Breakthrough With Ultra-Fast Xrays

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Electromagnetically-induced transparency, or EIT, has been known in the visible realm for quite some time. The process is used to control such characteristics as dispersion and absorption in gases, allowing the gases to become transparent at a certain wavelength from an interacting laser. Until now, EIT has not been used in x-rays.

Researchers at Argonne National Laboratory in Illinois are changing that. Their paper predicting EIT for x-rays in laser-dressed neon gas is titled "Electromagnetically Induced Transparency for X Rays," and published in *Physical Review Letters*.

"Very fast x-ray pulses are a subject of investigation now," one of the researchers, Christian Buth, tells *PhysOrg.com*. "With ultra-fast x-rays, we can watch atoms in a molecule move, almost like a movie." Linda Young, another of the Argonne researchers on this project, points out that being able to image the structure of a complex molecule could be one of the interesting applications to emerge from this work. "We could watch molecules reacting in real time, learning about fundamental interactions."

One of the reasons this method of getting ultra-fast x-ray pulses is interesting rests in the fact that it is relatively low cost. "Expensive x-ray sources are coming," says the third member of the group, Robin Santra, "and we have found that a laser could produce, in a practical way, short x-ray pulses." Buth adds that this method is "less expensive, and the shorter pulses are important, because with the longer pulses the molecule just vibrates, and the image is blurred."

Santra explains that this method can be applied in pump-probe experiments, making them more direct, allowing scientists to learn more about the actual changes. “In all pump probe experiments,” he explains, “you give a molecule a well-defined ‘kick,’ perturbing it in a controlled way. Then you wait a certain amount of time to see that molecule going into a specific change in geometry.” Santra says that right now, scientists look at the time evolution of light absorption, and the observation is indirect.

Ultrafast x-rays, Santra points out, allows direct observation. “With these ultra-fast x-rays, we hit the molecule with an initial pulse, and then probe it with another pulse. Each pulse is well defined, in time duration and relative time delay. You could even do more pulses, and directly watch the evolution of the molecule with these pulses in real time.”

In this particular instance, the Argonne researchers suggest using EIT in neon to produce ultra-short x-ray pulses. “We tried it with krypton,” Young explains, “but it has a high nuclear charge and showed small effects. Neon, on the other hand, has a lower charge and the inner shell decay takes longer, giving rise to dramatic changes.” She continues: “Our theory indicates that by putting on a 800 nanometer laser, we can make neon gas, which is normally opaque, transparent.” Young also points out that the transparency effect is reversible. “It is only transparent when the laser is on the gas.”

Even though this form of producing ultra-fast x-ray pulses would have its uses, the Argonne researchers admit to its limitations. “A tunable x-ray free electron laser is more useful for spectroscopy applications. The fingerprint of an atom or molecule provided by spectroscopy would make it possible to follow the changes associated with a particular atom or molecule in complex material. Right now we can’t do this.”

“At this point our scheme could do diffraction, but could only measure groups of atoms; it couldn't resolve single atoms," Santra adds. "If we could increase the resolution, suddenly atoms could be distinguished. The goal is to move to even shorter wavelengths."

EIT for x-rays is still at the theory stage. However, Young is planning an experiment at the Advanced Light Source at Lawrence Berkeley National Laboratory with Argonne's Atomic Physics Group. This should demonstrate whether or not the prediction for neon transparency can be substantiated experimentally.