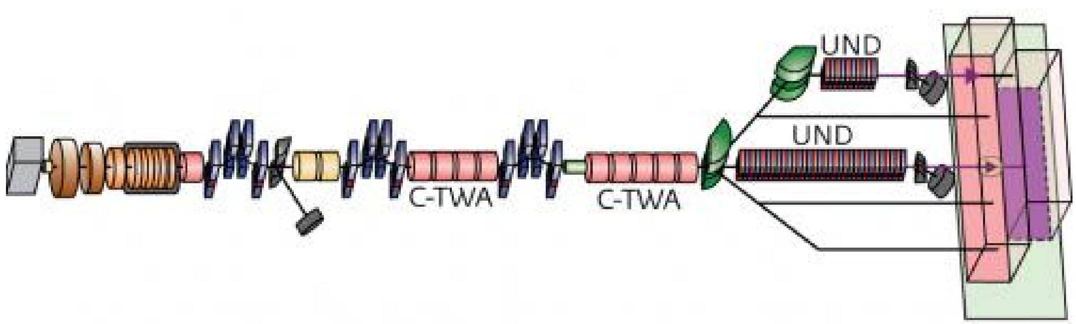
Measuring individual atoms with compact X-ray lasers

November 30 2012



The principle of SACLA. The laser consists of various electron acceleration stages (C-TWA) and focusing elements. Key to achieving short wavelength operation is, however, the design of the undulator (UND). Credit: 2012 Nature Publishing Group

To look at small objects typically requires big machines. For example, the study of single atoms with a laser requires x-ray radiation of such high energy that it is only produced by accelerating electrons in large facilities. Researchers at the RIKEN SPring-8 Center in Harima have developed a more affordable electron laser design, the SPring-8 Angstrom Compact free-electron Laser (SACLA), which is not only compact and therefore economic to build but also delivers x-rays with unprecedented short wavelengths.

User operation of SACLA began in March 2012. Makina Yabashi from the research team describes typical research as non-linear interactions of light and matter, biological imaging and ultrafast phase-transition in materials.

Construction of a high-energy laser is based on the concept that electrons accelerated by going very fast around a curve also emit radiation. The energy of this radiation, and therefore its wavelength, depends on the acceleration. The tighter the curved path, the shorter the wavelength of the light emitted. This is the operating principle of free electron lasers.

At SPring-8 the aim was to push free electron lasers to new limits by producing ever shorter wavelengths. This means sending electrons on a very tight twisting path in a section of the laser known as the undulator. Normally, the period of the curved electron beam is about several centimeters. The SACLA team have realized a period of only 1.8 centimeters by directly placing the magnets that deflect the electron beams into the vacuum chamber of the beam. This has enabled a reduction of laser wavelength down to 0.6 ångstrom, which is about the radius of a hydrogen atom.

The benefit of SACLA is that, in comparison to other free-electron lasers, the device is also smaller. "Our x-ray free electron laser facility has been designed to achieve a much more compact scale compared to those in the US and Europe," explains Yabashi. "The major reduction in construction and operating costs enables many research institutes or universities to build such a machine, and to utilize powerful laser light in a broad range of applications from biology, chemistry to physics," he says.

The team plans to increase the energy density of the laser beam, which would, for example, make biological imaging easier. Already there is strong interest from scientists to use the laser and other institutions are planning similar machines. In the meantime, SACLA is open for business.

More information: Ishikawa, T., Aoyagi, H., Asaka, T., Asano, Y., Azumi, N., Bizen, T., Ego, H., Fukami, K., Fukui, T., Furukawa, Y., et al. A compact X-ray free-electron laser emitting in the sub-ångström region. *Nature Photonics* 6, 540–544 (2012). www.nature.com/nphoton/journal … photon.2012.141.html

Provided by RIKEN