New technique opens door to tabletop X-ray laser

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A team of researchers at the University of Colorado at Boulder has developed a new technique to generate laser-like X-ray beams, removing a major obstacle in the decades-long quest to build a tabletop X-ray laser that could be used for biological and medical imaging.

For nearly half a century, scientists have been trying to figure out how to build a cost-effective and reasonably sized X-ray laser to provide super-high imaging resolution, according to CU-Boulder physics professors Henry Kapteyn and Margaret Murnane, who led the team at JILA, a joint institute of CU-Boulder and the National Institute of Standards and Technology. Most of today's X-ray lasers require so much power that they rely on fusion laser facilities the size of football stadiums, making their use impractical.

"We've come up with a good end run around the requirement for a monstrous power source," Kapteyn said.

A paper on the subject by Murnane and Kapteyn, CU-Boulder graduate students Xiaoshi Zhang, Amy Lytle, Tenio Popmintchev, Xibin Zhou and Senior Research Associate Oren Cohen of JILA was published in the online version of the journal *Nature Physics* on Feb. 25.

If they can extend the new technique all the way into the hard X-ray region of the electromagnetic spectrum, which they think is just a matter of time because there are no physical principles blocking the way, the ramifications would be felt in numerous fields.

"If we can do this, it might make it possible to improve X-ray imaging resolution by a thousand times, with impacts in medicine, biology and nanotechnology," Murnane said. "For example, the X-rays we get in the hospital are limited by spatial resolution. They can't detect really small cancers because the X-ray source in your doctor's office is like a light bulb, not like a laser. If you had a bright, laser-like X-ray beam, you could image with far higher resolution."

To generate laser-like X-ray beams, the team used a powerful laser to pluck an electron from an atom of argon, a highly stable chemical element, and then slam it back into the same atom. The boomerang action generates a weak, but directed beam of X-rays.

The obstacle they needed to hurdle was combining different X-ray waves emitted from a large number of atoms to generate an X-ray beam bright enough to be useful, according to Kapteyn. In other words, they needed to generate big enough waves flowing together to make a strong X-ray.

The biggest problem was the waves of X-rays do not all come out "marching in step" because visible laser light and X-ray beams travel at different speeds in the argon gas, Murnane said. This meant that while some X-ray waves combined with other waves from similar regions to become stronger, waves from different regions would cancel each other out, making the X-ray output weaker.

To correct this, the researchers sent some weak pulses of visible laser light into the gas in the opposite direction of the laser beam generating the X-rays. The weak laser beam manipulates the electrons plucked from the argon atoms, whose emissions are out of sync with the main beam, and then slams them back into the atoms to generate X-rays at just the right time, intensifying the strength of the beam by over a hundred times.

"Think of a kid on a swing," Kapteyn said. "If you keep pushing at the right time the swing goes higher and higher, but if you don't push it at the right time, you'll eventually stop it.

"What we found is essentially another beam of light to control exactly when the swing is getting pushed. By putting the light in the right place, we don't allow the swing to be pushed at the wrong time."

Source: University of Colorado at Boulder

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