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Researchers find world's first x-ray laser produces most coherent x-ray radiation ever

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Experiments show that the world's first X-ray laser, the Linac Coherent Light Source, produces the most coherent (laser-like) X-rays ever measured. (Photo by Brad Plummer)

(PhysOrg.com) -- The world's first x-ray laser, the Linac Coherent Light Source (LCLS), first unveiled in 2009 at the Stanford Linear Accelerator Center in Palo Alto California, has been undergoing testing by group of physicists determined to find out how many of the photons it emits are synchronized and have found, as they describe in their paper in *Physical Review Letters*, the x-ray radiation that it produces, is the most coherent ever measured.

Following on the heels of the maser, invented in 1957, which was based on microwave radiation, researchers have searched for ways to make lasers with shorter and shorter wavelengths, with the hope being that coherence could be improved. Coherence is a measurement of how in-sync the photons in a laser beam are; the best laser would be one where all of the photons flow perfectly in sync with one anther, but of course, at least thus far, that's not possible. This leaves researchers working to see how close they can get. The better or higher the coherence a laser has the more precise it can be diffracted which means it can be used to create sharper images of atomic structures.

To measure the coherence of the LCLS, the researchers shone the laser beam through two successive materials, each with a tiny hole in it, then measured the bands of dark and light produced on the other end; they found the contrast to be very high. Then by slowly increasing the size of the hole, they were able to see the interference introduced by those photons that were not in sync with the others causing a decrease in visibility. It is in measuring the decrease that the coherence of the beam can be measured. For the LCLS, it was shown to be 16.8 microns.

The team also tested the laser's monochromatic abilities, which is a way of saying they measured the coherence time of the laser. The coherence time is the time interval that the wave is considered to be predictable. To do this they examined the edge patterns created when shooting the laser beam through the very tiny holes. For the LCLS they found the coherence time was 0.55 femtoseconds. The end result was that the majority (78%) of the photons were held within the confines the of the directed beam.

This all means that researchers using such an x-ray laser will soon be able to more precisely understand the atomic structure of materials they are working on, which should prove useful for pharmaceutical, archeology and engineering projects.

More information: Coherence Properties of Individual Femtosecond

Pulses of an X-Ray Free-Electron Laser, *Phys. Rev. Lett.* 107, 144801 (2011) DOI:10.1103/PhysRevLett.107.144801

Abstract
Measurements of the spatial and temporal coherence of single, femtosecond x-ray pulses generated by the first hard x-ray free-electron laser, the Linac Coherent Light Source, are presented. Single-shot measurements were performed at 780 eV x-ray photon energy using apertures containing double pinholes in “diffract-and-destroy” mode. We determined a coherence length of 17 μm in the vertical direction, which is approximately the size of the focused Linac Coherent Light Source beam in the same direction. The analysis of the diffraction patterns produced by the pinholes with the largest separation yields an estimate of the temporal coherence time of 0.55 fs. We find that the total degree of transverse coherence is 56% and that the x-ray pulses are adequately described by two transverse coherent modes in each direction. This leads us to the conclusion that 78% of the total power is contained in the dominant mode.

Linac Coherent Light Source (LCLS): slacportal.slac.stanford.edu/s … c/Pages/Default.aspx