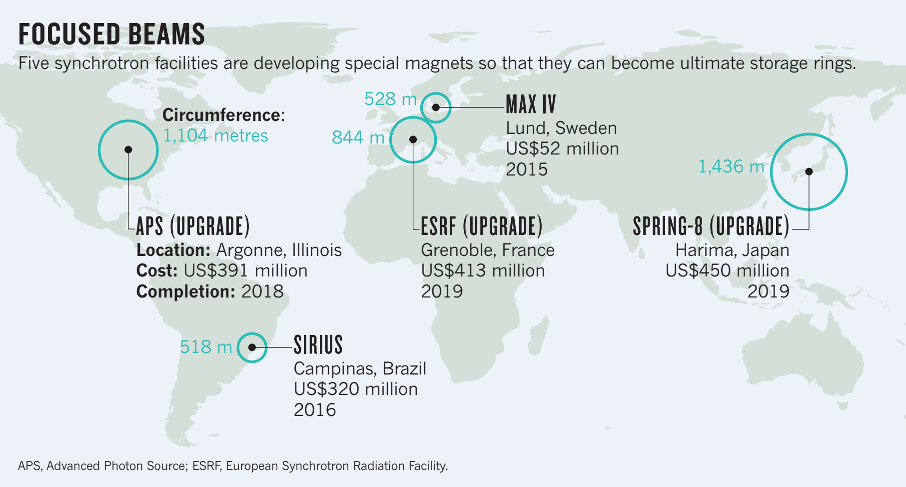

SOURCE: US DEPARTMENT OF ENERGY/BESAC; MAX IV

laser, useful for making 'molecular movies' of chemical reactions, among other things (see *Nature* **500,** 13–14; 2013). But such a laser would have limitations: its strongly peaked light pulses would destroy delicate materials. Ultimate storage rings, by contrast, satisfy a need for more gradually peaked pulses of light.

Researchers say that these storage rings could revolutionize X-ray imaging by making it possible to map evolving chemical processes. Current X-ray sources are not bright enough to track changes in materials with nanometre and nanosecond resolution, because there are not enough coordinated photons in the beams. Ultimate storage rings would change that. "A whole class of new problems opens up," says Paul Evans, a materials scientist at the University of Wisconsin–Madison. For example, he says that the rings could be used to investigate what happens chemically and electrically at the interface between materials inside a battery as it runs out.

The APS is seeking to tack the installation of ultimate-storage-ring technology on to a separate upgrade that had already been approved. Cost calculations are still ongoing, but Stephenson hopes that the multi-bend achromats can be included without raising the upgrade budget much above US$391 million. MAX IV is implementing the technology for only 340 million Swedish kronor ($52 million), but that ring is smaller and the price tag would not include the overhead costs that are charged at US energy-department labs.

After its upgrade, the APS could surpass MAX IV by approaching the theoretical limit for the most focused beam possible. The Swedish synchrotron will contain 20 multi-bend achromats, whereas the APS upgrade calls for around 40. In 2012, physicists at SLAC National Accelerator Laboratory in Menlo Park, California, showed that the number of multi-bend achromats around a larger ring could be pushed even higher without fundamentally destabilizing the electron beam. "The key is to make the bending gentle," says Yunhai Cai, head of beam physics at SLAC.

Alongside APS, the European Synchrotron Radiation Facility (ESRF) in Grenoble, France, has also opted for a multi-bend-achromat upgrade, after a working group concluded last October that the technology was affordable. ESRF director-general Francesco Sette says that accelerator physicists there showed that multi-bend achromats could work with the facility's existing injector, a part of the machine that supplies extra electrons to the main ring a few times each day. He had previously thought that a new injector would be needed. "We are today in full swing to launch as soon as possible," he says.

Storage rings in Brazil and Japan will also be upgraded with multi-bend achromats, giving MAX IV a window of only one year from its projected completion date of 2015 before it faces competition (see 'Focused beams').

Some have suggested that particle-physics tunnels, too, could eventually be turned into light sources with multi-bend achromats. SLAC has an idle 2.2-kilometre-circumference tunnel that originally housed a particle accelerator used to compare the decay rates of matter and antimatter. And a 6.3-kilometre tunnel used by the now-closed Tevatron particle accelerator at Fermilab near Batavia, Illinois, is another candidate for conversion. Eriksson says that building ultimate storage rings of that size would not be realistic for Sweden, given the relative size of its science budget.

He knows that Sweden's time in the vanguard will be short-lived, and has mixed feelings about seeing other countries adopting the technology that he and his colleagues pioneered so enthusiastically. "We are both happy and a little sorry," he says. ■

CORRECTION

The News story 'NASA ponders Kepler's future' (*Nature* **501,** 16–17; 2013) inflated the size of asteroids that the probe could watch for — they would be several hundred metres in diameter rather than several hundred kilometres.