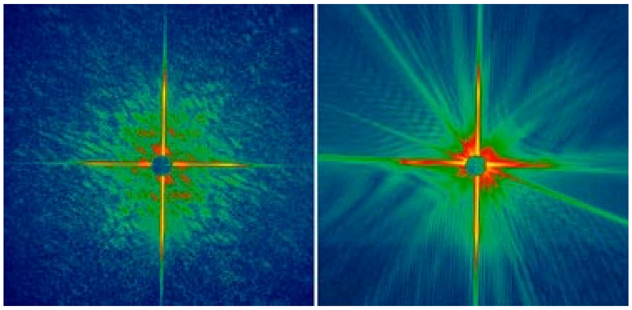
'Supermicroscope' shrunk down to lab-size

Oct 2, 2009 6 comments



Seeing with X-rays Laser replace established research facilities

Physicists in the UK and Germany have created a powerful yet highly compact X-ray source, which they claim could come to replace some of the world's major research facilities.

X-ray beams have become a valuable tool for scientists because they can "see" deep inside matter, illuminating its internal structure at the atomic scale. Indeed, the technique is now applied across a wide range of science, from revealing the structure of viruses to tracking chemical reactions as they happen.

As scientists have begun to realize the full potential of X-rays, they have come to require much more advanced X-ray sources than those available at their academic institutions. This has led to the formation of a number of specialist facilities that provide the international research community with a centralized source of high-quality X-rays.

Shake it like a synchrotron

These centres, like ESRF in France and Diamond Light Source in the UK, generate X-rays as a form of "synchrotron" radiation. In the standard process, high-energy beams of charged particles are accelerated using electric and magnetic fields around loops that can be hundreds of metres in size. As the particles veer around the circle, they constantly shed energy in the form of X-rays tangential to the beamline.

In most modern synchrotrons, the particles are also passed through a periodic magnetic structure, known as an undulator, which forces the electrons to "wiggle" and emit X-rays each they change direction.

While these synchrotron facilities have proved very popular and provide researchers with an opportunity to mix with their international peers, they are not without their critics. Some feel that the high set-up and running costs are unnecessary, and it is notoriously difficult to provide all research applicants with sufficient time on the beam line. Moreover, the large size of the accelerators and the air-miles accumulated by all the international visits means that these facilities have a number of sustainability issues.

Determined to overcome these problems, Stefan Karsch of the Max Planck Institute for Quantum Optics and his colleagues have realized an alternative method for generating X-rays. They have developed a technique that has gained recognition in the last few years known as "laser wakefield acceleration".

Ride the wave

News archive

2009
- September 2009
- August 2009
- July 2009
- June 2009
- May 2009
- April 2009
- March 2009
- February 2009
- January 2009

2008
2007
2006
2005
2004
2003
2002
2001
2000
1999
1998
1997

Related stories

Plasma wakefield "turbocharges" particle accelerator
Table-top accelerators make progress
World's brightest synchrotron powers up
European synchrotron secures €177m upgrade
Seeing chemicals at the nanoscale

Related links

Stefan Karsch
ESRF
Diamond Light Source

The physicists begin by firing a 37 fs laser pulse at a cell of hydrogen atoms, energizing the electrons and causing some of them to try to break free. However, the positive attraction of the nucleus acts to cling onto the electrons and they end up oscillating back-and-forth about the nucleus – resulting in a form of plasma wave in the cell. Some of the other electrons then "ride" down this wave at relativistic speeds, generating X-rays as they change direction.

Laser wakefield acceleration has been demonstrated previously but never before to generate soft X-rays – that is, electromagnetic radiation that can resolve the structure of matter on the atomic scale. One of the important developments in this latest research was to introduce a miniature version of the undulator present in synchrotrons. The combination of a 1.5 cm accelerator and a 30 cm magnetic undulator enabled the physicists to accelerate electrons up to energies of 210 MeV.

The energy of these electrons is comparable with those in synchrotron facilities, producing X-rays with the same brilliance, but the generator is 10,000 times more compact. "In the long run we aim to replace large, costly synchrotron and linear accelerator facilities with something small and affordable, namely a high-power laser-driven plasma accelerator of cm-size," Karsch told *physicsworld.com*.

