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LCLS: The World's Largest Laser Writer?

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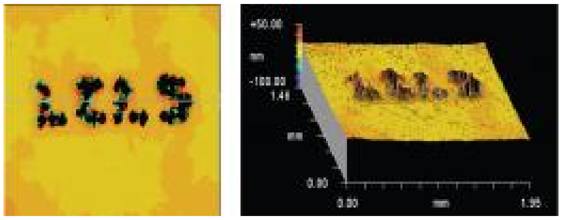

The letters "LCLS" were etched into boron carbide during tests to prepare the X-ray laser for user science. The image to the right reveals the letters' depth. (Image courtesy the LCLS scientific team, and taken at LLNL according to Hau-Riege.)

(PhysOrg.com) -- While not the smallest lettering ever created, the tiny initials "LCLS" have been written with what may be the world's most potent pen. Etched into boron carbide, a super-hard substance used in accelerator shielding and body armor, the lettering has helped researchers at SLAC National Accelerator Laboratory explore the capabilities of the world's first hard X-ray laser, the Linac Coherent Light Source.

A collaboration of scientists from SLAC and partner labs created the writing in September as part of experiments to characterize the LCLS X-ray beam and its interactions with materials. The team worked intensely to prepare for arrival of the first LCLS scientific users October 1.

"I was quite nervous before the experiment" said LCLS physicist Jacek

Krzywinski, who coordinated five experiments in the effort. "Nobody before has tried to characterize such a powerful X-ray beam. We have already successfully measured micron-size, focused beam at the FLASH facility [in Germany] but here [at LCLS] the wavelength was order of magnitude shorter. Fortunately, it worked."

The team characterized several significant properties of the LCLS beam, including the wavefront—the pattern of incoming X-rays of various energies and intensities—the intensity distribution across space, total beam energy, as well as the beam exposure required to damage materials in its path.

"These were all performed within one week—very cramped," said Lawrence Livermore National Laboratory physicist Stefan Hau-Riege, the team leader of the damage experiments. For the September tests, Hau-Riege joined LCLS staff and other future scientific users to commission the laser and its first scientific instrument, the Atomic, Molecular and Optical science instrument.

The main purpose of the AMO instrument is to concentrate the LCLS X-ray beam into a tiny focal spot, and study the effects of the super-intense, focused X-rays on simple atoms and molecules in gasses. To examine how the LCLS would affect solid materials, the group built a custom, movable stage within the AMO instrument. "It was really a challenge to design and integrate the required hardware into a chamber that was not initially designed for this experiment," Krzywinski said. "We had to fight for every millimeter to avoid collisions with the existing hardware. The SLAC Mechanical Fabrication Department did a superb job here."

The team used this custom setup to position a sample of boron carbide in the beam for exposure at different beam intensities and wavelengths. Boron carbide is tough stuff; for that reason, it's used in safety components of the LCLS beamline. Thick chunks of the material provide beam stoppers to prevent escape of errant X-rays. But no material can completely withstand the extreme intensity at the X-ray focus inside the AMO chamber. Hau-Riege, Krzywinski and their colleagues varied the beam focus size and attenuated the LCLS X-ray beam in order to vary the power levels hitting their samples, to find the damage thresholds. With a tightly-focused beam, the damage craters were used to measure just how small the focal spot became. By moving the sample stage just so between exposures, the team spelled the X-ray laser's initials in small craters blown out of the boron carbide.

The lettering provided a map of sorts on the sample material. The researchers used the clearly-imprinted "LCLS" as a landmark for locating less-obvious effects of tests at lower energies.

"You can easily find the LCLS logo," Hau-Riege said. "From there, you can find the other spots that we tested."

To assess the depth of the X-rays' penetration into the surface, the group used a white light interferometer—a microscope that shines visible light at the surface and measures differences in the distance the light travels as is bounces from the sample to a detector. The result is a height map showing depth variations across the surface, indicating how far the X-ray beam has penetrated the material.

"The nice thing about this technique is that it actually gives the depth," said Hau-Riege, "and so you know how deeply affected the samples are." The researchers, notably team members from LLNL, the German physics lab DESY, Prague and Warsaw, also used scanning electron and atomic force microscopes to assess the damage threshold and the extent of the damage, as indicated by its depth and roughness. With this information, they can estimate beam characteristics such as the diameter at its focus, and the intensity distribution of its X-rays.

The painstaking post-exposure analysis is ongoing, Krzywinski noted. "But we already know that the average radius of the focal spot is close to the design target." Further analysis and ongoing user experiments will show more about what this unique X-ray source can do.

More information: Sub-atomic-scale Writing Using a Quantum Hologram Sets New Size Record (w/ Video)

Provided by SLAC National Accelerator Laboratory (news : web)

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