The researchers now intend to develop their technique to generate X-rays with an even higher brilliance than those in synchrotrons. "Through an ongoing laser upgrade, we first aim at increasing the electron energy to 1–1.5 GeV to reach keV photon energies, which could serve as a first ultrashort X-ray source for application experiments on solids," he said.

About the author

James Dacey is a reporter for *physicsworld.com*

6 comments

Add your comments on this article

1 **Oliver K. Manuel**
Oct 2, 2009 2:58 PM
United States

When do electrons emit x-rays? What can they see?

"The particles are then passed through a periodic magnetic structure, known as an undulator, which forces the electrons to "wiggle" and emit X-rays each" TIME (?) " they change direction."

What can these x-rays see? Can they gleam information on the nature of the neutron-neutron interactions inside the nucleus?

With kind regards,
Oliver K. Manuel

Reply to this comment   Offensive? Unsuitable? Notify Editor

2 **amcevoy**
Oct 2, 2009 3:56 PM
United States

"What can these x-rays see? Can they" GLEAN (?) "information on the nature of the neutron-neutron interactions inside the nucleus?

...

Reply to this comment   Offensive? Unsuitable? Notify Editor

3 **fiski**
Oct 2, 2009 10:05 PM
WorkTech, New Zealand

Quote:

> *Originally posted by **Oliver K. Manuel***
> "The particles are then passed through a periodic magnetic structure, known as an undulator, which forces the electrons to "wiggle" and emit X-rays each" TIME (?) " they change direction."
>
> What can these x-rays see? Can they gleam information on the nature of the neutron-neutron interactions inside the nucleus?
>
> With kind regards,
> Oliver K. Manuel

As the article states the X-rays are used to probe matter on the atomic scale not the nuclear scale.

Neutron-neutron interactions inside the nucleus are investigated using different techniques, e.g. by scattering neutrons from nuclei.

Regards,
Ian Fisk

Reply to this comment Offensive? Unsuitable? Notify Editor

4 **Oliver K. Manuel**
Oct 2, 2009 11:50 PM
United States

Quote:

> *Originally posted by* ***fiski***
>
> As the article states the X-rays are used to probe matter on the atomic scale not the nuclear scale.
>
> Neutron-neutron interactions inside the nucleus are investigated using different techniques, e.g. by scattering neutrons from nuclei.
>
> Regards,
> Ian Fisk

Thanks, Ian.

There is no need for neutron scattering experiments.

Rest mass data of the 3,000 different types of nuclei have already shown that n-n interactions are repulsive and symmetric with Coulomb-free p-p interactions.

With kind regards,
Oliver K. Manuel

Reply to this comment Offensive? Unsuitable? Notify Editor

5 **Oliver K. Manuel**
Oct 2, 2009 11:53 PM
United States

Quote:

> *Originally posted by* ***amcevoy***
>
> "What can these x-rays see? Can they" GLEAN (?) "information on the nature of the neutron-neutron interactions inside the nucleus?
>
> ...

Right! My bad.

Oliver

Reply to this comment Offensive? Unsuitable? Notify Editor

6 **MikeMcc**
Oct 9, 2009 11:47 AM
Royston, United Kingdom

Quote:

> *Originally posted by* ***Oliver K. Manuel***
> "The particles are then passed through a periodic magnetic structure, known as an undulator, which forces the electrons to "wiggle" and emit X-rays each" TIME (?) " they change direction."
>
> What can these x-rays see? Can they gleam information on the nature of the neutron-neutron interactions inside the nucleus?
>
> With kind regards,
> Oliver K. Manuel

If you look at the Diamond Light Source website, they have details of quite a few of the applications that have yielded results. They have beamlines dedicated to perticular measurement systems that allow for subjects as wide ranging as protein crystallography, looking at thin film magnetics, reading Dead Sea scrolls without having to unroll (and potentially damage) them, and structural investigations of the wood from the Mary Rose to help with the preservation. They are presently building the phase II beamlines, one of which will allow large components to be observed in situ (for instance jet engine turbine blades), some of the intensities are truely awesome (the JEEP beamline will be hoping for pulse powers in the several kW range!).

The 4th Generation Synchrotron devices described will certainly help with the lower powered applications but won't be as versatile or capable as a full sized synchrotron. Despite the wording in the article they should be viewed as complementary systems rather than competitive.

Reply to this comment Offensive? Unsuitable? Notify Editor